TABLE OF CONTENTS

| Sponsor Listing                      | 2 |
| Conference Committees               | 3 |
| Oral Presentations                  | 4 |
| Poster Presentations                | 237 |
| Short Videos                        | 317 |
| Workshops                           | 321 |
place of different biomes. Decades of overgrazing from goat farming has led to massive vegetation loss and soil degradation in the region.

Monitoring plays an important role in the conservation and recovery process. Yet many monitoring programmes do not provide clear results on the success of restoration efforts.

This study focuses on the impact of goat farming on the landscape and the success of restoration efforts in the region. It highlights the importance of monitoring programmes for effective conservation and recovery strategies.

The need for ecosystem restoration continues to increase, and worldwide, many ambitious initiatives, ranging in scale from local to global, have been launched to address this need. The Bonn Challenge, for example, was created in 2009 as a movement to restore 15 million hectares of degraded or deforested lands by 2050. However, very few of these initiatives have demonstrated significant success.

The Mediterranean region is particularly vulnerable to the effects of climate change, and many areas are experiencing increased rates of desertification and degradation. The region is also home to a diverse range of biomes, including forests, wetlands, and grasslands, which are all under threat.

The development of a traceability system for native species is essential for the success of restoration projects. This involves characterising the landscape, identifying the reasons for system failure, and assessing biodiversity and ecosystem services.

Planning Tool to support collaboration during the planning, design, and implementation of ecological restoration projects can help to ensure the success of restoration efforts. This involves creating a decision-support tool for forest restoration, exploring the meaning and measurement of innovation, and considering the geographical overlap of biodiversity-carbon co-benefits.

Some countries are seeking to achieve their Bonn Challenge goals and implement their forest landscape restoration strategies. In South Africa, for example, the Thicket rehabilitation project is focused on socio-economic development in the Baviaanskloof region.

In the Mediterranean region, the use of fire as a management tool is crucial for maintaining biodiversity. Fire regimes that deviate from historical norms are a concern for biodiversity in biodiverse, fire-prone ecosystems.

In the case of the Fire Islands, a series of wildfires caused by humans has led to the invasion of grassland by scrubland vegetation, which has had a negative impact on the biodiversity of the area. To address this, a strategy was developed to enhance biodiversity and carbon sequestration.

The project involved creating species-diverse resource-conserving plant patches, which contributed to the restoration of the area. It also helped to establish a traceability system for native species, which is essential for the success of restoration efforts.

Further sampling will determine if co-restoration ensures the long-term persistence of plots and facilitates higher biodiversity. The study suggests that co-restoration can be a successful method for restoring degraded lands, but more research is needed to evaluate its long-term effectiveness.

The restoration of land, water, and society is a complex process that requires collaboration among stakeholders. The development of a traceability system for native species is essential for ensuring the success of restoration efforts.

Linking biodiversity and ecosystem services to socio-economic development can help to ensure the long-term success of restoration efforts. This involves considering the development of a traceability system for native species, which is essential for the success of restoration efforts.

In conclusion, the restoration of land, water, and society is a complex process that requires collaboration among stakeholders. The development of a traceability system for native species is essential for ensuring the success of restoration efforts.
Arid ecosystems management nexus approach: Toward a holistic system of thinking of managing arid ecosystems

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Ecosystems in arid regions play a pivotal role in providing services to vulnerable environments with considerable challenges: extreme temperatures, low precipitation, variable climate change, and infertile soil. The countries of the arid regions are facing more challenges in land degradation, biodiversity loss, scarcity of the water and food resources and protecting their inhabitant's public health. In many cases, policymakers in these countries are aware of the challenges, but they are seeking through scientific communities to develop clear sustainability and resiliency plans. Due to the complexity associated with arid ecosystem services, the scientist communities are still to develop integrated ecosystem management approaches. Within this line of commitment to our future generation, the paper in hand presents a framework for an arid ecosystem management nexus approach (AEMNA). The core of this nexus approach is to understand and quantify the interlinkages between the ecosystem components, internal and external stresses, and society needs. The paper also identifies key questions to be considered when applying the AMENA approach to arid ecosystem management plans.

A landscape approach is needed to improve farmers' livelihoods while reforesting degraded reserves in Ghana

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A study about the patterns of deforestation in Ghana from 1986 to 2015 identified that expansion of agriculture is a major contributor to deforestation in the country. The study therefore recommended the practice of agricultural intensification on existing farmlands to reduce farm expansion into the remaining forest. However, the intensity of the deforestation has turned some forest reserves into grassland. Sustainable Development Goal 15 stresses the protection of remaining forest and the restoration of degraded forest through afforestation. We therefore studied the willingness of farmers to participate in a reforestation project as a means to restore degraded forest and support the livelihood of farmers. We used Ongwam II Forest Reserve in the Ashanti region of Ghana, and we engaged farmers in two communities fringing the forest reserve for the research. We found that farmers' level of participation in reforestation is determined by the worth of their farm in the forest, the location of their farm, farming experience, the location of the project, and the motivation attached to the project. Inter-planting food crops with trees could reduce the effects of arable farming on deforestation, limit the clearance of trees from farmlands, and enhance the provision of ecosystem services. The effective implementation of several small-scale reforestation projects could together lead to forest transition, more trees in agricultural systems, and better protection of residual natural forests.

Assessing the potential for seed-based restoration in a highly degraded freshwater marsh

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In highly invaded ecosystems, establishment from any restoration seeding may be limited. Evidence to support seed-based restoration in wetlands, where invasion pressure is often disproportionately high, is more limited than in terrestrial systems. Despite the importance of a priori investigations of the potential for seed-based restoration to succeed, efforts to quickly and effectively ascertain limitations to this method are not well-established. Methodology for seedbank assays and vegetation cover assessments are typically intensive efforts designed to answer research questions, rather than minimal cost approaches to guide management. Keeping effort levels minimal as directed by project managers, we characterized the potential for seed-based restoration for five management units within a degraded freshwater wetland in central Florida, USA. We assessed potential barriers to seeding success, including colonization from extant vegetation and emergence from the seed bank, to determine potential competition from undesirable species. Analysis confirmed the plant community was sufficiently characterized within the time constraints determined, and that seed-based restoration potential differs with management unit. For instance, 1) invasive species more likely challenge native seeding via emergence from the seed bank in units that have saturated, as opposed to field capacity, soil moisture; 2) invasive cover is spatially variable in some units, creating opportunities for selective invader removal, and colonization from extant desirable vegetation; and 3) suitability of seed-based revegetation varied with dominant guild of the desired vegetation type for any given unit. We characterize the unique challenges these wetlands present to seed-based restoration and suggest strategies to overcome them.

An assessment of restoration efforts in South African estuaries and a socio-ecological approach to sustaining ecosystem services

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South African estuaries are essential biodiversity hotspots. At the same time, they serve as foci for development, tourism, and recreation, and their biological resources support subsistence and commercial fisheries. Human activities have caused the health and provision of ecosystem services in several estuaries to decline. This study assessed efforts to restore normal functioning in degraded estuarine lakes (St Lucia and Nhlabane) and temporarily closed estuaries (Mdloti and Mhlanga). These systems have been impacted by reduced freshwater inflow and the effects of urban, industrial, agricultural, and mining activities. Restorative efforts included breaching the estuary mouth, using artificial structures to restore tidal action (Zandvlei), and constructing canals to re-establish water flows (Isipingo, Zeekoevlei). The success of these efforts has been varied. In a few cases (Great Brak, Zandvlei), restoration removed negative pressures and the estuary recovered but, in most cases (e.g. Isipingo and Siyaya), restoration efforts failed. The assessment highlights the importance of identifying and addressing the root causes of deterioration instead of focusing on measures to fix the symptoms. For example, frequent artificial breaching of small closed estuaries can exacerbate poor health by causing sedimentation and shallowing. Restoring normal freshwater inflow is a more effective solution. This critical assessment showed that most rehabilitation attempts have been unsuccessful and a coordinated national effort supported by appropriate human and financial resourcing is needed. A socio-ecological systems approach for the restoration of estuaries and delivery of multiple ecosystem services is outlined that provides opportunities for job creation and contribution to the blue economy.

Capacity building for restoring land

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The status of the global environment has deteriorated in the last decades, with major increases in degraded land, freshwater uses and greenhouse gases in the atmosphere. Land degradation has become a major threat to both earth's ecosystems and human
livelihoods, accelerating climate change, causing land to be more predisposed to natural disasters, risking food security, and contributing to increasing conflicts and refugee crises. With an ever-growing world population, demand for land will continue to rise, putting more pressure on land resources and increasing people’s vulnerability to food insecurity and poverty. Land restoration is highly important to address these challenges. Restoration reverses land degradation and helps mitigate and adapt to climate change, while at the same time it improves people’s livelihoods. The UN University Land Restoration Training Programme has for over 10 years built capacities of specialists working for local institutions in several African countries in ecological restoration and sustainable land management. In this talk, we discuss the role of capacity building for restoring land in Africa. We will present results from a survey sent out to former trainees on how the training has strengthened their individual capacity as well as the capacity of their institutions, to improve land health and people's livelihoods.

Perception of stakeholders on the posting of reclamation bonds in the small-scale mining sector in Ghana: A case study of Prestea Huni-Valley District, Ghana

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The small-scale mining sector in Ghana contributes greatly to the country’s economy, yet it is also associated with negative environmental impacts, such as land degradation and water pollution. Most miners in the sector have shifted from the mining methods used during colonial time, which involved the use of simple or hand-held equipment, to the use of high technological equipment for the extraction of the mineral. Reclamation bonds have been continuously deployed in the large-scale sector to promote sustainability and ensure reclamation of mined site in their operation. Introduction of reclamation bonds at the small-scale mining sector would help curb the extensive degradation caused by these activities. Based on these issues, this study assessed the perception of stakeholders on the introduction of reclamation bonds in the small-scale mining sector from three communities in Prestea Huni-Valley District, Ghana. Based on interviews with concession owners, representatives of regulatory institutions, and miners' associations in the district, introducing reclamation bonds would ensure compliance in the sector, enforce miners to practice concurrent reclamation sustainably, and mitigate some negative environmental impacts. Findings suggest that, reclamation bond fees must be moderated when introduced to enable miners to comply. Additionally, payment of the bond must not be full payment at the initial stage of operation but rather as the mine progresses. To achieve this, miners must be well trained and educated about reclamation bonds. There is a need for government assurance to the miners on how funds will be refunded to them after a successful reclamation.

Managing for surprise and uncertainty in ecosystems

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Resilience is an emergent property of complex systems that provides systems with latitude to absorb disturbance. The term resilience has exploded in usage in recent years, and two competing definitions have risen to the forefront. In addition, an emergent property, resilience is often interpreted as the ability to bounce-back, and under this definition resilience is simply a measure of the amount of time necessary for a system to recover following disturbance. The definition used has implications for restoration. Bounce-back implies that all systems will recover, given sufficient time. However, this definition of resilience is partial, as complex systems are non-stationary and may have critical thresholds. Non-stationarity means that it is difficult, or impossible, to know what, exactly, to bounce-back to. And a critical threshold means that surpassing that threshold (exceeding the resilience of the system) will cause the system to collapse and reorganize as
something possibly very different. Non-stationarity and thresholds are sources of surprise and uncertainty in restoration and ecosystem management. Managing for resilience is an approach that explicitly seeks to avoid critical thresholds. Such an approach fosters resilience of systems that are in desirable states and seeks to erode the resilience of systems in undesirable states in order to transform them to something more desirable. These approaches account for scale and cross-scale interactions and maintaining positive feedbacks. Diversity is important, but the distribution of diversity within and across scales is paramount, as is dealing with both spatial and temporal aspects of scale, ideally in tandem.

The economic case for sustaining the marshes of southern Mesopotamia

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With limited water resources, there is increasing demand on water from various stakeholders in Iraq. Upstream stakeholders use the water for agriculture using sumerian flood irrigation techniques. These irrigation techniques were adequate when there was a flood pulse that healed the farmlands from salt, however, with building dams upstream, floods have stopped and the agricultural lands in Iraq have become more saline with time, reducing productivity. In order to provide an incentive for decision makers to dedicate adequate water resources for the marshes, Nature Iraq in 2008 conducted a series of interviews with 256 families throughout the central marshes to evaluate the economic output form the central marshes and compare that to to the productivity of farms. In 2016 a smaller effort was conducted to update the numbers, and in both cases, there are convincing data that prove that the economic output from water (especially marginal water) invested in the marshes has equal or better results for the overall economy. A summary of both studies will be presented.

Integrating TEK and geospatial methods to restore indigenous grasslands

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Western Science and traditional ecological knowledge (TEK) complement each other in understanding a changing world. Native fescue (Fescue spp.) grasslands of the North American Intermountain West remain scarce due to modern agriculture, loss of Indigenous peoples’ land management practices (e.g. prescribed fires), and bison extirpation (Bison bison bison). TEK shows why losing these components negatively impacts the prairie and why both are essential for resilience. This grassland is a biodiversity hotspot, essential wildlife habitat, and an important carbon sink. Our study site on the Rocky Mountain Front in Waterton Lakes National Park, Alberta, Canada, consists of 30 aspen stands (Populus tremuloides) encroaching on the prairie. Parks Canada is conducting ecological restoration to suppress aspen expansion and increase prairie land cover. Prescribed burns decrease woody vegetation through adult stem mortality while stimulating aspen growth, which is subsequently browsed by elk (Cervus elaphus). We measured aspen stand structure before and after a spring 2017 prescribed burn to determine pre- to post-burn change in aspen stand area. We measured pre-burn stand area during summer 2016 using mapping grade GNNS. We collected imagery for post-burn measurements during summer 2017 via drone (unmanned aerial system). Stand area did not decline significantly for any of the stratified aspen stand layers we measured. We found an observational decline in total canopy area. Our findings demonstrate the importance of integrating TEK regarding the role of keystone forces such as fire and bison and geospatial techniques into ecological restoration and how the two can inform management.
Restoration, projectality and the projectization of local development

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The Bonn Challenge, WRI’s AFR100, the UN Decade for Deserts, the Great Green Wall initiative, and the like, reflect the traction being gained globally by the land restoration movement. However, the political and socio-economic dimensions of the “movement” tend to be under-analyzed. Using conservation techniques (“zai”), and farmer managed natural regeneration (FMNR) as examples of local indigenous technology adaptation particularly in West Africa, this paper hopes to lay out some concerns about the underlying processes and assumptions of the movement. Local communities, reacting to pressures and drivers, indigenously innovate and adapt (partially through technologies mentioned above). When these innovations are “discovered” by exogenous actors (including research centers and NGOs) they enter a process of projectization where they are standardized, made quantifiable, subject to “value-addition”, and made legible to the exogenous actors. We introduce the concepts of projectality and green projectality to help describe and understand this process. Local development may be projectized, co-opted and fed back to the communities through “extension”, training and other activities. Pre-existing local adaptation techniques and practices are re-packaged as projects of “expert technological innovations” so that the communities who developed them must now be trained and formed to adopt them. The incentive to projectize is strong as exogenous actors are able to capture funds, visibility and business through projects. This process seems to ultimately co-opt local knowledge and adaptation capacity, and may re-enforce dependency, which in turn can become reliant on projectization.

Landscape change or climatic extremes? Analyzing the main drivers of megafires and the barriers to ecological restoration in the Chilean Mediterranean-climate region

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Chile differs from other Mediterranean-climate regions because fire has not been a major factor shaping vegetation composition and structure for most of the Holocene. Since 1990, a clear pattern of increasing human-ignited fires poses a major threat to conservation, ecosystem services, and human lives and property. In Chile, megafires devastated nearly a million hectares of agroforestry lands and native vegetation and affected thousands of people between 2017 and 2019. In contemporary Chile, catastrophic fires are strongly linked to: (1) the vicinity of roads and the expansion of the urban-rural interface, (2) the massive expansion of forest production systems based on plantation of highly flammable species (mainly Pinus and Eucalyptus spp.), and (3) climate warming and recent regional droughts. In response to synergies between fire and grazing, vegetation in central Chile is shifting from originally-continuous closed canopies to a mosaic of shrub patches and forestry plantations over a fire-prone ephemeral herbaceous cover that is dominated by non-native species. Recovery and restoration of biodiversity in Chile under this scenario will be complex, as we are dealing with a system going through a critical transition. Reduction of fire risk will depend on our ability to manage the landscape away from the fire-prone condition. While other Mediterranean ecosystems with a long history of fire have ecological legacies and plant traits that favor or speed up recovery, ecosystems in central Chile will likely become dominated by fire-resistant species that prevent recolonization by the original native vegetation.
Gondwana Link – are we there yet?

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Gondwana Link, a program established in 2002, is focused on achieving transformational restoration of habitats and ecosystem functions across 1000 kilometres of south-western Australia. Much has been achieved that we can be proud of. This ranges from the technical, such as the practical restoration techniques adopted for patch scale replanting in habitat gaps to achieve maximum ecological restoration at minimum cost, through to attempts to restore traditional fire management over millions of hectares. As the program matures, a myriad of projects, often managed quite independently, work loosely together as a cohesive, if not collaborative, effort adding up to meaningful change at scale. Difficulties include building effective cohesion between the different efforts in a funding world built largely on competitive behaviour; the need to raise funds beyond current environmental expenditure levels in Australia; and the challenge of measuring impact at numerous different scales. In this presentation we will set out the three different organisational structures we have worked through so far, test their strengths and weaknesses, and explore the underlying philosophy of change that has underpinned steady growth. We will also explore how our program straddles a broad spectrum of approaches, incorporating elements of what has been termed ‘novel’ ecosystems and ecosystem service payments, such as for carbon sequestration, through to focused attempts to precisely replicate reference ecosystems.

Topsoil removal compromises campo rupestre regeneration by reshaping diaspore fate and interactions with potential ground-dwelling dispersers

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Anthropogenic disturbances, such as soil removal, are known to hamper regeneration in edaphic grasslands. However, the role of fruit-frugivore interactions in modulating natural regeneration is overlooked. We performed field experiments to investigate how soil disturbances affect diaspore removal and interactions with ground-dwelling fauna in campo rupestre vegetation, megadiverse edaphic grasslands in southeastern Brazil. We used artificial and natural diaspores from five native species to compare removal in degraded areas and adjacent pristine sites. We controlled ant and vertebrate access to determine their contribution to diaspore removal and identified species of ants interacting, their behavior towards diaspores, and destination of diaspores removed, to build multilayer networks between sites. Removal rates were relatively high (between 50 and 100%) but varied significantly among species. Soil disturbance reduced interactions with ants and overall removal rates by 20%. Ants were the most important removal agents in both site types. Seed predating ants were more common in degraded sites. Nearly 40% of the diaspores in degraded sites were transported to pristine sites, but no diaspores were transported from pristine to degraded sites. Ant-diaspore networks in pristine sites were more diverse and more robust than in degraded sites. Soil disturbance did not reduce diaspore removal. However, disturbance changed the identity of ants interacting with diaspores, resulting in contrasting outcomes from ant-diaspore interactions. Our findings help to explain why natural regeneration is compromised after soil removal, which strongly influences diaspore fate and interactions with potential ground-dwelling dispersers, resulting in different ecological outcomes and strong influences on vegetation regeneration.
Building community resilience to climate change impacts through watershed restoration in Alebtong District, Northern Uganda

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Uganda is a landlocked nation in East Africa where over 80% of the population depends on rainfed agriculture, which is affected by climate change (MEMD 2017/2021). The Alebtong district, located in Northern Uganda, experiences prolonged dry spells and erratic rainfall, which distorts the crop calendar and drives communities to reclaim watersheds for crop production. This is a maladaptation strategy to climate change impact because watersheds in the form of seasonal or permanent wetlands are crucial for ground water recharge, water purification, water storage, rainfall formation, climate modulation, and flood control. Through implementation of the Northern Uganda Social Action Fund III (NUSAF III), provided by World Bank and the Office of the prime Minister, Alebtong District is building community resilience towards climate change impact through watershed restoration. The fund is given directly to community groups who are guided by technical staff to invest in and implement projects such as: (1) nursery bed establishment (exotic and indigenous tree species), (2) institutional and roadside greening with seedlings purchased from nursery bed projects, (3) pond fish farming, (4) cage fish farming, (5) ox-traction and crop production and, (6) community access road construction in flood prone areas. Environment and social management plans are developed for all projects to prevent or minimize environmental impacts. Projects have also helped to resolve underlying tensions that would ordinarily emanate from the fact that wetlands are a common property resource. Currently, pond fish farming generates approximately 4,131 US Dollars income per annum for each of the ten fish farming groups.

A water sensitive Cape Town: Wetland restoration at a city scale?

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The City of Cape Town’s draft water strategy commits the City to a more ‘water sensitive’ paradigm and proposes to make use of stormwater and urban waterways for the purpose of urban regeneration, flood control, water quality improvements, aquifer recharge, water reuse, and biodiversity. This is a welcomed proposition but how this will be realised needs further consideration. The area of most hydrologic relevance in this regard is the Cape Flats, a coastal low-lying plain previously characterised as a system of dunes, dynamic streams, and seasonal wetlands. Due to urbanisation, the landscape has changed dramatically, comprising for the most part formal and informal townships, agricultural small holdings, and light industry. Such activities pose significant contamination threats to waterways and the underlying Cape Flats aquifer. Moreover, the seasonal connectivity of rivers and wetlands to the primary aquifer, an important driver of their functionality, has been altered as a result of canalisation and intentional drainage of the area. This paper considers the issues of scale and understanding in urban waterway restoration, where there is a significant need for macro-level understanding with a view to informing ground-up civic engagements. Endeavours are required at multiple scales to see the establishment of a water sensitive city that is hydrologically and ecologically functional. This research aims to: 1) quantify the present spatial extent of the various wetland ecosystems as observed through remote sensing products, 2) assess the seasonal variability thereof, and 3) characterise their current functionality in regulating and supporting ecosystem services.

Comparing two contrasted methods of sand dune restoration after Eucalyptus clearing

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10
Coastal dunes are vulnerable ecosystems, threatened by both direct and indirect human pressures. In Israel, over the past century, well-intentioned efforts were made to stabilize coastal dunes, using exclusively non-native woody plants. Today these species, especially Eucalyptus camaldulensis, cover large areas, effectively stabilizing sand and profoundly modifying native ecosystems both above- and below-ground. In the current research (2015-2018), we tested two different treatments for kick-starting a restoration process: (a) cutting the Eucalypts (assisted regeneration), and (b) cutting the trees, removing all leaf litter, and reintroducing local plant species (active restoration). We established a protocol for collecting a large database on soil structure, nutrient content, soil bacteria, vascular plants, arthropods, and reptiles. We compared data collected from sites undergoing both treatments to the data collected under uncut Eucalyptus, and nearby never planted sand dune ecosystems. Three years after clear-cutting we found significant similarity between Restoration plots and sand dunes control plots. However, Regeneration plots were not significantly different from sand dunes or Eucalyptus controls. We also found significant differences in species composition. Restoration plots were richer in endemic and psammophile plant species, Regeneration plots were richer in foreign plant species. Chalcides sepsoide, a highly adapted skink, did not colonize any of the restored plots. Both Ablepharus rueppellii, and Cyrtopodion kotschy, generalist reptiles, were found only in the Regeneration plots. We concluded that although the litter removal treatment demands larger initial investment, it yields faster and better results for kickstarting self-recovery processes for the degraded coastal dune ecosystem under study.

Restoring mutualistic interactions on scenarios of climate change

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Recovering interactions between plant and animal species is essential for the restoration of degraded lands. Especially important are mutualistic interactions where animals act as pollinators (bees) and seed dispersers (birds) of native plant species. Thus, identifying plants that provide abundant food resources (e.g. pollen, nectar, seeds, fruit) for these taxa can help with the recovery of wider communities and ecosystem functions. Anticipating the effect of climate change on interacting species can also help define strategies for restoration programs, since it is important to rely on potentially less vulnerable species in the mid to long term. Aiming to support projects focusing on the restoration of degraded land in the National Forest of Carajás and vicinities (Eastern Amazon, Pará), interaction networks between bees (pollination) and birds (seed dispersal) with native plants were evaluated. Particularly important are those species of flora and fauna that interact with many partners (generalists), since they maintain the structure of the interaction network as a whole. The identification of such interactions and the potential impacts of climate change on the interacting species are key to maintain the functioning of the ecosystems to be restored. Such strategies could enhance the efficiency of land restoration programs, thus increasing their chance of success and, eventually reducing their costs. Results can also be applied in management and conservation programs by highlighting priority species to maintain ecosystem functions.

Ecological opportunities and constraints for wetland restoration for water quality enhancement

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It is internationally recognised that a number of wetland ecosystem services contribute to improving water quality, namely: nitrate, phosphate, and toxicant assimilation; sediment trapping, and erosion control. Although the South African Working for Wetlands Programme, whose objective is to protect wetlands, promotes wise-use and restoration of degraded wetlands, has made significant strides in restoring degraded wetlands nationally, a large portion of the South Africa's water resources remain in poor condition. In order to assist Working for Wetlands and other restoration initiatives, a set of published guidelines were developed to aid in selecting restoration sites, assessing wetland condition and functionality, and evaluating restoration interventions. These include the WET-Prioritise, WET-Health, WET-EcoServices and WET-RehabEvaluate, respectively. This presentation aims to draw from case studies on how an outcomes-based approach, which includes an assessment of opportunities and constraints of wetland features for restoration, can add value and strengthen the existing abovementioned guidelines with regard to the improvement of water quality-related ecosystem services. The assessment of the ecological constraints and opportunities of key wetland features includes, but is not limited to: condition, land cover, potential to increase contact time, source of water inputs, wetland attributes, wetland context, and wetland area to be enhanced. These features, which are associated with the wetland's capability to contribute towards improving water quality, can inform the selection of wetland restoration sites, which specifically contribute towards improved water quality, prioritising restoration interventions within a subset of restoration sites as well as contributing to the evaluation of wetlands post-implementation of restoration interventions.

Using a landscape approach to overcome barriers to restoration: Lessons from Tanzania

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Africa is the next frontier for transformation through rapid economic growth. New investment targets infrastructure and activities in the agricultural, mining, and energy sector - natural resource-based industries that provide anchors for new trade opportunities, job creation, and ultimately, poverty reduction. However, with poor planning and biodiversity management, such developments risk causing an overall negative impact on communities as well as biodiversity and ecosystem services. Governments and businesses, with increasing participation from civil society, are working together to proactively shape investments in geographically defined development initiatives called 'growth corridors'. These frameworks also offer the means to be able to collectively identify strategic opportunities for landscape restoration. IUCN will present its lessons learned from its work in Tanzania through the SUSTAIN initiative. Partners from the public and private sectors and rural communities have been supported to demonstrate how climate-resilient solutions for land, water, and ecosystem management can be coupled with economic growth initiatives to build and sustain water and food security. Lessons include: the importance of governance as a critical entry point for ensuring social inclusion and requiring interventions that proactively build local community participation in economic decision making, including resource use and allocation; having an integrated approach to water, land and ecosystem management backed by up-to-date and scientifically robust knowledge; and the role of businesses as key actors for bringing forward solutions and innovation but also to influence with other actors in the landscape.

Cape Flats Dune Strandveld - an endemic vegetation type in need of a helping hand

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Cape Town is globally renowned for its floristic diversity as part of the Cape Floristic Region, the smallest and richest of the World's six floral kingdoms. Cape Town is home to 20 national terrestrial vegetation types, one such veld type is the Endangered Cape Flats Dune Strandveld. Endemic to Cape Town, it is mainly confined to the coastal margins and comprised of a series of sand dunes and dune-slack wetlands inhabited historically by large herbivores such as hippopotami and rhinoceroses. Currently less than 24% of this veld type remains and not only is the flora under threat, but so too is the fauna. Two butterflies that are endemic to Cape Town are on the brink of extinction. The Critically Endangered Kedestes barberae bunta, which has an estimated abundance of just 50 individuals and the Endangered Kedestes lenis lenis. Both of these species utilize the same larval host plant, sword grass, which is generally confined to the dune slack wetlands. Ecological shifts such as the absence of large herbivores, changes in fire regimes, and the lowering of the water table are thought to be some of the main reasons for the decline in the populations. The Project has undertaken various habitat interventions, using simulated herbivory as a habitat restoration tool, aimed at improving the habitat not only for the threatened butterflies but for the system as a whole.

Desert soil seed banks: A refuge for plant diversity and a resource for regeneration
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After disturbances, regeneration from seed plays an important role in plant community recovery. Soil seed banks can lead to natural regeneration, or landscapes can be actively managed by adding seeds of desirable species. Arid systems tend to experience high environmental variability, which can lead to high levels of seed dormancy. This can result in a higher amount of species diversity within the intact soil seed bank than exists within the above-ground vegetation. When seeding is necessary, understanding seed dormancy can be critical for achieving restoration goals on short timescales (e.g. managing for temporal continuity within above-ground native plant communities). When a passive restoration approach may be desirable, it is important to understand when and where dormant seeds have accumulated in soil seed banks awaiting appropriate conditions to stimulate their germination. I will present information on species and population-level differences in seed germination characteristics for a suite of common, native Great Basin forbs in the western United States, showing the variety of dormancy strategies exhibited among species and across landscapes. Further, I will present information on seed bank variation across 17 locations within the Great Basin sagebrush (Artemisia) steppe, asking whether there are environmental or biotic predictors associated with seed diversity and abundance. Understanding when soil seed banks can help or hinder restoration and understanding the range of seed dormancy strategies that exist among species and populations can help managers decide when, where, and what to seed, or when it may be appropriate to take a passive approach to community recovery.

Suzano experiences with Forest Landscape Restoration in Brazil
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The areas of native vegetation in the Atlantic Forest suffered degradation for the use of wood in the construction of cities and development of agriculture. In the middle of century XX, areas with less capacity for agricultural production were used for eucalyptus plantations. Seeking to conserve natural resources, the Forest Code was created and revised in 2012, which defined a series of rules related to certain environmentally protected spaces. This review defined important legal instruments to promote compliance with land use guidelines and recovery of degraded areas. This led to the need to restore degraded areas by landowners. Suzano, the world's largest pulp producer, has an area in the state of São Paulo of 351,000 hectares, of which 118,000 hectares are destined for conservation.
108,000 hectares are composed of native vegetation in several stages of regeneration, but there is still a gap of 10,000 hectares to be restored.

Due to the complexity of large-scale forest restoration, Suzano has been developing its program, based on three pillars: Sustainable Forest Management, Passive and Active Ecological Restoration. After a decade, the program has already reached 8,300 hectares of areas under restoration. The (i) geographic location of nurseries, (ii) landscape diagnosis, (iii) monitoring of projects and (iv) existence of public policies to strengthen the need for forest restoration are fundamental to the success of the program. The opportunities are related to the use of geotechnology for project planning and the engagement of society through “shared value” among the landscape’s actors to promote conservation of natural resources.

Collaborative action plan to boost adoption of direct seeding as a restoration technique in Brazil

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The direct seeding technique is an option for restoration projects that is significantly cheaper, more efficient, and reaches higher impact compared to planting seedlings, contributing to large scale restoration. Yet its adoption in Brazil is still small, due mainly to the lack of knowledge of the technique itself among researchers and practitioners. Other barriers that can discourage or prevent direct seeding adoption are the supply of seeds, diversity of implementation activities for different vegetation and physical conditions, and regulatory barriers, among others. In this context, the Seed Pathway Initiative was developed to leverage direct seeding adoption in Brazil, enabling conditions for its large-scale use through a multi-stakeholder roadmap that resulted in an Action Plan to increasing direct seeding in restoration projects. Government, researchers, NGOs, service providers, seed networks, and other relevant stakeholders contributed for a diagnostic, analysis and prioritized actions, also considering regional particularities. The Action Plan contains strategies and actions designed for each focal region of the initiative (São Paulo and Mato Grosso states), as well as those of national scope and for other specific regions, important in the country's environmental context. The Action Plan covers a 5-year horizon, setting out the strategy for the entire country with lessons for other countries and considering the activities with the greatest impact on the technique adoption. Some of the actions are technical demonstration units for capacity purposes, outreach activities (publications of booklets and projects database), professionalization of seed networks, changes of specific regulations, and establishment of public-private partnerships.

Drought affects transitions between dominant plant species in California annual grasslands

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In Mediterranean annual grasslands, vegetation communities are sensitive to environmental variation and historical contingency (priority effects). Keen observers in arid and semi-arid systems have long recognized the importance of these drivers, employing qualitative state and transition models (STMs) to guide restoration and management practice. However, there are few empirical tests of assumptions made by these models, related to the number and composition of vegetation “states” and frequency of transitions between them. In light of predicted climate change effects across Mediterranean grassland systems, quantitative approaches to generating STMs may better predict long-term vegetation patterns used to identify key thresholds and windows of management action. Using experimental plantings of three classically-defined groups of grassland taxa – native
perennial grasses, naturalized annual forage grasses, and noxious invasive species—we examined transitions between vegetation types over a period encompassing typical precipitation patterns (2007-2010), drought (2011-2015), and post-drought recovery (2016-2019). Through unsupervised classification and multi-state modelling, we assessed the value of these group definitions and quantified transition probability as a function of historical contingency and climatic variation. We found that classic California grassland STMs do not account for a distinct 4th group of species that respond strongly to drought. We also found that vegetation states differed significantly in their transition frequencies; native species, in particular, were resilient to state change once established, but rarely invaded other communities. These results contribute to the growing evidence of contingency and environmental effects in annual grasslands, in addition to development of quantitative approaches that complement existing management tools.

State of the research: Using activated carbon in herbicide protection pods to simultaneously reseed desirable species and treat invasive annual weeds

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Restoration of desirable plants can be challenging in dryland settings, and the challenge is compounded when competing exotic species are present. Pre-emergent herbicides are frequently used to reduce competition from exotic annual plants prior to seed-based restoration. After application, reseeding desirable species usually must wait up to a year or more until herbicide toxicity has waned, and this herbicide-fallow period necessitates additional site visits to reseed. Also, if rapid annual reinvasion occurs, there may be little benefit from herbicide application. Herbicide protection pod (HPP) technology allows for simultaneous seeding and herbicide application by protecting desirable seeds inside pods or pellets containing activated carbon, thereby eliminating herbicide-fallow periods and allowing for single-entry restoration approaches. This technology has shown promise in multiple laboratory and field experiments to date, but many important questions remain and are under investigation. We present a review of the technology, then summarize recent results and ongoing research with emphasis on 1) optimizing HPP efficacy via modifying size and formulation, 2) comparing different delivery methods, and 3) scaling up production. Optimal HPP formulation and geometry depends on seed size and species, and refinement can decrease cost and improve efficiency. Traditional seed-delivery systems may need modification to ensure maximum performance of this technology. Industrial mass-production will be crucial to scaling up but presents challenges in maintaining product quality. We highlight additional opportunities and challenges and propose goals and priorities for ongoing research of this developing technology, which could prove to be transformative for restoration of invaded drylands.

Can delaying germination reduce winter mortality of fall-sown seeds in cold deserts?

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Efforts to restore semi-arid wildlands in the western United States predominantly use seeds and frequently occur in the fall. Fall conditions are often more amenable to seeding,
and successfully over-wintered seeds/seedlings are poised to take full advantage of spring moisture. However, winter mortality of fall-germinated seeds has been shown to be a common barrier to seeding success in some regions. Postponing seeding until spring avoids this barrier but presents other risks and drawbacks. One solution proposed to avoid winter mortality, without sacrificing the benefits of fall seeding, is to delay the onset of germination of fall-sown seeds. At six field sites over three consecutive years (18 combinations) in the northern Great Basin of the United States, we compared germination timing and first-year success of seeds treated to delay germination (“treated”) to untreated seeds in drill-seeding experiments. We asked: 1) does the treatment result in delayed germination, and, if so, 2) does a delay reduce winter mortality? Treated seed produced less winter germination than untreated in all 18 site by year combinations. Treated seeds also resulted in higher seedling density in 8 combinations, including 7 of the 8 combinations in which the majority (>50%) of untreated seeds germinated in the winter. We conclude that our treatments consistently delayed germination in the field, but improved seeding success only when winter mortality was a barrier. These findings support continued experimentation with germination-delaying treatments and highlight the need for models that define and predict winter mortality risk.

Creating species-diverse resource-conserving plant patches: A way forward to restore drylands

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The particular structure-function relationships of dryland landscapes are rarely considered in the design of dryland restoration actions. Promoting the establishment of species-diverse plant patches that enhance resource conservation could contribute to restoration success and biodiversity conservation in drylands. Using experimental plantations on bare slopes, we investigated the effect of increasing plant density and/or diversity within the plant patch on the productivity, resource conservation, and restoration potential of the target area. On 56 experimental plots, we created replicated patchy plant communities that varied in the number of both individuals and species per patch (1, 2, 4 and 8) and, for certain patch sizes, only in the number of species. For the first three years after planting, we found that increasing plant diversity and density, and thus patch size, reduced individual plant growth due to increasing competition within the patch. However, the individual biomass reductions did not compromise a positive net increase in total patch biomass with increasing patch size and diversity, which suggests some degree of functional complementarity within the patch. For equal patch size, increasing diversity either enhanced or did not affect individual plant growth, depending on the plant functional group considered. In general, larger and more diverse vegetation patches benefited from a higher sink capacity for rainfall and runoff water and a higher capacity for trapping sediments. Our results demonstrate that patch diversity and size control the recovery of drylands and highlight the potential of establishing functionally-diverse plant patches as a cost-effective approach for dryland restoration.

Using patch dynamics to inform ecological restoration of semi-arid and Mediterranean-type fields in Namaqualand, South Africa

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Namaqualand is situated in the Succulent Karoo Biome, a globally recognised biodiversity hotspot. The Kamiesberg mountain range in Namaqualand contains two vegetation systems heavily degraded by cultivation. The diverse floras are being converted into single woody species-dominated communities: Galenia africana in the lower-lying Karoo and Elytroppus rhinocerotis in Mediterranean-type mountainous Renosterveld. Traditional
restoration practises often ignore the role of patch dynamics, and the principles of facilitation and succession in arid systems. We tested how best to use pioneer plants and biodegradable shelters (using boxes and brush-packs) to mimic patch dynamics for successful seedling establishment in two vegetation systems in close proximity along an aridity gradient. We conducted a factorial field experiment for three years, seeding 18-20 species from a variety of functional groups in three habitats: under pioneer plants, in areas of recently removed pioneer plants, and in open areas. The Karoo and Renosterveld gave contrasting results. Seeding under G. africana plants resulted in low numbers of establishment but excellent growth rates, whereas seeding under E. rhinocerotis was less effective. Seeding into areas of recently removed G. africana was less successful compared to seeding in open areas; and the opposite results were found with E. rhinocerotis. Succulent Aizoaceae species established successfully in the Karoo, whilst in Renosterveld, grasses and herbs established was greater. Our study showed that it is better to sow seeds into open areas with sheltering structures in the Karoo, including under G. africana. Whilst in Renosterveld, we recommend sowing seeds into the space of recently removed E. rhinocerotis.

Sudbury, Ontario, Canada: 40+ years of healing and creating novel functional ecosystems on a smelter-impacted landscape

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Sudbury houses major nickel mining and smelter complexes. The impacts of sulphur gases from roast yards before 1928 through to the more modern smelter operations emitting sulphur gases and metal particulates created a barren landscape of ca 17000 ha and an additional 64000 ha of stunted forest. The accumulation of bioavailable and potentially toxic metal levels in the acid surface soils, accompanied by soil erosion, lack of organic matter and soil nutrient depletion, impeded natural vegetation recovery. The requirement for reduction of emissions (now 95%) from the largest smelter complex led to the construction of the 381 m Superstack employing gas and particle-capture technologies. The stage was set for an assisted landscape recovery program. Over the past forty plus years the Sudbury Regreening Story, based on effective interaction between community, government, academia and industry, describes the regional transformational program now recognized globally as a model to emulate. The Sudbury Protocol for technogenic barren landscape restoration has evolved from regreening activities that involved application of dolomitic limestone, fertilizer, seeding of agricultural grasses, legumes and planting of tree seedling to a more complete biodiverse restoration strategy. By 2018, 3478 ha had received soil amelioration and ca 10 million trees and shrubs had been planted for approximately $32.7 million while employing over 4775 individuals. The outcome of the Regreening Program is a new image for the city and environs which has helped to attract new business enterprises, tourists and encouraged an increased respect for the environment.

Predicting the existence and performance of U.S. water quality trading programs

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Support for market-based environmental policies that rely on ecological restoration, such as water quality trading (WQT) programs, centers on improving economic efficiency of pollution reduction. However, program performance is uneven; while several WQT programs have found frequent use, many experience operational barriers and exhibit low trading activity. Evaluations of WQT programs tend to focus solely on a few successful programs, producing little evidence about what sort of program trading structures exist, or even if trades regularly occur. Few studies explain the abundance of WQT programs, their locations, and where trading actually occurs. Little research has looked across geographies and market designs to comparatively study different types of trading programs.
Comprehensive analysis is needed to better understand the factors promoting, or detracting from, the viability of WQT as a resource protection strategy and to synthesize policy lessons for improving program design, implementation, and performance. What are the common inhibitors to implementation WQT programs? Where and why have these programs become productive and when do these programs frequently become stalled in their implementation? We present the most complete geo-database of WQT programs in the United States, detailing separately traded pollutants, distinctive geographic service areas, market designs, and distinct trading mechanisms. Drawing on demographic, political, and environmental co-variates, we use logistic regression modeling to understand the existence and relative operating state of WQT programs. We use this analysis to inform program design and implementation, as well as improve understanding of program implementation barriers.

Integrated Restoration System – a web-platform for large scale restoration

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Some countries are seeking to achieve their Bonn Challenge goals and implement their forest landscape restoration commitments. Monitoring the evolution towards the pledged goals is fundamental to ensure the success of these commitments. The Integrated Restoration System – or SIR, the Portuguese acronym, is a web-system with a spatial database that allows and facilitates the management and monitoring of forest restoration projects. SIR's main objectives are: to register restoration projects and to track their results, from donations (providing high financial transparency) to implementation on the ground. SIR allows the application of ecological forest monitoring protocols through an app developed for the Android System. Additionally, SIR can import information from monitoring systems and store it to analyze results and provide reports describing the evolution of restored areas. The system has the following technical characteristics: LINUX OS; PostgreSQL / PostGIS relational databases; and is built using PHYTON and other free software. Initially, The Nature Conservancy developed SIR for its local partners and its own use. Currently, besides Brazil, SIR is being used in Argentina, with a dynamic dashboard that provides information about restored hectares, estimated sequestered CO2, and financial investments and jobs generated by the country's restoration activities. Because SIR is developed on an open platform and has a friendly application, it can be adapted for use in other restoration programs worldwide, reporting the evolution of restoration commitments made by different countries, such as the 20x20 Initiative in Latin America, for example.

Using disturbance as a conservation tool in Mediterranean temporary ponds

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The Mediterranean temporary ponds (MTP) are seasonal freshwater habitats classified as priority (3170*) by the European Habitats Directive. Their persistence has not only been compatible but also favoured by extensive human activities. So, MTP conservation must bear in mind that this habitat results from a long human presence in the Mediterranean region. Recently, there has been a decay of the ponds conservation status due to the lack of both grazing and superficial tilling resulting in grass encroachment that led to the disappearance of rare/less abundant flora species, and to the invasion by opportunistic
heliophytic plants. We, therefore, simulated this traditional land-use regime in 8 MTP in the Southwest Coast of Portugal in Spring 2018 to recover, among others, Apium repens (Jacq.) Lag., a priority species for conservation under the Habitats Directive. This experiment allowed more light into the soil level and enhanced germination of the tiny plants characteristic of MTP that have been brought to the surface through superficial tillage. The methods proved to be efficient as plant species richness increased, resulting from bringing to the surface the seeds that were still in the soil seed bank and thus providing them with enough light to germinate. This positive effect was even more evident in the 2nd year of the experiment monitoring. These results open new questions like: what is the resilience associated with the results obtained? Is it sustainable to carry out regular recovery actions, either environmental or economically speaking?

Thicket rehabilitation for socio-economic development in the Baviaanskloof, Eastern Cape

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Since 2008 Living Lands has facilitated and implemented land rehabilitation in the Baviaanskloof Hartland, an area of approximately 32,000 hectares in the Eastern Cape. The area is characterised by high levels of degradation of thicket vegetation (about 9,000 ha), mainly due to overgrazing. This results in rising levels of soil erosion, reduced water retention, and creation of gullies. Living Lands implements rehabilitation in collaboration with the local community, through an approach that pursues four positive returns across environmental, economic, social, and inspirational dimensions (“Four Returns”). The Baviaans, along with the Kouga and Kromme rivers provide approximately 70 percent of the water supply for the Nelson Mandela Metropolitan Municipality and a vast farming industry in the region. To date, more than 2,000 hectares have been brought under rehabilitation through various means, under various mandates, and with varying degrees of success. Current collaborations with the sustainable land management project funded by the Global Environmental Facility 5, and with Rhodes University, seek to bring 1,000 additional hectares under rehabilitation, along with sustainable land-use management practices. In restoration practices, we are faced with a multitude of ecosystem problems and socio-economic challenges. To be successful in our attempt to restore the Baviaanskloof to a greater functional capacity, whilst attaining impact in the four returns, we have to use a multitude of approaches. These include traditional as well as novel techniques to modifications of restoration practices, while maintaining the links to socio-economic complexities and inspiring action under challenging circumstances.

Restoring trophic cascades and the need for baselines and monitoring

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As conservationists we aim to conserve representative and functional ecosystems across the world. However, current conservation practices are inadequate as global biodiversity continues to decline drastically. Many species are not covered by our network of protected areas. Protected areas are often too small and/or too isolated to allow for all natural processes to occur such as top-down and bottom-up regulation, movement of species, and natural disturbance. Static boundaries prevent adaptation to long-term change. These ecosystems will not persist and as a result, species continue to decline and go extinct even when protected. Rebuilding complete native food webs through the restoration of trophic interactions and habitat, as envisioned by rewilding and large-scale restoration, is needed to complement conservation. The common goal is self-sustaining and fully functional native ecosystems maintaining high levels of biodiversity. To achieve this, we need an existing reference ecosystem, or a model informed by science and local or traditional knowledge. This is the baseline or endpoint. Having a defined endpoint allows
us to assess the progress of recovery, deviations in the trajectory and persistence of the
system over time. It also enables us to measure resilience of an ecosystem following
disturbance and guide management and active intervention where needed.

Rewilding as an approach to large landscape restoration: An update
on the work of the IUCN CEM Rewilding Task Force

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Rewilding as an approach to large landscape restoration has been gaining substantial
traction. We describe it as the process of restoring native ecosystems, following major
human disturbance, to create a complete food web at all trophic levels as a sustainable and
resilient ecosystem using biota that would have been present had the disturbance not
occurred. Rewilding can be seen on a continuum of ecological restoration towards
increased ecosystem integrity and autonomy and reduced human impact and
intervention. It is complementary to other conservation approaches, such as protection
and community conservation, which so far have failed to stop the continuous decline of
species and degradation of nature. Rewilding has an important social dimension, engaging
communities in the restoration of "wild" nature and providing hope for healthier
ecosystems. The IUCN CEM Task Force on Rewilding consults with a broad community of
experts and practitioners and aims to provide IUCN with a clear understanding of rewilding
and a link to CEM priority areas. So far, the task force conducted a systematic review of the
literature, developed initial guiding principles and performed a survey of rewilding
pioneers. Two workshops in the US and Europe were held with academics, advocates, and
rewilding practitioners. The workshops highlighted similarities and differences between
the two continents in the ecological and human aspects of rewilding. A set of principles
emerged as part of an ongoing development. The next steps aim to broaden the expertise
and geographic scope and more workshops are planned in 2019 (online) and early 2020
(India).

An efficient method of coating native seeds: Single seed pellets vs
multi seeds pellets

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In ecosystems where the severity of disturbance precludes autogenic recovery, targeted
seeding with a diverse mix of native species can be the only means of restoring
ecosystems. However, the success rate of broadcast seeding can be constrained by biotic
and abiotic factors that impair seedling emergence and development. These effects are
felt most strongly for small seeded species. Pelleting small seeds has emerged as a
promising strategy to address issues such as poor seedling emergence, physical soil
crusting, seed predation, and low rates of seedling establishment. However, there have not
yet been any comparative studies undertaken to understand whether single seed or multi-
seed pellets represent the most effective strategy for delivery of native seeds in seed-based
restoration activities. In this study, the efficacy of single versus multi-seed pelleting was
assessed for three different small seeded species from the Midwest region of Western
Australia, Eucalyptus loxophleba subsp. supralaevis, E. leptopoda subsp. elevata and
Melaleuca hamata (Myrtaceae). Seeds were coated using a Pan Coating machine due to
their small size and mass, representing the first such attempt based on review of the seed
coating literature for native seeds. The study focused on the comparative performance of
un-pelleted seeds, single seed pellets and multi-seed pellets based on the pellet's physical
quality and germination performance in lab-based experiments.
Forest Landscape Restoration: Conservation outcomes and lessons from Terai Arc Landscape, Nepal

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Nepal has adopted landscape an approach of conservation, establishing the Terai Arc Landscape in 2004. Tropical and subtropical broadleaved forests, riverine forests, grasslands, and floodplains of the Terai Arc Landscape harbor meta-populations of tigers, elephants, and rhinoceros. WWF Nepal initiated the Terai Arc Landscape Program in partnership with the Government of Nepal to mobilize local communities and stakeholders for effective management and restoration of critical corridors and bottlenecks within the landscape to create and maintain ecological connectivity linking protected areas with community forests, plantations, and other conservation-friendly land-uses. A total of 22,791 ha of degraded forest and degraded land has been restored in critical corridors during last 15 years. Moreover, 237,050 families have been managing 162,818 hectares of forests as community forests that increase access to forest resources to local communities. Forest restoration and community-based forest management resulted in an increase in tiger and rhino populations. The tiger population has nearly doubled in the last ten years from 121 in 2009 to 235 in 2018, whereas the rhino population increased from 372 in 2005 to 645 in 2015. Water springs have reappeared in the restored areas within the landscape. Local communities have benefited from economic opportunities through forest and farm based green enterprises and ecotourism. It is recognized that government ownership and community stewardship could bring significant positive results in forest and landscape restoration and in increasing populations of targeted wildlife species.

Restoration of degraded dryland ecosystems: A case study of Kuwait

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Kuwait’s native flora comprises 256 annuals, 83 herbaceous perennials, 34 shrubs and one tree species. Historically, native vegetation in Kuwait is subjected to several natural (harsh, unpredictable weather, scanty and unpredictable precipitation, extended drought, and relatively short growing period) and anthropocentric (overgrazing, off-road vehicular movements, camping) pressures. The invasion of Kuwait by Iraq in 1990, and the two Gulf wars that followed subjected the desert resources, including the native vegetation, to additional pressures. Because dryland ecosystems are very slow to recover, the State of Kuwait initiated specific short-to-medium and long-term restoration measures under the Kuwait Environmental Remediation Program (KERP). In this program, five protected areas covering a total area of 1,680 km² spreading across different dryland ecosystems were established, and a revegetation island approach was adopted to restore the ecosystems. Seeds of keystone native species (Rhanterium epapposum, Farsetia aegyptia, Calligonum comosum, Pennisetum divisum, Panicum turgidum, and Haloxylon salicornicum) were mass produced and nursery facilities for raising large volumes of quality seedlings were established. Both direct seeding and seedling transplantation approaches along with seed enabling technologies are being tested to maximize revegetation success, which is being assessed through long-term ecological monitoring. This program represents one of the world’s largest dryland restoration efforts of its type. When successfully implemented, the lessons learned from Kuwait’s efforts will undoubtedly contribute significantly to the state-of-the-art knowledge on revegetation under arid climatic conditions. The presentation will cover the findings of several years of ecological restoration efforts in Kuwait.

Germination strategies of selected Kuwaiti desert plants and their implications for dryland restoration

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Desert plants use a number of strategies to survive in arid environments, which are characterized by extremely high temperature, intense radiation, strong winds, low and erratic rainfall, high evaporation rates, soil erosion, and lower nutrient availability. These species produce certain structures that help in seed dispersal to suitable microsites and/or regulate their germination response to prevailing conditions. Some species also produce heteromorphic seeds or maintain aerial seed banks to cope with extreme environmental conditions. The adaptive mechanisms in three of Kuwait’s native plants, namely, Farsetia aegyptia Turra (presence mucilage), Seidlitzia rosmarinus Boiss. (presence of wings) and Calligonum comosum (heteromorphic seeds) were studied and their germination behavior under different temperature and light regimes and elevated salinity conditions was determined in the present study. Irrespective of incubation temperature regimes and photoperiods, de-winged S. rosmarinus seeds germinated better (76-88% total germination) than intact seeds (24-41%) with the low temperature regime (20/15 °C) resulting in 10% higher germination (85-88% vs. 76-78%). Although the presence of mucilage and thermoperiod did not affect the germination, longer storage significantly increased the germinability of C. comosum seeds. Increasing salinity levels decreased the germination of all three species, but ungerminated seeds were able to germinate when the salinity stress was alleviated. These mechanisms allow them to minimize the impact of adverse habitat conditions and maintain seed viability. The implications of these adaptive mechanisms for dryland restoration will be discussed in this paper.

Bringing research and catchment restoration planning and management into conversation with rural development

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The preceding talks in this symposium all aim at widening the usual “science-management” (technocratic) power nexus. This entails additional linkages that effectively engage the “rest of society” beyond scientists and managers. While these extensions should not be overbearing, there is growing recognition of the need for collaborative polycentric governance. Projects reflected in this symposium have engaged in various ways more deeply than before with a range of user and client groups, right through to catchment residents, in various potentially empowering ways, including a focus on livelihoods. Building on these specific examples, this presentation will discuss more generally our experiences with trust-building, co-production of goals and knowledge, and the move towards appropriate levels of joint decision-making, or at least meaningful joint recommendations with a high likelihood of implementation. These projects all fall in the domain of landscape or catchment rehabilitation/restoration. During the trust-building and collaborative phases of these projects with “wider society”, especially in the poorer regions in southern Africa, many other developmental needs surface – say needs for healthcare, education, or security – often more pressing than the locally expressed immediate need for restoration. Whilst poorer communities generally opt for participation in any such restoration initiatives, this situation has led us to reflect on (a) whether restoration is done, as we increasingly try to carry it out, in a developmental framing; and (b) how the bigger picture of expressed local needs and top-down developmental plans could best play out, with restoration as a socially and economically beneficial contribution to this.

Developing a holistic thread of thought on restoration of land, water, and society: A synthesis and experience from southern Africa

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This presentation tracks development, interrelationships, and common provenance of frameworks used in the RESILIM-O and Tsitsa projects in this symposium, and benefits,
challenges, and meta-learnings emerging from this longer-term process. These projects emphasise particularly systemic, collective co-construction, and (invariably transformative) learning to support restoration and related practices. This evolved, over time, effectively splicing social science, biophysical science and collectively lived experience into a functional trans-disciplinary praxis. Antecedents included the decade-long Kruger National Park Rivers Research Programme, emphasising strategic adaptive management (SAM), and the Save the Sand Project in which systems thinking and resilience aspects were further developed. Innovative social learning frameworks were progressively added in the latter project and in RESILIM-O. Seeing restoration practice and contexts (system(s) of interest) as nested interconnected wholes enables feedbacks at multiple scales to be utilised for monitoring and learning, both formal and tacit, and for realist-style evaluation. Together with SAM philosophy, this encourages addressing selected immediate crises, balancing this against reflection and building pre-emptive capacity. This overall way of working promotes modesty, tries to accommodate existing structures, but has to confront perversities and promote patience and trust-building. It often defuses tensions and enables different groups to move forward together. Resource management decisions often flow from emergent outcomes of wide reflection and sufficient consensus. Although helping, the methods do not in any direct way address persistent power asymmetries. Requiring time and ongoing thoughtful development, incremental learnings from this approach give hope for more durable, better agreed-on, and sufficiently responsive restoration of land, water and society.

Novel ant assemblages in multi-perturbated Neo-Caledonian ecosystems: Limit or opportunities for their restoration?

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Human activities such as the extraction of mineral resources and man-made fires have permanently altered the valuable New Caledonian mining ecosystems. Involved in numerous biotic interactions, ants are considered today as real ecosystem engineers. Because of their diverse above and below-ground impacts, ants can be either key engineering tools or a restoration challenge in the case of invasive species. As part of an ecological restoration, we focused our study on the myrmecofauna's composition, species richness and structure along an ecological succession on ultramafic soils and a chronosequence of restored sites. We showed a clear distinction between ant communities of degraded open habitats (stripped bare, scrubland and restored sites) and preserved forest habitats. In addition, we showed that open habitats were characterised by similar novel ant communities mainly composed of exotic and invasive species, whereas communities of preserved ecosystems are composed of native and endemic species. We discuss here the consequences in terms of ecological restoration of the establishment of novel ant assemblages in the first stages of the vegetation succession of highly diverse forest ecosystems.

Landscape restoration in Rwanda: Experience with the development of a Payments for Ecosystem Services system

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It is conservatively estimated that the loss of topsoil in Rwanda equates to at least 4 tons per person per year. This loss of soil can be directly attributed to erroneous soil disturbing land use management practices. These practices, and the resultant soil erosion, reduce the productive capability of the soil, increase the cost of electricity generation and water treatment, and is the source of a loss of life and livelihoods, among others. It is especially the loss of agricultural potential that has an impact on the level of nutrition and public
health. Rwanda has embarked on a programme under the ambit of Vision 2050, its long-term development focus, to reduce soil erosion as a matter of national security risk reduction. One of the instruments to be used in achieving this objective is a Payment of Ecosystem Services (PES) mechanism. This is a market-based instrument incentivising the change in land use practises. This paper will explore the details of this PES project and consider some of the initial results following the launch of its pilot on 22 March 2019.

A 10-year case study of tropical grassland restoration using a whole-turf translocation method

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Integration of economic activities with environmental integrity is the greatest contemporary challenge, especially in the case of mining activities. In Central Africa, southeastern Democratic Republic of Congo and adjoining regions in the north of Zambia, called the “Copperbelt”, comprise hundreds of copper-cobalt outcrops. Cu-Co outcrops present original grassland communities with over 600 metallophytes, including 56 endemic taxa. This unique vegetation includes a diversity of life forms, including taxa having developed woody underground system as xylopods. Most outcrops have now been allocated to mining companies and are expected to be irreversibly impacted in the coming decades. While pristine metalliferous habitats are threatened by mining operations, the two plant communities, i.e. the steppic savanna and the steppes, benefit from a conservation program. A concrete ecosystem-scale conservation option is currently considered through ecological restoration, using the whole-turf translocation of plant communities. Short-term experiments showed that the main structure of steppes is recovered after two years, whereas for the steppic savanna, weeds are excessive and targeted species (i.e., xylopods) are missing. This study evaluates the success of the whole-turf translocation of plant communities after 10-years of restoration of copper-cobalt ecosystems in order to provide guidelines for practitioners.

Restoring old-growth grasslands: A major problem in the aftermath of global tree-planting

William Bond
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Afforestation has been widely promoted to ‘restore’ deforested and ‘degraded’ land. For example, the Bonn challenge plans to afforest 3.5 million km² by 2030, an area half the size of Australia and greater than the entire land area of the European Union. The motivation is primarily carbon sequestration for wealthy countries and currency earnings for developing countries. Africa has been targeted for afforestation of 1.5 million km² within the next decade. More than a dozen countries have signed up to afforest their ‘degraded’ lands. Degradation, as defined by the World Resources Institute, is any process that damages trees, including wildfire and mammal browsing. Thus, by definition, Africa's vast savannas are all ‘degraded’ and a major global target for afforestation. However African savannas include ancient ecosystems that have been maintained by fire and large herbivores for millions of years. Rather than ‘degraded’, these grassy biomes are now seen as alternative states to closed forests. Attempts to restore biodiversity in old-growth grasslands planted to conifers and then clear-felled has proven very difficult. Instead, it makes more sense to avoid planting biodiverse grasslands in the first place. As yet, markers for rapid evaluation old growth grasslands are still being developed and it is not yet possible to clearly distinguish between secondary and old growth grasslands from satellite imagery. There is an urgent need to direct tree-planting programs to truly deforested areas to avoid major
disruption of the biota of open ecosystems because of ill-conceived quick-fix global afforestation plans.

**Restoring fragmented habitats using eland as a veld management tool**

**Petro Botha**
Cape Town Environmental Education Trust, South Africa

With the ongoing threats to biodiversity and pressure from human activities on the unique flora of the Cape, the need for modern restoration and conservation practices has emerged. Experimenting with new tools to restore and conserve fragmented habitats is creating opportunities for novel veld management practices in the urban environment. The aim is to reach a balance between human needs while restoring and protecting biodiversity and eco-system services and functioning in the face of climate change. Remaining natural areas within the Cape hold a high biodiversity value and through understanding and enhancing the way we restore these fragmented areas, we will enhance the way people experience and value such sites. The Gantouw Project is testing a restoration tool for modern conservation practises on small, isolated conservation areas in Cape Town, and involves using habituated eland antelope to combat bush encroachment. It is expected that the eland’s browse and trampling activity will reduce canopy size, opening up the veld resulting in changes to faunal and floral communities, mimicking historical actions of large herbivores. The method of using eland as a veld management tool, apart from the ecological value, is also proving to have other beneficial spin-offs to youth of the local community. Employment opportunities are created for youth as eland monitors. Eland monitors go through various skills development programmes, contributing to growing the green economy of South Africa. Mystical eland, once a sacred animal to the San people of southern Africa, are important ambassadors, connecting people, young and old, with nature.

**Selecting native plant material for restoration projects in different ecosystems: Successes and challenges**

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Due to loss of natural ecosystems and biodiversity around the world, international initiatives are being developed to establish a foundation for the restoration of diverse ecosystems, prioritizing ecosystem biodiversity and resilience while also recognizing impacts on rural livelihoods and carbon storage. A shift from revegetation with available material to using native genetic plant material (NGPM) of known genetic origin has been underway and achieving increasing priority at an international level. Through research and collaborative partnerships, on local, regional and international levels, and between public and private sectors, approaches are being developed that addresses the challenges in using NGPM in ecological restoration. Four study cases from different geographic locations and climatic conditions were selected to demonstrate the successes in using NGPM for native genetic resource management, and meeting challenges according to every ecosystem’s limiting factors. In Jordan’s desert ecosystem a developed native seed strategy has majorly improved seedling quality and post-planting survival rate. In the tropical ecosystem of Guinea Conakry, the major challenge is to identify best seed collection times and seed handling techniques to improve seed germination and propagation of native seedlings through seeds for the restoration of the Bossou corridor. Within Morocco’s Atlas Mountains, an emphasis is being made on the development of a traceability system for NGPM used in restoration projects, considering the genetic variability within native species, starting with Cedrus atlantica. In Lebanon, considering the diverse ecosystems, a scheme
for the selection of NGPM is developed within every restoration project, for dryland, riparian or forest ecosystems.

Selecting and growing seedlings for desert ecosystems

Karma Bouazza\(^1\), Antony S. Davis, Mohammad El Nsour

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The desert ecosystem in the Middle East, also known as the North Arab Desert, stretches into Syria, Iraq, and Saudi Arabia with elevations varying between 600 and 900 meters. The Eastern Desert in Jordan, also known as the Badia region, comprises around 75 to 80% of Jordan. The region is characterized by its harsh extreme conditions in summer and winter, particularly by its dry weather and low rainfall, which averages of less than 50 mm annually. In recent years, international and local efforts have been initiated to revitalize Badia ecosystems and communities that rely on this land. However, restoring the Badia using shrub planting and other water catchment systems faces many challenges. Post-planting survival of nursery-grown rangeland seedlings in Jordan has typically been low, due to poor planting and tending practices as well as a lack of scientific principles being applied in the nursery production process. The Sustainable Environment and Economic Development (SEED) project, funded by USAID and implemented by USFS IP, has worked extensively on developing native seedling production practices based on more scientific approaches that are quantitative, reproducible, and affordable, from seed collection and handling to outplanting. Following the principles of the Target Plant Concept, these practices result in the production of high-quality rangeland seedlings of known genetic origin with an average of 80% post-planting survival rate in their natural habitats on most sites.

What is the real cost of pursuing socio-ecological thinking at the catchment scale? Using the Tsitsa Project, South Africa, as an example

Michael Braack

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The use of socio-ecological frameworks grounded on bottom-up approaches is widely promoted by conservation practitioners and planners. Rehabilitation with the aim of restoration needs to be resilient and must ensure sustainable livelihoods. But what does restoration based on socio-ecological thinking really cost? An example of this is the Tsitsa project, an initiative spearheaded by South Africa’s Government through the Department of Environment, Forestry and Fisheries, Chief Directorate of Natural Resource Management. The Tsitsa project vision is to: “Support sustainable livelihoods for local people through integrated landscape management that strives for resilient social-ecological systems and which fosters equity in access to ecosystem services.” The key features of the upper Tsitsa River catchment in the Eastern Cape Province (with an approximate area of 5,000 km\(^2\)) are high levels of landscape degradation and extremely dispersive subsoils, which generate large silt loads in the rivers. The Tsitsa project provides a holistic and integrated natural resource management plan (within the context of the Land Degradation Neutrality framework under Sustainable Development Goal 15, specifically pursuing planning to avoid degradation) at the catchment scale. The project seeks to harmonise the priorities and wishes of the local residents and to integrate the advice of scientists and engineers. The rehabilitation plan has projected a US$2 billion investment spread over the next 10-20 years. Between 2015 and 2019, the engagement, monitoring, and learning components will cost US$3.7 million, with a total projected cost of about US$6.9 million over 8 years.
Mitigation–driven translocations: Phased destruction or an effective applied science?

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One of the major conservation tools used to safeguard threatened species is reintroduction, the intentional release of organisms with the purpose of augmenting, establishing or re-establishing wild populations. Mitigation-driven reintroductions are a supply-driven form of reintroduction where the current population is under threat of extinction, largely due to human activities, and reintroduction is required to mitigate the resulting extinction risk. As mitigation reintroduction is a crisis discipline that requires immediate action to prevent extinction, it often fails to uphold suitable applications of scientific principles and scrutiny and may have very limited documentation of outcomes. Mitigation reintroductions can therefore be a controversial form of management, with questionable conservation efficacy due to a lack of a priori testable hypotheses, direct comparison of management techniques, and long-term monitoring commitments. This suggests the potential for a negative cycle of wildlife relocated away from the public eye for a more socially acceptable ‘phased destruction’, with a high cost to managers and little conservation value. The aim of this review was to undertake a selective, systematic, quantitative review of the global reintroduction literature to determine the inclusion of a priori goals, comparison of management techniques, and the addressing of key population, meta-population, and ecosystem level questions in mitigation reintroduction studies. Whilst there was a positive correlation between a number of these factors and reintroduction success, there is both a need for a larger budget and a commitment to long-term monitoring if future mitigation reintroductions are to have a significant conservation value.

The impact of a lack of policy framework for restoration in South Africa

Samantha Braid
Waterlore, Kenilworth, South Africa

Just because the word “rehabilitation” appears in the South African National Environmental Management Act, Act 107 of 1998 (NEMA), does not mean that it happens, or that there are institutional structures or mechanisms in place to ensure active rehabilitation of environmental degradation. The NEMA does not call for the proactive rehabilitation of environmental degradation, but only for enforcement-driven rehabilitation where an environmental crime has been committed. This means that where environmental degradation or pollution has taken place historically (i.e. before the legislation came into effect) there is no legal framework, organisation, or mechanism to proactively rehabilitate this damage. Similarly, where activities that may once have caused environmental damage have been abandoned (i.e. there is no legal person continuing with the activity), again there is no legal framework, organisation, or mechanism that will ensure the environmental degradation is stopped, mitigated, or rehabilitated. The result of a lack of framework has resulted in extreme, cumulative environmental damage. Without supporting legislation, the rehabilitation activities are viewed as “new developments” and must crawl through the same onerous, complex, and costly authorising process as an actual environmentally degrading activity (e.g. dredging a wetland or mining). Ultimately, rehabilitation of environmental degradation is not carried out, and only to a limited effect under enforcement driven rehabilitation. Of relevance, the South African legislation has been replicated in other countries in Africa. This paper highlights the pitfalls and resultant impacts of a lack of policy framework for rehabilitation and makes suggestions on the way forward.
Advancing towards the 15M hectares target: The Atlantic Forest Restoration Pact completes its first million hectares

Pedro Brancalion
University of São Paulo, Piracicaba, Brazil

Many ambitious restoration targets have been pledged in recent years, but very few of them have demonstrated that achieving these targets is doable or have developed a reliable monitoring mechanism to check progress and report results. In this talk, I will present the approach adopted by the Atlantic Forest Restoration Pact in Brazil – a multistakeholder coalition with over 300 organizations that aim to restore 15 million hectares of native forests by 2050 – to monitor the advancement of the area undergoing restoration. An estimated 673,510-740,555 ha of native forests were restored from 2011 to 2015 in the Atlantic Forest, and it is expected that a total of 1.35-1.48 Mha of native forests will be under recovery by 2020, thus achieving the 1 million hectares goal that the Pact committed to the Bonn Challenge. However, restoring the additional 14 million hectares in the next decades will require alternative approaches that allows farmers to profit from restoration through payments for ecosystem services and production of timber and non-timber forest products in order to overcome land opportunity costs and transform restoration into a financially viable land use.

Challenges for large-scale restoration of tropical forests

Pedro Brancalion
University of São Paulo, Piracicaba, Brazil

Tropical forest restoration relies on permanent changes in land use that, although resulting in multiple benefits for society at large, may require farmers to forego agricultural land use and invest additional funding in a new and still unprofitable activity. The main challenge for upscaling tropical forest restoration is then its economic viability, as farmers will make decisions based on traditional market factors that have guided their work – and in some cases promoted deforestation – like the returns on investment, risks, and direct benefits. Restoration is then dependent upon a more favorable economic environment, in which: i) society recognizes the multiple benefits of restoration and provides financial incentives for it in the form of private or government instruments, like donations, tax reduction, payments for ecosystem services, and subsidies; ii) novel technologies reduce restoration costs and risks; iii) alternative restoration schemes allow the commercial production of timber and non-timber forest products in such a way that the revenues obtained with these products can overcome those that resulted from previous land uses; iv) effective legal frameworks promote restoration in the private sector. The creation of this favorable economic environment may depend, however, on multiple sectors of society that highlight the importance of multi-stakeholder coalitions. In this talk, I will present examples to illustrate what has been done in the Atlantic Forest region of Brazil to establish such a favorable environment for restoration and explore how innovations developed in this context could be adapted to other regions with high demand for restoration efforts.

Tools and knowledge products to scale up forest restoration

Pedro Brancalion
University of São Paulo, Piracicaba, Brazil

Forest restoration is an emerging human endeavor that aims to reverse a long history of land degradation and destruction of native ecosystems for expanding agriculture production, but that still relies on rudimentary tools for achieving such ambitious goal. The Atlantic Forest Restoration Pact in Brazil is aware of the need for innovation and technological advancement for upscaling restoration, and has invested in many different fronts to develop effective tools and knowledge products to contribute to this aim, including: i) restoration schemes designed to maximize the production of timber and non-timber forest products of native and exotic species of commercial value for transforming...
restoration into a profitable activity; ii) developing predictive models of restoration costs and multiple benefits in order to support the prioritization of sites offering higher restoration opportunities; iii) a web-based system to register and monitor restoration projects and a biome-scale analytical approach to check progress towards national and international agreements; iv) a monitoring framework to collect ecological, economic, and social indicators to check progress of restoration projects and guide adaptive management; and v) promoting innovative legal frameworks for improving restoration governance. In this talk, I will describe how the aforementioned strategies to upscale restoration were developed and how they have performed and explore their potential use in other socio-ecological contexts in such a way as to promote benchmarking in restoration.

Co-creating conceptual and working Forest and Landscape Restoration frameworks based on core principles

Pedro Brancalion, Robin Chazdon, Victoria Gutierrez, Lars Laestadius, Manuel Guariguata
University of São Paulo, Piracicaba, Brazil

We will present the development of a high-level conceptual framework and linked tailored working frameworks to guide the initiation, practice, and assessment of Forest and Landscape Restoration (FLR). Existing guidelines and best-practices documents do not satisfy, at present, the need for guidance based on core principles of FLR. Given the wide range of FLR practices and the varied spectrum of actors involved, a single working framework is unlikely to be effective, but multiple working frameworks can be co-created based on a common conceptual framework (i.e. a common core set of principles and a generalized set of criteria and indicators). We present relevant background regarding FLR concepts, definitions, and principles; and discuss the challenges that confront effective and long-term implementation of FLR. We enumerate the many benefits that a transformative criteria and indicators framework can bring to actors and different sectors involved in restoration when such framework is anchored in the FLR principles. We justify the need to co-develop and apply specifically tailored frameworks to help ensure that FLR interventions bring social, economic, and environmental benefits to multiple stakeholders within landscapes and adjust to changing conditions over time. Finally, we describe existing FLR guidelines and what we can learn from them. Our goal is to incentivize a process of engagement and co-creation rather than to deliver a fully developed set of FLR frameworks.

Global restoration opportunities in tropical rainforest landscapes

Pedro Brancalion, Aidin Niamir, Eben Broadbent, Renato Crouzeilles, Felipe Barros, Angelica Almeyda Zambrano, Alessandro Baccini, James Aronson, Scott Goetz, J. Leighton Reid, Bernardo Strassburg, Sarah Wilson, Robin Chazdon
University of São Paulo, Piracicaba, Brazil

Over 140 Mha of large-scale restoration commitments have been pledged across the global tropics, yet guidance is needed to identify those landscapes where implementation is likely to provide the greatest potential benefits and cost-effective outcomes. We identify restoration opportunities in lowland tropical rainforest landscapes by overlaying seven recent, peer-reviewed spatial datasets as proxies for the socio-environmental benefits and feasibility of restoration. Restoration opportunities, areas with higher potential return of benefits and feasibility, were found throughout the tropics. The area with the top 10% of the restoration opportunity score (i.e. restoration hotspots) covers 88% and 73%, respectively, of the global biodiversity hotspots for conservation priorities and countries committed to the Bonn Challenge, a global effort to restore 350 Mha by 2030. However, a small proportion of the total extent of the Key Biodiversity Area network (19.1%) were restoration hotspots. Concentrating restoration investments in landscapes with high benefits and feasibility would maximize the potential to mitigate anthropogenic impacts and improve human wellbeing.
Using genomics to restore ecosystems and biodiversity

Martin Breed1, Peter Harrison2, Colette Blyth1, Margaret Byrne3, Virginie Gaget1, Nick Gellie1, Scott Groom1, Riley Hodgson1, Jacob Mills1, Thomas Prowse1, Dorothy Steane2, Jakki Mohr4
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Billions of hectares of natural ecosystems have been degraded through human actions. While the global community has agreed on targets to halt and reverse these declines, the restoration sector faces the arduous task of implementing programs to meet these objectives. Today's genomics toolbox offers current options and possible future avenues to help achieve these restoration targets. Genomics could improve the resilience of restoration plantings to global change, provide a means of assessing and monitoring aspects of ecosystems that are currently difficult to measure, and derive new genotypes to better meet environmental challenges. This talk will attempt to highlight the knowledge that can be gained through genomics, identify emerging applications of genomics, and describe the challenges and the barriers to the application of genomics in a restoration context. Overcoming such barriers to initiate a restoration genomics revolution will greatly improve the odds of meeting today's global restoration challenges.

Barrier removals vs maintenance: Redundant dams in Africa

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Digby Wells Environmental, Johannesburg, South Africa

The economic benefit and viability of dams has long been the topic of controversy. While many countries have begun to realise both the economic and ecological benefit of removing dams, Africa remains at the forefront of proposed dam constructions. The provision of electric power, flood control, water supply, and reservoir creation are attractive motivators for dams in third world countries such as those dominating the African continent, where the lack of electricity and sporadic water supply due to intermittent rainfall patterns remain as key social concerns. However, no dam is the same and thus, efforts to generalise from a few continues to cause controversy and debate. Dam removal decisions are complex, requiring owners and regulators to weigh a dam's current value in accomplishing its original purpose, such as water supply for agriculture or industries and power generation, against the dam's ongoing effects on public safety, water quality, water quantity to the downstream resources, impacts to fish migration and populations, etc. In rural Africa, the social implications of dam removals are considered less straightforward, as communities have been observed to adapt their lifestyles based on the continuous provision of a water supply and year-round food security many dams provide. In the presentation we will consider the evaluation of the practicality of dam removal in the context of long-term maintenance costs, against the costs of removal including several of the social considerations once communities have become reliant on the relatively short-term benefits of these structures.

New global guidelines for shellfish reef restoration

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When The Nature Conservancy and National Oceanic and Atmospheric Administration first published a practitioner’s guide in 2006, shellfish reef restoration was still in its infancy and practiced largely in the United States. Over the past decade, restoration has expanded and matured with small and large-scale projects throughout Asia Pacific, Europe, and the Americas. With this expansion, a host of different environmental and logistical challenges
Linking land and water conservation to community development in ecological restoration policy and projects: Lessons from South Africa

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Gouritz Cluster Biosphere Reserve’s Jobs for Carbon Project rehabilitates degraded arid landscape by planting Spekboom where it used to occur naturally. Spekboom is an iconic plant that historically dominated large parts of the arid Klein Karoo region. Severe degradation through overgrazing and erosion over time resulted in reduced water infiltration, loss of productivity, and destruction of biodiversity. We present a case where approximately 80 hectares of an organic olive farm was used to plant 100,000 Spekboom cuttings for which the farmer signed a 50-year Memorandum of Understanding with the project. Activities included implementation of fine scale mapping of potential restoration sites and landscape carbon assessments, training of 60 local labourers, harvesting and planting of Spekboom cuttings, and excluding livestock in planting sites. We found that major impacts were generated by the project. First, the formerly poor and unemployable labourers have experienced a boost in their self-confidence, and are found to be economically empowered, proud, and skilled. This has had an exponentially positive benefit for the village and will sustain long-term benefits for their children. Secondly, Spekboom sequesters carbon into the soil, it improves water infiltration, and facilitates germination and survival of other plant species – this would otherwise be impossible in similar arid conditions. The mature Spekbooms are surrounded by other mature trees and plants in good variety, providing shelter, food, soil food, and habitat for a variety of micro-organisms, insects, birds, and animals. It is therefore expected that a restored eco-system will emerge from the barren soil.

Native fish recovery following the eradication of alien smallmouth bass from the Rondegat River

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The Rondegat River, situated in the Cape Floristic Ecoregion biodiversity hotspot of South Africa, is regarded as a keystone case study for the eradication of invasive alien fishes and subsequent recovery of an imperilled endemic fish community. This study evaluates the recovery of the native fish community by monitoring fish diversity, abundance, and size structure for seven years after rotenone treatment in 2012, using snorkel surveys and remote underwater video (RUV) footage. Snorkel surveys demonstrated that no smallmouth bass were detected following the rotenone treatment and that native fishes
rapidly re-colonised the previously invaded reach. In 2017 native fish densities in the treated reach were similar to those in previously uninvaded environments. Occupancy modelling using RUV data indicated that after an initial colonisation surge from 2012-2013, colonization rates varied annually, suggesting that other external factors (such as water abstraction and damming) are drivers of population change. A more intensive RUV programme was initiated in April 2018 to assess responses to additional threats. The data from the more intensive surveys indicate that the Rondegat fish assemblage shows signals of resilience to stressors such as sedimentation and drought conditions, though it remains vulnerable to external impacts. By identifying which anthropogenic stressors are most important, suggestions for directed management interventions required for the continued recovery of the fish community are made.

Application of an EFlows Model in the eco-revitalization of the River Ravi, Pakistan

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The River Ravi is one of six transboundary rivers comprising the Indus River system. Approximately 50 million people live in the basin, with more than 10 million in Lahore, its largest city. Political differences and careless development have come at profound cost to the River Ravi. In terms of the Indus Water Treaty, all Ravi flow upstream of Pakistan is abstracted by India, and flow downstream is dominated by heavily polluted discharges from cities that lack any effective infrastructure, policies, or regulations to treat their effluents. Most river reaches do not sustain aquatic life throughout the year. In the cities and towns, the stench is overwhelming, affecting the health, safety, and enjoyment of residents and eroding property prices and tax bases. Eco-revitalization efforts in the basin are multi-pronged and include status assessments, visioning, policy and institutional analyses, and investigation of cost-effective waste water treatment. The nature and level of interventions required to meet stakeholders’ visions are being guided by an ecosystem-based EFlows model that uses scientific reasoning and logic to model river ecosystem responses to past influences and interventions aimed at improving water quality, promoting year-round flows, and restoring river channels. The model captures the understanding of driving catchment processes and functioning of the rivers and uses this to provide information on how the implementation of suites of interventions would affect river ecosystem condition and, as a consequence, the potential cultural, recreational, and public health value of the River Ravi and its tributaries.

Protecting direct seeded grasses from herbicide application: Can new extruded pellet formulations be used in restoring natural plant communities?

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Innovative seed enhancement technologies can help to improve restoration success in highly degraded landscapes across the globe, including the Banksia woodlands in the southwest of Western Australia. After clearing of pine plantations, or completion of sand mining, these once Banksia woodland areas, become heavily dominated by exotic grasses such as perennial veldt grass. Veldt grasses are known to modify the woodland structure, negatively impact soil conditions, and alter the growth and establishment of native species. Herbicides are commonly used to control exotic grasses but may also negatively impact seeded native species. Activated carbon (AC) extruded pelleting can be used to negate the detrimental effects of herbicides, allowing simultaneous application and
seeding. I will discuss the results from a proof-of-concept study which tested different concentrations of AC in extruded pellets. The lowest concentration of AC (10%) increased seedling tolerance to Simazine (a pre-emergent, soil applied herbicide), with mortality reduced from 96% in non-pelleted seeds, 77% in pellets containing no AC, to 22% in pellets containing AC. Building upon these results, my PhD research will focus on further refinement of pelleting formulations for a suite of Banksia woodland species. I will also investigate the use of biochar as an alternative to AC, and its use in seed enhancement technologies, presenting preliminary results on its effectiveness in protecting seeds from Simazine. AC extruded pelleting and other seed enhancement technologies play an important role in overcoming a number of challenging restoration barriers faced in highly degraded landscapes across the globe.

Benefits and costs of investing in ecological infrastructure for water security: Lessons from the uMngeni Catchment, South Africa

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This study sought to explore and reflect on the potential costs and benefits of investing in ecological infrastructure (EI) for water security through several case studies. Cost-benefit analysis was applied to evaluate proposed wetland rehabilitation. The analysis focused on the incremental increase in the effectiveness of the wetland for nutrient removal as a result of rehabilitation. In a second case study, multi-criteria assessment, supported by a cost comparison, was used to evaluate urban water management opportunities across ecological, built, hybrid and social capital options. A third case study considered costs, benefits and financial flows at a catchment scale and included an analysis of the relationship between raw water quality and water treatment cost. Results show (i) an investment in wetland rehabilitation to be economically worthwhile provided the capital costs of the alternative are included; (ii) urban ecosystem-based solutions are multifunctional relative to many grey infrastructures, often at relatively lower cost; and (iii) under investment in EI relative to benefits at a catchment scale. The case studies highlight that both ecological and socio-economic data are fundamental to demonstrating benefits but are often lacking. A key implication is the need to incorporate long-term monitoring into restoration practice and implement catchment scale monitoring programmes. This would provide greater evidence of the long-term benefits of investing in EI as well as identifying which kinds of interventions are more cost-effective. The study demonstrates the value in the process of economic assessment as it compels interdisciplinary discussion and debate.

Investing in natural capital for a sustainable tourism economy

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Tourism is seen as a vehicle for sustainable development. Its success and potential growth, however, are strongly influenced by natural capital and the flow of services that ecosystems provide (e.g., clean water, clean air, mitigation of extreme events). Degradation and loss of natural capital is a threat to tourism and its growth potential. So, what can be done? This study explores the inter-dependencies between natural capital and tourism in South Africa in light of expected global changes towards identifying actions to support sustainable tourism. The focus is freshwater ecosystems at a national and case-study level through a combination of economic modelling, stakeholder surveys, and participatory community engagement. The findings suggest several actions as a way forward. The tourism sector should become an active supporter of the preservation and restoration of
natural capital. This includes investing in: (i) the effective management of natural capital (e.g., water source areas); and (ii) measures to mitigate tourism's own impacts on natural capital (e.g., resource, water and energy savings, waste reduction, natural capital stewardship at tourism assets / destinations). Practising sustainable tourism necessitates understanding the tourism sector as a complex system. Tourism businesses operate within a system of interacting social, environmental, and economic elements. Taking a holistic value chain approach is a first step in practising sustainable tourism, which is capable of delivering on its development potential. Transforming the concept of sustainable tourism into action requires strategic planning and in-depth, recurring stakeholder consultation and collaboration, involving industry stakeholders, ecologists, communities, policy-makers and researchers.

The implications of a "project" mindset on ecological restoration at the community level - Mpophomeni township as a case study

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The Mpophomeni enviro-champs are lauded as a best practice model for a community-based approach to catchment management and restoration. Vital work to help "Save Midmar Dam" has been undertaken by a handful of community members for several years, and they were recently mentioned in the Presidential Jobs Summit Framework Agreement. However, when one scratches under the surface, the tale of the Enviro-champs and their essential work is one of two steps forward, and one step back. Funding has been from several sources, over various time frames, with disparate objectives, resulting in loss of momentum, and at times disillusionment. The Mpophomeni Enviro-champs are just one example of how short-term funding cycles impact negatively on effective, sustainable ecological restoration at a community level.

The approach to community-based ecological restoration needs to shift to long-term programming that is built into the "operations" of responsible authorities. The business case for this approach is clear, with the annual operating cost of maintaining community teams much lower than the cost of refurbishment, rehabilitation and/or replacement due to the lack of daily maintenance of our ecosystems. The benefit to the natural environment is only one of the impacts; the social impact within the broader community being equally important. With a long-term funding mindset, ecological restoration moves from the simple tasks of clearing, cleaning, and monitoring, to broader education and social change of an entire community and its relationship to the natural environment. Surely this should be our goal.

Genomics and gene editing innovations in restoration

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Genomic analysis has facilitated new research opportunities, particularly in identification of signals of adaptation to climate. Studies in many species are identifying signals of adaptation across climate gradients that provide an evidence base for the use of climate adaptation strategies such as climate-adjusted provenancing to maximise the resilience of restoration plantings to future climates. Applications of genomics are becoming more prevalent in restoration, paving the way for more advanced innovations. Gene editing is revolutionising many fields and has potential for future applications in restoration. CRISPR/Cas9 gene editing enables production of novel genotypes with desirable traits and gene drives can then spread these genes through populations. To date, considerations in conservation have mainly focused on application of gene drives to control disease vectors and exotic pest species. In plants gene editing is being used in breeding, and in restoration could be used to generate new genotypes suited to challenging, novel environments, whilst retaining existing desirable traits and a local genetic background and may be applicable to large scale control of exotic weeds prior to restoration of native ecosystems.
These applications require significant knowledge of particular genes and desired traits. Considered evaluation of gene editing for invasive species control or restoration of challenging environments will require scientific discussion, community acceptance and establishment of regulatory control mechanisms based on risk assessment frameworks. While field-based applications of gene editing and gene drives are some years away, it is imperative that scientists contribute to informed discussion of these innovations.

**Fast-tracking tropical forest restoration: Testing scalable approaches to re-establish forest structure, function, and wildlife**

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Recently identified global priorities to restore degraded lands require a paradigm shift that can fast-track tropical restoration. The current tropical restoration paradigm relies on natural regeneration or planting hardwood trees in rows. Results from these approaches may yield a “new forest” decades later, but likely one that lacks structure and diversity compared to original climax forests. We suggest a shift in this paradigm, to kick-start restoration through active reforestation using native pioneer trees and passive rewilding techniques, an approach that could be scalable and effective in recovering forest structure, function, and wildlife. As one of Central America’s last wild places and biodiversity hotspots, the Osa Peninsula, Costa Rica, offers an ideal location for trialing restoration approaches. Building on prior fast-tracking (but non-native) restoration work in Costa Rica by Dr. Daniel Janzen, we launched a restoration experiment using native pioneer Ochroma pyramidale (balsa). Over 20,000 trees were planted in 40 half-hectare plots in 2017-2018, with different ratios of balsa in 30 plots and 10 plots of natural regeneration. Rewilding techniques were incorporated in half of the plots of each restoration treatment to expedite the return of wildlife and their critical ecological functions. Baseline data has been collected on soil properties and biodiversity to monitor treatment effects on soil composition, biodiversity, and tree growth. Just two years old, the plots already show clear visual differences in forest structure. By using native pioneers and rewilding techniques, this new paradigm could accelerate ecosystem recovery and be scaled to achieve ambitious global restoration goals.

**The role of Brazil in leading the global restoration movement**

Miguel Calmon
WRI Brasil, São Paulo, Brazil

The implementation of forest and landscape restoration (FLR) in Brazil has been going on for decades, which has helped to accumulate a significant amount of science-based knowledge and experience from the several successes and failures. However, the current scale does not reflect this track record. Among the 58 national and regional commitments made to restore more than 170 million hectares of degraded lands and forests under the Bonn Challenge, Brazil is one of the most promising countries in terms of showing and reporting the implementation of its commitment of 12 million hectares. Brazil has one of the most innovative and ambitious forest laws in the world that set aside 20-80% of private lands to conservation and sustainable management practices, in addition to the preservation of land along rivers, springs, water recharge areas, and others. The country also has a national policy and plan to restore native vegetation of all ecosystems in all biomes. Because of this potential, several subnational, multi-stakeholder restoration initiatives were established during the last decade to accelerate and increase the scale of restoration. With all those enabling conditions, we will show the world how Brazil is ready to restore millions of hectares based on the best science, engaging millions of private landowners, and mobilizing public and private finance. The impact from this endeavor in the Paris Agreement and Sustainable Development Goas (SDGs) may take longer to
materialize but will certainly change the way future generations protect and steward the natural capital that our lives depend on.

**Who are the sponsors of the forest? The role of the private and public sector in financing forest and landscape restoration**

**Miguel Calmon**
WRI Brasil, São Paulo, Brazil

Although forest and landscape restoration (FLR) is recognized as one of the most cost-effective land use solutions to mitigate climate change and maintain the temperature increase within the 1.5-2.0 °C range, the funding available and allocated to FLR has been much lower than needed to reach the scale proposed by international agreements. The knowledge, experience, and awareness of the role of FLR to mitigate climate change and generate many other direct economic, social, and environmental benefits have, however, increased significantly during the last two decades with the establishment of the Global Partnership on Forest and Landscape Restoration (GPFLR) in 2003 and the Bonn Challenge in 2011. Since then, the global restoration movement have flourished, and more than 50 commitments were already made by countries and regional initiatives to restore more than 170 million ha by 2030. Despite the increasing awareness of the importance of FLR, the question “who will pay the bill?” remains unanswered. The leverage potential and limitations of private and public finance, grants, investments, and loans to support restoration is better acknowledged today, so the challenge is to combine and customize the different financial actors and modalities to landscapes that can accelerate the pace of restoration. We will present in this talk several examples on how public and private finance benefit from each other to support the restoration of the global target of 350 million hectares.

**Thirteen years of direct seeding for forest restoration in the Brazilian Amazon, Cerrado, and Atlantic biomes**

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South Amazon forests have been highly deforested since the 1970’s. The Y Ikatu Xingu watershed campaign direct seeded 5 000 ha of forests from 2006 up to 2018. Direct seeding is considered a feasible, inexpensive, and effective method for ecological restoration with advantages that facilitate large-scale use, such as mechanized operations. Nevertheless, little is known about the successional trajectory of tropical forests restored through direct seeding. We sampled 72 direct seeded sites (1-10-y old), three seeding planted sites, and six natural regeneration sites, along a latitudinal gradient of 600 km in the state of Mato Grosso, Brazil. Sites began dominated by herbs and shrubs (green manure, short cycle leguminous), followed by 1 to 5 light-demanding tree species, while slow-growing species were present in the understory. After four years, direct-seeded sites formed a multi-layered canopy and were starting to be colonized by non-planted species. We sampled 90 species from the 152 seeded plus 68 colonizer species. Seeded communities present more orthodox, wind-dispersed seeds than reference forests. However, animal-dispersed and recalcitrant seed traits are found in colonizers. Canopy frequently closed (80%), forming a tall secondary forest with high height-to-diameter ratio trees that do not bifurcate in the first 3 years. Broadcast seeding sites had higher seeding and sapling densities than sites that received other restoration methods. In conclusion, direct seeding was a successful method for tropical forest restoration, promoting a structure that was more like resilient natural regeneration sites than to non-resilient natural regeneration sites and seedling planting sites.
DroneSeed: Using UAVs to conduct surveys, herbicide applications, and aerial seed deployment in forests and rangelands

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DroneSeed is a Seattle-based startup that is developing software, hardware, and infrastructure for operational capacity of Unmanned Aerial Vehicles (UAVs) to conduct surveying, herbicide application, and aerial seed deployment in forests and rangelands. Their mission is to provide more efficient and rapidly scalable survey and revegetation services for myriad ecosystem management needs. They are currently paid per acre to survey, mitigate invasive species with herbicides, and plant (enabled seed) for the largest timber companies in the US. They are also partnered with The Nature Conservancy and have begun seed-based rangeland restoration work in Oregon and post-fire forest restoration work in other locations in the American West. The presentation will provide an overview of the company's technology, review projects and milestones, and outline the research and development supporting their data-driven approach. Wildfire and other large-scale ecosystem disturbances are increasing in frequency and severity. Constraints to post-disturbance revegetation include accessibility to remote areas, difficulty distributing seed precisely at scale, invasive species mitigation, and associated costs. DroneSeed is developing a multi-pronged approach to revegetation using UAVs that is applicable to large-scale post-disturbance revegetation and native plant management at an effective cost. Their supervised classification platform is the basis for a machine learning software being developed for seed placement (i.e. micrositing) for optimizing germination and survival. DroneSeed is increasing operational capacity using swarm technology, enabling multiple heavy lift aircraft to move material payloads across restoration areas with increased precision. The company is precedent setting in the regulatory environment allowing for this work.

The functional and restoration ecology of the Succulent Karoo, South Africa

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The winter-rainfall Succulent Karoo is the most biodiverse desert on earth and home to >6000 species (c. 2000 endemic), of which >1000 are succulents. Leaf-succulent shrubs and non-succulent shrubs predominate in most intact habitats, while an early-succession, non-succulent shrub is mono-dominant in most degraded habitats. These represent alternate stable states, maintained in the instance of leaf-succulents by shallow root competition (an adaptation to prevalence of small rainfall events in this biome), and in the instance of early-succession shrubs by reproductive failure in other shrubs due largely to florivory. Seeds of annuals are abundant in most degraded areas and produce dramatic floral displays in spring. However, the seeds of perennials are scarce in the seedbanks of most habitats, and those of many common species are entirely lacking from degraded habitats. Thus, there is a need to maximise seedling establishment with the available perennial seeds. There are two clear ways to assist the growth and establishment of seeds: seedling shelters and soil amelioration. Both of these natural dynamics are diminished in degraded habitats. A complex interaction pertains to shelter among the different plant groups. Succulents may not benefit from shelter, while biodegradable boxes and brush-packing are frequently beneficial to non-succulents, but the devil is in the detail and the most common early-succession plant may represent a rare example of allelopathy. On the other hand, simple methods supplying nutrients in ecologically relevant concentrations, either by making use of existing fertile islands or by applying small quantities of fertiliser, routinely increase seedling establishment rates.
Participative governance in the social and environmental recovery process: The case of Renova Foundation in the Rio Doce Basin, Brazil

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The extension and magnitude of environmental and socioeconomic damages due to the rupture of the Fundão Dam demanded quick answers that have been materialising through and Extrajudicial Agreement, called the Transaction and Conduct Adjustment Term (TCAT) by Brazilian legislation. It is an instrument where regulatory agencies and entities of the environment and mining public sector defined the reparation and compensatory determinations of SAMARCO Company and its shareholders, Vale and BHP, having a primary goal to remedy and mitigate environmental damage and material and moral damages of people directly and indirectly affected by the tragedy. The agreement as signed represents the conditions of governance established to manage the political and regulatory challenges of the restoration process. In line with the federative organisation of the Brazilian State, it innovatively created an Inter-federative Committee (IFC) with collegiate deliberations, composed by the Union and Federal States of Minas Gerais and Espírito Santo, which share the territory of the affected watershed. An entity called Renova Foundation, governed by private law but under the supervision of the IFC, was set up as a body that performed the commitments established in the agreement, assumed by the companies responsible for the tragedy. This management system provides mechanisms for the participation of the affected community, recently strengthened by an addendum to the original Agreement, which includes representatives of these communities in the decision-making instances of the IFC and the Renova Foundation, institutionalising a collegial and participative essential management to deal with the injured rights by the tragedy.

Strategies for a social construction of restoration in the Columbian Amazon

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In Colombia, Amazonia represents more than 40% of the territory, however almost 20% has already been anthropogenically modified. The department of Caquetá is the third largest department with the highest annual deforestation rate in Colombian Amazon. Caquetá has also been the epicenter of the armed conflict and the war on drugs in this country. Therefore, the environmental dimension, is necessarily central in the dialogues of peace and in post-conflict development. Thus, the generation of sustainable productive alternatives is one of the main purposes of institutional goals in Caquetá. Important actions have been conducted in this direction, such as promotion of effective participation by the different territorial actors in the landscape restoration process, seeking social understanding of the causes of ecological degradation and the development of socio-ecological alternatives. This process was organized to establish the political activation of “relationality” and show ways to deepen reflection, practices, and narratives to favor recognition of the negative consequences of current land use based on intensive agriculture and livestock grazing and visualize the importance of socio-ecological restoration. Since 2016 networks of farmers, researchers, and politicians have been developing and gaining strength, and an ambitious educational program of ecology and restoration for citizens and stakeholders was implemented. The development of restoration strategies in Caquetá with the earnest participation of the actors could build a collective learning and a common meaning about degradation and restoration. Along with the scientific knowledge generated by the Sinchi Research Institute, a social construction of restoration is on its way.
Using ecological resilience concepts to prioritize restoration efforts and determine effective strategies

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In an era of rapid global change, it is increasingly important to target restoration efforts where they are most likely to have ecological and socio-economic benefits and to use strategies that optimize success. Application of ecological resilience concepts provides the basis for locating and implementing restoration actions to enhance the ability of ecosystems to cope with stressors and disturbances over time. Scaling up to the landscape provides the necessary perspective of how ecosystem attributes and processes interact with landscape characteristics to influence the capacity of ecosystems to support resources and habitats and effects of disturbances. Here, we discuss developing an understanding of how resilience differs across landscapes to create resilience-based frameworks and decision-tools to inform restoration policies, goals, and actions. Knowledge of general resilience, the broad ability of ecosystems to maintain fundamental processes and functioning following disturbances, can be used to assess relative ecosystem recovery potentials and risks of crossing critical thresholds. Information on spatial resilience, or how spatial attributes, processes, and feedbacks vary over space and time in response to disturbances to affect resilience, provides the basis for evaluating spatial constraints on ecosystem recovery and resource and habitat availability to support biodiversity. Coupling information on general and spatial resilience, the predominant disturbances, and capacity to support resources and habitats provides the basis for prioritizing management actions and determining effective strategies. Spatially explicit approaches and decision matrices allow managers to quantify and visualize differences in resilience in relation to focal resources and predominant disturbances and to make informed restoration decisions.

Community participative eco-restoration of degraded sacred groves in the Western Ghats, a global biodiversity hotspot in Southern India

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Sacred groves are important ecological sites that are conserved by indigenous communities as biodiversity repositories. Kodagu in South India lies in Western Ghats, a World Heritage site and biodiversity hotspot. Kodagu is watershed of river Kaveri and home to many wildlife sanctuaries. Kodagu has a long tradition of conserving sacred groves and has over 1200 sacred groves covering 2% of its area. However, these repositories face anthropogenic pressures like diversion to commercial uses, fragmentation, over-exploitation resulting in degradation. Only 40% area remains intact in 1991 as compared to 1904. Many groves are impacted by invasive alien species like Lantana camera and Senna spectabilis. Forest First Samithi (www.forestfirstsamithi.org ), a grassroots ecological restoration non-profit, has been working for the last ten years on restoring degraded groves through a community-participative model. A diversity-maximisation methodology is practiced where over 150 indigenous species are introduced after removal of Lantana. Species selection is based on biological importance, keystone characteristics, threat status, medicinal value and riverine-ecosystem criticality. Contour trenches are dug along slopes to ensure soil moisture retention and prevention of rainwater run-off. Activities like nursery management, mulching provide livelihoods. All projects are initiated jointly with community involvement through Kodagu Model Forest Trust (www.kmft.org) and with temple committees pledging their support. Key outcomes are improved custodianship of their ecology, livelihoods, revival of traditional ecological knowledge and creation of local stakeholder capacity, which are in line with IUCN principles. Ecologically restored groves provide for a germplasm of floral diversity with potential for propagation to nearby forests.
Brush and green seed harvesting: A comparison of species capture, viability, and cost in mesotrophic and calcareous grasslands

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Brush harvesting, hay transfer, and other ‘near-natural’ direct harvesting techniques are effective and well-established means of overcoming seed limitation in grassland restoration. The species composition and viability of seed captured by these techniques significantly influences restoration success, varying according to grassland type, local environmental conditions, and harvesting methodology, but is not always fully understood or accounted for in restoration projects. In this study, carried out at RBG Kew’s Millennium Seed Bank (MSB), we compare the species composition and viability of seed harvested using brush and combine harvesting techniques in mesotrophic grassland, and brush and green hay transfer techniques in calcareous grassland. The effectiveness of each technique in capturing the species-diversity of the donor community is assessed, including interactions between harvesting technique and key plant traits including dispersal time and height. Costs and practical considerations associated with each technique will be discussed alongside new MSB protocols for species composition analysis and viability testing of large mixed-species harvests.

Geospatial tools and public policy: The decade of integration opportunities in the context of restoration commitments

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This year, the United Nations General Assembly declared the period of 2021 – 2030 as the UN Decade on Ecosystem Restoration. This reinforces the importance of international commitments on restoration that arose in the current decade (e.g. Aichi targets, Bohn Challenge, Initiative 20x20, AFR100) and that will increase in the next one, but it also brings light to a crucial issue: How will we monitor such ambitious goals? Besides international commitments, many national and subnational policies establish the need to monitor ecosystems undergoing restoration, especially concerning biodiversity conservation and ecosystem services provisioning. Nevertheless, many of these efforts still lack good monitoring systems, sometimes using only declared information with no spatial validation within the territory. We discuss in which ways new geotechnologies and platforms developed relying on them, such as NASA`s Global Ecosystem Dynamics Investigation (GEDI), FAO`s Collect Earth Online (CEO) and the Brazilian MapBiomas could enhance effectiveness of existing environmental policies and foster creation of new ones. LiDAR approaches, such as GEDI, can be used to better understand forest structure worldwide, bringing information about what is happening in their understory, with all its importance to understand forest dynamics and adaptation to climate change. Automatic classification using machine learning algorithms (e.g. MapBiomas) is promising, especially in the context of mandatory restoration (e.g. that required by law in Brazil), which must be monitored through time. We argue that integrating these geospatial tools with public policy is a key element for successfully upscaling ecosystem restoration in the next decade.

Response of the ecological restoration plant Neyraudia reynaudiana for use in alleviation of heavy metal contamination

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Vegetation rehabilitation is one of the most cost-effective ways to realise heavy metal rehabilitation and comprehensive treatment in contaminated mine sites. Neyraudia reynaudiana was used as a slope restoration plant originally in many parts of China, but in
the survey of mine waste sites in Sichuan province, China, we found that it accumulated more heavy metals than common landscape plants. In order to explore the possibility of using N. reynaudiana in ecological restoration, we hypothesised that by planting N. reynaudiana in soil with different concentrations of heavy metals (Cr, Cd, Pb) that the species could hyper-accumulate and ameliorate the contaminants. The results showed that heavy metals had inhibitory effects on plant height as the concentration increases. In order to cope with heavy metal stress, the activity of antioxidant enzymes of N. reynaudiana changes. We also found that the increase of heavy metal concentration in soil, increased the activity of plant-based enzymes, but when the concentration of heavy metals in soil exceeds 200 mg/kg, the activity decreased. N. reynaudiana is not a hyper-accumulative plant, but a high accumulation plant, and has value in use in slope stabilisation. The potential, multi-functional remediation opportunity presented by N. reynaudiana represents a good choice for phytoremediation projects.

**Trajectories of old field succession and prairie restoration in the US Midwest: Cases for passive and active restoration**

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The “passive” approach of restoration, which relies on natural process such as spontaneous succession for recovery of natural ecosystems after degradation or destruction, has been a subject of debate in the recent years. Advocates argues that passive restoration is less expensive and often is faster and more successful than active restoration. Critics do not agree with this argument, noting slower recovery time, higher risk for invasion of exotic species, and lack of remnants that may serve as sources of native propagules. The feasibility of passive restoration was tested by comparing vegetation trajectories of actively restored prairie (RP) and old field fallow (OF) that underwent spontaneous succession in the US Midwest. According to a NMS (non-metric multidimensional scaling) ordination for 2008-2018, RP revealed noticeable dynamics of vegetation from Monarda fistulosa (bergamot) to Eryngium yuccifolium (rattlesnake master) dominance, while the OF vegetation appeared to be arrested due to a strong preemption by initial colonizers such as Solidago canadensis (Canada goldenrod) and Poa pratensis (Kentucky bluegrass). RP also exhibited a significant increase in species diversity (H') from 1.78±0.05 to 1.96±0.05 (p<0.01) during the same period. Species diversity in OF was much lower, and its increase was not statistically significant (from 1.19±0.08 to 1.36±0.07, p>0.10). Relative dominance of exotic species reduced significantly in both RP (from 19±3 to 13±1%, p<0.02) and OF (from 61±2 to 48±4%, p<0.01). Spontaneous succession may become a passive path to restore tallgrass prairie. However, it would take considerably longer period of time than active restoration.

**Arthropod assemblages in restored prairie, old field, and monospecific stands of reed canary grass (Phalaris arundinacea) in the US Midwest**

*Eric Kelleher, Young Choi*

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We investigated the effects of floral restoration on arthropod assembly in restored prairie (RP), old field fallow (OF), and monospecific stands of exotic reed canary grass (RCG) in the US Midwest. The enhanced plant species diversity in RP did not appear to promote the diversity of arthropod taxa. However, according to our CCA (canonical correspondence analysis) ordination, the arthropod assemblage exhibited a strong divergence in the three sites, corresponding to the composition of plant species. Pollinator abundance was greatest at RP and least at RCG with strong positive correlation with forb species diversity. Herbivore abundance was also greatest at RP with positive correlation with plant species diversity. Predator abundance was significantly greater at RCG than OF and RP with positive correlation with C3 grass cover, a characteristic of the structurally homogenous RCG site, and negative correlation with forb species diversity, a characteristic of the diverse
and more structurally complex RP habitats. Given the apparent non-random distribution of arthropods in the three sites, our results suggest plant species composition has a significant effect on arthropod assembly. The monoculture grass stand was found to have a predator-dominated arthropod community supported by a small, diverse herbivore community. It is concluded that the prairie restoration has resulted in alteration of arthropod communities supporting greater pollinator and herbivore abundance and a more balanced ratio of herbivores to predators due, in part, to increased plant structural diversity.

The Working for Water Programme
Guy Preston, Christo Marais
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South Africa’s national Working for Water (WfW) programme began in October 1995 and has grown to be country’s biggest conservation programme. It has spawned many associated programmes, including the Working on Fire, Working for Wetlands, Working for Ecosystems and the Value-Added Industries programmes. A primary focus is on the labour-intensive control of invasive plants. WfW has provided work opportunities for over 50,000 participants per annum and has cleared over 3,2 million hectares of land (≈50% of Ireland), with almost 10 million hectares of further follow-up work. The programme has strengthened with the promulgation of the Alien and Invasive Species Regulations. The full implementation of bio-security legislation will be critical to achieving the prevention, control and restoration for biological invasions. Biological control is playing an increasing role. We are intensifying a search-and-destroy capacity for emerging invasive species. Strides are also being made in our focus on controlling invasive plants in mountainous and riparian areas, because of their impacts on ecosystem services. We are escalating our use of fire as a measure of control. Incentivising good land-use practices is increasing. There is a major focus on value-added industries, using invasive biomass to make products useful to Government (notably fire-proof buildings). This is set to radically change the efficacy of our programme. There are also foci on other taxa, such as the polyphagous shot-hole borer, the Indian house crow, mice on Marion Island, and other destructive invasive species. Bureaucratic procedures have inhibited the programme, and we are looking at an optimized institutional arrangement.

Reversing biodiversity decline in forest remnants: A restoration experiment using biocontrol beetles and manual clearance
Beverley Clarkson, Scott Bartlam, Corinne Watts
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The ecological health and functioning of lowland forest ecosystems on agriculturally-modified floodplains in northern New Zealand are under serious threat from weed invasion. The most widespread alien plant species is the monocotyledonous herb, Tradescantia fluminensis. Tradescantia forms dense carpets covering the ground, which prevent the regeneration of native forest species, especially in farm remnants fenced from stock. A restoration experiment was established in 2016 to compare two different approaches to management of Tradescantia, namely three biocontrol beetle species from Brazil (released as a trio), which target different parts of the plant, and hand clearing. We set up the experiment at four sites (two with lower nutrient soils, two with higher nutrient soils) to assess the impact of biocontrol beetles and manual clearing on Tradescantia biomass and native plant regeneration. Monitoring of browse damage indicates establishment of all beetle species occurred within one year, and widespread dispersal (several hundred metres) of at least one biocontrol beetle species within three years. Although decreases in Tradescantia biomass occurred in all biocontrol plots by year three, the biomass at the two nutrient-enriched sites remained relatively high. At the end of three years, woody seedling establishment was highest in the hand-cleared plots, second highest in the biocontrol treatments, and lowest in the control treatments. Although the
experiment needs to continue for several years before noticeable ecological benefits are achieved, it provides early promise of the use of biocontrol beetles in slowing or reversing biodiversity decline in floodplain forest remnants.

Urban ecological restoration in Aotearoa, New Zealand

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Urban ecological restoration has been the focus of our New Zealand government funded research since 2005. Our most recent research programme People, Cities and Nature (https://www.peoplecitiesnature.co.nz/research) was initiated in 2016. The programme seeks to improve the quality of life, health and economic wellbeing in New Zealand’s cities and towns through advanced understanding of urban ecology and the creation of flourishing natural environments. Multidisciplinary research is being undertaken in nine NZ cities via six inter-related projects:

- Restoration plantings
- Urban lizards
- Mammalian predators
- Māori restoration values
- Green space benefits
- Cross-sector alliances

While our emphasis was on the ecological science of urban biodiversity restoration at the outset, we have become increasingly involved in understanding the multiple benefits of urban ecological restoration projects including social cohesion and health and recreation benefits. Our presentation will focus on the progress made in bringing indigenous nature back into Hamilton City on North Island NZ since the advent of two community-based initiatives the Gully Restoration Programme (2000) and the establishment of Waikhakareke Natural Heritage Park (2004). Our research has strongly underpinned the design and management of both projects and documented the many benefits they provide to the city and its people.

Building systemic praxis towards integrating sustainable livelihoods with ecosystem restoration in a South African ecological infrastructure flagship project

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The pernicious effects of apartheid spatial policies are evident in many parts of rural South Africa (SA) and carry the legacy of systematic underdevelopment combined with ecosystem degradation and poor natural resource management. In order to have a long-term impact in underdeveloped areas, restoration activities should be paired with the development of sustainable livelihood strategies. The Tsitsa Project (TP), implemented by Rhodes University with partners, is the flagship ecological infrastructure project of the SA Department of Environment, Forestry and Fisheries, which is experimenting with innovative ways of tackling these challenges in the degraded Tsitsa Catchment. In recognising the interconnected challenges of integrating sustainable livelihood strategies with restoration activities, TP includes a capacity development component of praxis-oriented systems thinking and modelling ('systemic praxis'). This includes (1) training and facilitation in the use of systems thinking and modelling, and (2) dedicated systems modelling of complex problems using system dynamics (SD) modelling. Instead of doing client-based, expert modelling that results in 'black box' models, the aim is to build systems literacy and systems thinking and modelling capabilities within the project team and ultimately, between the team, project stakeholders, and research end users. Progress to date includes three Maste’rs projects; 16 provincial government officials having completed introductory training in ‘systems thinking in practice’; eight university researchers trained in technical SD modelling; and the development of five SD models. This
presentation traces the background and provides the rationale for the work and then reflects on the successes and challenges of building systemic praxis in TP since mid-2018.

**A relational understanding of social-ecological restoration: New perspectives for restoration research, policy, and practice**

Jessica Cockburn, Eureta Rosenberg  
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There is increasing recognition that restoration is embedded in complex social-ecological systems (SES), and that a clearer focus on social processes and outcomes is needed to build resilience through restoration programmes. This is echoed in calls for social-ecological restoration. Seeing restoration as situated in SES is a particular way of understanding the nature of restoration, i.e. an ontology. Adopting this ontology has implications for managing and researching restoration programmes. To consider some of these implications, we focus on one of the key characteristics of complex SES: they are relationally constituted, meaning that system characteristics emerge out of dynamic relations between system components. To illustrate how a relational understanding shifts the way we approach restoration and sustainable landscape management, we present two cases: the Tsitsa River Catchment and the Greater Langkloof Region (both in Eastern Cape, South Africa). We emphasise inter-personal and social relations between the many actors involved in landscape restoration. A relational understanding of restoration can help programme developers and implementers gain deeper insights into the texture of multi-stakeholder processes in social-ecological restoration. We draw on the notion of 'relational agency' to propose a new perspective on multi-stakeholder collaboration, which is widely regarded as a key success factor for social-ecological restoration. From this perspective it becomes apparent that dialectical, transformative learning processes are also key to the social-ecological change processes which restoration initiatives inherently are. We discuss the theoretical and practical implications of a relational understanding and ways in which transformative learning for social-ecological restoration programmes can be fostered.

**Phenotypic and molecular genetic differentiation of Prosopis flexuosa (Leguminosae) provenances: Implications for Argentinian arid lands restoration**

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Prosopis flexuosa (Leguminosae) is an important native multipurpose tree species from arid lands of Argentina that is valuable from an economic and ecologic point of view. Aiming to give restoration recommendations for the use of this species for fast recovery of the plant cover in the Monte desert, we quantified the genetic basis of phenotypic differences in height and basal diameter and the genetic differentiation of 8 neutral molecular markers (microsatellites) among five provenances installed in a progeny-provenance trial. We sampled 125 trees, representing 25 families with 5 individuals per family, belonging to 5 provenances (Fiambalá, Pipanaco, Mogna, Chilecito and Algarrobo del Aguila-Limay Mahuida) from the latitudinal distribution of the species in Argentina. Our results suggest that the morphological variation has a significant genetic basis and differences among provenances may be explained by local adaptation. Low but significant genetic differentiation was detected by microsatellites among provenances. From our results the recommendation to provide a broad genetic basis in a restoration programme is obtaining seeds representing all genetic clusters identified, rather than all provenances. This implies avoiding sampling of more than one provenance embracing the same genetic clusters. If the priority of the programme is reaching ground cover in a short time, the representation of different clusters in the source sample may be adjusted according to a
Mondi’s wetlands restoration experience

**Brent Corcoran, David Lindley**
Mondi South Africa (Forestry), Hilton, South Africa

Mondi South Africa manages approximately 250,000 ha of landholdings in the eastern region of South Africa, with approximately 60,000 ha managed for ecological benefit. In 1997, Mondi catalysed and helped develop and pilot an innovative approach to wetlands delineation, resulting in the restoration of thousands of hectares of wetlands. It did this in partnership with environmental NGOs such as WWF and WESSA, government agencies and other forestry companies. In 2005, the government water regulator, Department of Water and Sanitation, recommended this wetlands delineation methodology as the preferred approach to wetlands delineation for all land uses in South Africa. For existing forestry plantations, forestry companies, and some small growers have voluntarily applied the methodology. Any new plantations developed since mid-2000s are now legally required to apply wetlands delineation before any new planting takes place. Over a period of 10 years, Mondi South Africa, has completed wetlands delineation for more than 95% of its plantation landholdings, and given up approximately 4-6% of its commercial planting area for wetland restoration. With the voluntary uptake by other forestry companies, there has been a significant river basin impact on a landscape scale. One of the key learnings is the importance of partnerships to deliver shared solutions to ecosystem management at a landscape scale. A key driver in catalyzing these partnerships was developing a common understanding across key stakeholders that water security is a shared risk, and as such needs to be tackled in a coordinated way to ensure effective water stewardship outcomes at scale.

Community-based seed production for large scale restoration: Socio-ecological challenges

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Direct seeding is a well-recognized technique to reintroduce native herbaceous plants for restoration of grasslands and savannas. Due to low seed viability and germination, high seeding density is recommended to enhance restoration success. Since 2012, we have tested and developed seed harvesting, handling, and planting techniques for dozens of herbaceous species in the Brazilian savanna. Based on this developing demand for direct seeding, local communities have supplied seed for restoring 200 hectares within central Brazil since 2016. We identified socio-ecological challenges and possible solutions to improve community-based seed production of herbaceous plants for restoration. First, scientific knowledge of plant taxonomy, phenology, seed production and germination of herbaceous plants in tropical grasslands and savannas are extremely limited. Since native herbaceous plants are also less commonly used and cultivated than woody species, local knowledge on their ecology is also limited. We have developed active research with seed collectors to establish techniques, practices, and prices for marketing seed of 14 herbaceous species. Second, native seed production has strengthened the household livelihoods of 66 collectors who have supplied more than eight tonnes of seed and generated USD 50,000. However, the restoration market is still incipient and not well structured. At the same time, in Brazil, plant material trade is heavily regulated based on bureaucratic and technical standards. Although the herbaceous seed supply for restoration can be a community development strategy linked with biodiversity conservation,
institutional systems, applied research, and policies must develop approaches to upscale local capacities, knowledge, and technologies to overcome seed shortage.

**Tropical savanna restoration by direct seeding: Steps forward**

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International commitments set a target for Brazil to restore 12 million hectares of natural habitat of which 5 million hectares are within the Cerrado (savanna) region. To achieve such commitments, we need restoration methods that are cost-effective and practical at a large scale. Since 2012, we have tested and developed direct seeding techniques to decrease costs and improve restoration success on grasslands and savannas. More than 200 hectares have been direct seeded to restore areas in central Brazil. The direct seeding techniques have been applied by an increasing number of private and public companies to promote restoration. We were able to establish more than 70 native grasses, shrubs and trees species; and significantly changed soil cover from exotic to native species. However, many challenges persist, especially the control of African grass species, widely introduced for pasturelands that become aggressive invaders. We tested mechanical control of invasive grasses (IG) through repetitive soil plowing before direct seeding and the introduction of different functional groups. A mixture of native species with perennial grasses and fast-growing shrub and tree species improves restoration success, especially in less fertile soils where IG fitness is reduced. Mechanical control decreases IG but does not eliminate them, and it causes severe soil disturbances. The use of chemical control, even inside legally protected areas, is highly recommended to improve restoration success in tropical grasslands and savannas where shading by thick tree layer would eliminate IG but create inadequate restoration endpoints. Improving native species harvesting and seeding techniques is also essential.

**Are the ‘building blocks’ of South Africa’s wetland restoration working? A focus on the integrity and functioning of structural interventions**

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While it is recognised that the metric of success for wetland restoration is derived from multiple components, within a South African context two aspects are considered critical, namely: 1) integrity and functioning of structural interventions, and 2) land user engagement and aftercare. The importance of structural interventions towards achieving wetland restoration success suggests that these ‘building blocks’ be carefully considered and monitored using a reliable tool. Existing tools for assessing the success of wetland restoration applied at various sites across South Africa were found to be lacking in terms of guidance and consideration of different intervention types. Through Water Research Commission funding, an updated check sheet was developed in collaboration with the Working for Wetlands programme. This check sheet was applied at multiple sites to evaluate the integrity and function (towards meeting predefined objectives) of structural interventions. Through these evaluations, trends were identified relating to the integrity of different types of interventions and their success within different wetland hydro-geomorphic settings. The study found that concrete and gabion structures were most often adopted as interventions across the study sites with concrete generally requiring less maintenance than other intervention types. With the adoption of earthen structures, a review of land use was identified as being critical to understand whether livestock
trampling will pose a threat. Recurring issues affecting the structural integrity of the different types of interventions were identified. These have been highlighted and fed back into the planning and implementation process to improve future wetland restoration efforts.

Fire, drought, and invasion of nonnative species interact to influence ecosystem resilience

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One of the most critical challenges in the 21st century is promoting ecosystem resilience to novel disturbances. Ecosystem resilience is fundamental to sustaining biodiversity, ecosystem services, and human well-being. However, global changes and invasion of exotic species are altering ecosystems and disturbance regimes in ways that may erode ecosystem resilience and lead to novel trajectories. The objective of this research was to examine the resilience of native forest communities to the interactive effects of invasion by non-native species, drought, and fire. We counted stems and estimated percent cover of native species and a coexisting invasive shrub, Lonicera maackii, in a Midwestern U.S.A. oak-hickory forest over three growing seasons: before, during, and after a drought. Treatment plots (fire x invasive shrub) were replicated three times in sites with and without the invasive shrub and half of the plots were burned during the drought year using prescribed fire. We found that the invasive shrub moderated the simultaneous effects of drought and fire; species richness was higher during and after drought in burned plots where the invasive species was present. Furthermore, multivariate analyses show that the plant community composition was more resilient after multiple disturbances when the invasive was present. We suggest that the invasive shrub created shaded, mesic microsites during drought, thereby promoting native species survival. These results highlight the potential benefit of an invasive species to the resilience of ecosystems that experience multiple disturbances.

Bet hedging through fine-scale intraspecific variation in seed dormancy and seed germination cues in the Australian arid tropics

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Seed biology in the annual herbaceous flora of ecologically stressful, seasonally wet habitats remains largely unexplored. Temporal and spatial species turnover among these habitats is often high, yet little is known about how fine-scale habitat variation drives intraspecific variability in seed dormancy depth and seed germination requirements. We present seed biology data from over 50 species of wetland plants from the Australian Monsoon Tropics, as well as complementary habitat data, and show that fine-scale differences in the thermal and hydrological conditions of seasonally wet habitats appear to be strong drivers of dormancy depth. Widely distributed species exhibit high levels of plasticity in seed-dormancy depth and germination response to germination stimuli such as biogenic ethylene among different habitats, with similar responses being observed for sympatric species. Sediment seed banks may represent significant drivers of species persistence and diversification in these ecosystems, and inhabitant flora display a high degree of adaptation to local hydro-geological conditions, potentially reflecting a long and relatively geologically and climatically stable evolutionary history.
Ecological restoration on magnetite tailings: Six years of lessons learned

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Mine tailings are challenging substrates for ecological restoration as the establishment of diverse native plant communities can be constrained by a range of edaphic factors. Understanding the effect of edaphic filters on community establishment is foundational for developing effective restoration solutions for tailings and requires a clear evidence-base as to what types of species and communities are likely sustainably reinstated. We present evidence from six years of glasshouse and field studies examining species and community establishment on magnetite tailings. While the majority of native plant species and nutrient-acquisition guilds (approximately 75% of reference floristic biodiversity) are selected against on unweathered tailings with plant growth limited by a lack of available nitrogen and high alkalinity (pH >9), a small number of species exhibiting particular functional and nutrient acquisition strategies represent potential pioneer taxa capable of kick-starting critical ecological processes. Achieving successful restoration goals on alkaline mine tailings is likely unsuccessful unless strategies to ameliorate substrate hostility such as acidification of the soil profile and improving N availability are prioritised.

Using monitors to monitor mine site restoration: How does Australia’s largest lizard species respond to mine site restoration?

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Globally, the increasing rates of mine site discontinuations are resulting in the need for immediate implementation of effective biodiversity and conservation management strategies. Over 60,000 mines across Australia have been identified as discontinued, yet despite restoration being a legislative requirement, the number of these sites confirmed as restored and officially closed is extremely low. Monitoring vegetation structure and condition is a common method of assessing restoration success, however monitoring animal responses is relatively uncommon. Animals are generally assumed to return to pre-disturbance abundances following the return of vegetation (Field of Dreams hypothesis; ‘build it and they will come’). In practice, recovering animal biodiversity and community structure can be some of the most difficult components to achieve and asses following the restoration of degraded sites. Using VHF and GPS tracking, and the T-LoCoH method of home range construction, we assessed the behavioural responses of a sub-adult female perentie (Varanus giganteus) to habitat change and differing thermal environments presented in reference and restoration vegetation at a Mid-West Western Australian mine site. We highlight a reduction of vegetation cover and spatial heterogeneity as a major constraint to the movements and behavioural ecology of the perentie, and hence although restoration may be facilitating return, behavioural use of restoration vegetation differs from that in the reference vegetation. Understanding the complex interactions between animals, and their behavioural responses to their environment is fundamental to their conservation in the face of ever-increasing rates of human induced habitat change and degradation.

Large-scale restoration in the Atlantic Forest: Current status and perspectives

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Brazil presented its intention of Nationally Determined Contribution for the global effort to mitigate climate change in 2015. A key proposed action is the recovery of 12 M ha of native vegetation by 2030 with approximately 6 M ha in the Atlantic Forest. The case for restoration in this biome is an example of how to build the necessary conditions for recovery of native vegetation at a large-scale for other biomes in Brazil and internationally. Three main government regulations have been assisted the Atlantic Forest recovery: the Atlantic Forest Law, the Native Vegetation Protection Law, and the National Policy for Recovery of Native Vegetation. The Atlantic Forest Restoration Pact is likely to be the largest bottom-up restoration movement worldwide and has been building key mechanisms of governance, communication and articulation; monitoring systems; and strategies to influence public policies. There are some emblematic examples of restoration projects showing restoration as an economically viable activity. Although competition with agricultural lands has been a critical bottleneck for recovery of native vegetation, there are some successful initiatives in the Atlantic Forest focused on: landscape planning that targets integration of productive actions, conservation, and recovery; recovery of native vegetation linked to sustainable agricultural intensification; and identification of priority areas for maximizing socio-environmental outcomes and minimizing competition with agricultural production systems. Brazil has assumed a key role of leadership in international forest landscape restoration negotiations, especially due to several examples in the Atlantic Forest, and any break in this path will result in several environmental setbacks.

There is hope for achieving ambitious commitments of Atlantic Forest restoration

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Achieving ambitious global restoration commitments is a huge challenge. The Atlantic Forest Restoration Pact, created in 2009 as a movement to restore 15 Mha of degraded/deforested lands by 2050, pledged 1 Mha towards the 2020 Bonn Challenge. The Pact defined and accounted as “Forest Landscape Restoration” only native vegetation recovery as the aim of the movement is to promote biodiversity conservation, nature’s contribution to people, a native species forest-based economy, and contribute to the implementation of public policies demanding ecological restoration. We documented the restoration of estimated 673,510-740,555 ha of degraded/deforested lands from 2011 to 2015 in the Atlantic Forest and expect that a total of 1.35-1.48 Mha of native forest will be under recovery by 2020. This is one of the first Brazilian restoration initiatives to monitor its international restoration commitment and provide evidence that established ambitious targets can be reached. Part of this success in large-scale restoration is related to three main Pact initiatives: i) governance, communication, and articulation; ii) monitoring system; and iii) vision and strategies to influence public policies. The experience and lessons learned by the Pact could be used: i) to guide, systematically, official governments and organizations monitoring reports about progress towards national and global commitments, ii) to inspire other restoration initiatives and commitments, iii) as a roadmap on how to create enabling conditions for large scale restoration to contribute to achieving global restoration commitments, and iv) to present a “bottom-up” smart governance mechanism that includes people in the restoration supply chain.

Tropical forest natural regeneration: predicting successes and accessing uncertainties

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Natural regeneration and the outcomes arising from it vary widely across multiple spatial and temporal scales and are affected by linked environmental and socioeconomic drivers. Investors operating in different businesses usually avoid high-risk transactions, which likely
constrains the flow of financial resources to restoration initiatives that are perceived as uncertain and risky. Although predicting both the potential rate and location of natural regeneration through time and how its outcome varies within landscapes is inherently difficult, but such knowledge is critical to policy design and evaluation. Here we predict and map both the potential for natural forest regeneration over the next years and the landscape variation in biodiversity recovery at the global scale. We demonstrate substantial opportunity for cost-effective, large-scale natural and assisted regeneration in the humid tropical forests that could achieve numerous economic, social, and environmental benefits. By far the most important predictor of the occurrence of natural regeneration was the proximity to forest. On the other hand, not only environmental variables, but also socioeconomic variables were critical to predict landscape variation for vertebrates, invertebrates, and plants. Therefore, our global maps are useful for guiding decision-making under several different circumstances, such as: i) prioritizing landscapes for restoration, ii) improving regulations on biodiversity offsetting, and iii) estimating implementation costs of forest restoration at the global scale. We capitalize on natural forest regeneration as an innovative perspective to guide global, national, and sub-national forest restoration policies and practices cost-effectively.

The impact of the removal of invasive alien plants on water resources system yield: Helping Cape Town to avoid day zero

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The City of Cape Town has recently experienced a severe drought that nearly resulted in a city of over 4 million people running out of water. In response to this crisis, the City of Cape Town has fast tracked a number of potential water supply augmentation options. One of the priority actions is to improve catchment management through the removal of invasive alien plants from the catchments of the major water supply dams. South Africa has embraced this aspect of catchment management primarily through the ‘Working for Water’ program, as it had been shown that the continued invasion of the catchment areas will have a significant impact on water resources availability and yield. In this study we review previous estimates of the potential benefits from the removal of invasive alien plants on the catchment areas of South Africa and show how a failure to adequately maintain catchment areas free of invasive alien plants may have contributed to the severity of the drought which affected Cape Town between 2015 and 2018. The study further examines what the likely benefits are for increased investments in the removal of invasive alien plants as currently supported by the Greater Cape Town Water Fund and how this may provide benefits under climate change.

Success stories in restoration actions across coastal-marine ecosystems: The potential for synergies


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Restoration actions are crucial to enhance the recovery of degraded ecosystems and to speed up the return to their original state. The increase of restoration actions in marine systems highlights the need to provide specific recommendations to prioritise and improve restoration strategies that make the practices more effective. A review of 498 studies on active restoration in the marine environment published in the last 25 years was carried out at global scale. We assessed how, where, at which spatial and temporal scales, and under which socio-ecological settings restoration studies have been carried out in order to reveal determinants of success. Results show that restoration efforts across coastal habitats are increasing, especially for seagrasses and coral reefs, but never approached at the ecosystem-level. Targets, methods, response variables, and standards are very heterogeneous. Among the factors considered in the review, habitat, human impact intensity, biogeographic realm, and methods of restoration emerged as good determinants of restoration success. Short project duration, relatively small restoration areas, and lack of controls and knowledge of baselines are still limiting factors for deriving generalities. Finally, restorations rarely consider the link with ecosystem services nor future challenges linked to global change, thus impairing evaluation of benefits and long-term success stories. Marine restoration science needs more robust approaches leading to the development of best practices (e.g. protocols, monitoring of the effects, reasons for failure) to be applied at spatial and temporal scales so as to answer to present and future disturbance regimes.

The multidimensionality of the Environmental Vulnerability Index in the process of recovery of the Rio Doce Basin, Brazil

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Vulnerability assessment is fundamental to environmental management as it allows the identification of areas or resources at risk and the threats posed by the decrease or loss of such resources. The Doce River Basin, which is historically characterized by agricultural degradation and deforestation, suffered in 2015 the most significant environmental impact in Brazil’s history from the mine tailings dam breach in Mariana (Minas Gerais state), which generated several environmental compensation activities, as the reforestation of 400 km² in water recharge areas (WRAs) and watercourses preservation areas (WPAs). The objective of this work was them to establish a methodology for mapping environmental vulnerability in the Doce River Basin to allocate space for environmental recovery. The WPAs were determined according to Brazilian legislation and the WRAs were determined using the multi-criteria Analytical Hierarchical Process (AHP), considering the relief position, climatological water balance, soil drainage, and depth and terrain planform curvature. Subsequently, an AHP was performed to identify the environmental vulnerability in the Basin, using the parameters land use adequacy, erosion potential, quantitative water balance, and fires/heat sources. Finally, a third analysis was done to prioritise the municipalities that presented the highest relative percentage of degraded WPAs and WRAs, generating the environmental vulnerability index (EVI). In all of the 228 municipalities of the Rio Doce Basin, those with the highest EVI were concentrated in the middle part of the Basin area around the cities of Governador Valadares, Aimorés and Colatina, which are characterised by lower rainfall indices, deforestation, and extension of livestock use.
Emergency recovery from the Fundão Dam failure: Preparation for ecosystem restoration

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The failure of the Fundão dam on November 5th, 2015, spilled approximately 40 million cubic meters of iron tailings over watercourses, floodplains, cities, native forests and agricultural lands along 600 kilometres of the Doce River to the Atlantic Ocean. Emergency Rehabilitation efforts have been conducted in the affected areas by the non-governmental organisation Renova Foundation, initially by reestablishing the vegetation and soils of impacted areas. The need for a fast-intervention protocol to address the adaptive management of this first emergency phase led to the combination of rapid-revegetation techniques through a mix of grasses and leguminous plants for erosion control, followed by bioengineering techniques and reestablishment of the river system, aiming to provide conditions for the restoration of ecological functions in the medium and long term. Conceptual projects for each environment were developed considering impacts on the geomorphology of the affected rivers, along with adjustments in the field at the time of execution, allowing a scale gain and significant time reduction in determining the emergency solution. The actions resulted in a prompt stabilisation of the main rivers, tributaries, and flood plains. Recent results from a monitoring program showed at least 90% soil-loss reduction was achieved in each of the erosion control treatments as a reduction in turbidity levels of the rivers and an increase in the microbial activity of soils in comparison to unaffected areas. Today, a program of ecological restoration of the watercourses preservation areas (WPAs) is taking place together with restitution of agricultural lands.

Evaluation of recreational value to a restored wetland ecosystem based on mobile signaling data

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In order to protect the ecosystem services of coal mining subsidence wetlands effectively, scholars are trying to quantify the valuation of their ecosystem services. The most challenging task is valuing the cultural ecosystem services, as reliable and effective data are often obtained difficulty. Therefore, this paper introduced mobile phone signaling data into the travel cost method and constructed the evaluation model of recreational services to subsidence wetlands. By utilizing the mobile phone signaling data, to explore the recreational participants’ duration of stay, the start and endpoint coordinates, movement trajectory and so on, this paper estimated each participant’s possible cost. Meanwhile, the empirical study was carried out in 2018 with a sample size of 25,087 recreational participants in Pan’an Lake wetland park, Xuzhou City, China. The data mining showed that: (1) Mobile signaling data has a unique advantage in determining the travel distance and accommodation of recreational participants; (2) The participants were distributed over 229 cities, but 87.2% came from a nearby city within 300km, and 72.04% were Xuzhou natives; (3) The average consumer surplus was about 132.75 China Yuan (CNY), with an average cost of 308.11 CNY for an individual recreational activity. The results showed that the recreational value of Pan’an Lake was about 823 million CNY in 2018. The results are similar to the recreational value of wetland parks in China and abroad, which indicated that the mobile phone signaling data can be used as a new data source in estimating the wetland park's recreational valuation.
Investigating the impacts of environmental pollution and highlighting the need for environmental restoration

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There is a lack of environmental health data in Africa, which is undergoing rapid development. The SA-Swiss Bilateral Research Chair in Global Environmental Health therefore aims to conduct locally and globally relevant studies in this setting. Project 1 included a cohort study that investigated the effects of chemical and biological air pollution on childhood asthma in four informal settlements of the Western Cape, South Africa. Project 2 is a cohort study investigating the effects of pesticide pollution on childhood reproduction and neurodevelopment. Project 3 include two cross-sectional surveys on the effect of water pollution and hygiene on diarrhoea among residents of informal settlements in the Lotus River catchment area in the Western Cape. Project 4 aims to investigate the effect of climate change on health. In the panel study, short-term fungal spore exposure was found to significantly decrease lung function even beyond the day of exposure. In the air pollution cohort study, nitrogen oxide levels (daily annual mean = 14 µg/m³) below international exposure limits significantly increased asthma symptoms and reduced airway inflammation at one-year follow-up. Preliminary findings from the pesticide study, show that more than 80% of participants reported exposure to spraying and about 20% reported contact with pesticides. In the water pollution surveys, more than 10% of samples had mercury and arsenic levels above health standards due to contamination of containers. Implications for policy interventions and environmental restoration will be determined and results will be communicated to relevant stakeholders.

MERCES: Marine Ecosystem Restoration in Changing European Seas (H2020 funded project)

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MERCES is an EU project focused on the restoration of different degraded marine habitats, with the aim of: assessing the potential of different technologies and approaches; quantifying returns in terms of ecosystems services and their socio-economic impacts; and defining governance frameworks needed to optimize the effectiveness of restoration approaches. Specific aims include: a) improving existing and developing new restoration actions for degraded marine habitats; b) increasing the adaptation of EU degraded marine habitats to global change; c) enhancing marine ecosystem resilience, and services; d) conducting cost-benefit analyses for marine restoration measures; and e) creating new industrial targets and opportunities. MERCES project consists of 10 work packages, including the project management (WP10) on: the inventory of EU degraded marine habitats (WPI), pilot restoration experiments on soft and hard bottoms, including deep-sea ecosystems (WP2, WP3, WP4), and the effects of restoration on ecosystem services (WP5). The legal, policy and governance outputs will make effective the potential of marine restoration (WP6), and one dedicated WP will assess the socioeconomic returns of marine ecosystems’ restoration (WP7). The transfer of knowledge and the links with the industrial
stakeholders will be the focus of WP8 and the results of MERCES will be disseminated to the widest audience (WP9). MERCES will contribute to the Blue Growth by improving the EU scientific knowledge on marine restoration, contributing to EU Marine Directives, implementing the Restoration Agenda, enhancing the industrial capacity in this field, increasing the competitiveness of EU in the world market of restoration, and offering new employment opportunities.

Managing dynamic freshwater ecosystems with the competing demands of built environments and biodiversity: An assessment of the rehabilitation of the Dawidskraal wetlands, South Africa

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This paper considers some of the challenges affecting rehabilitation projects where protection of urban infrastructure that potentially compromises ecosystem function and sustainability is required in an area with high conservation value. It provides critical assessment of the outcomes of major structural interventions and early-stage evaluations of rehabilitation outcomes. The Dawidskraal wetlands are extensive valley-bottom wetlands, dominated by palmiet – a South African endemic. The wetlands lie within the Harold Porter National Botanical Gardens in Betty's Bay on land largely owned and managed by the South African National Biodiversity Institute (SANBI). Complicating their management is the heritage of inappropriate past development, resulting in residential floodplain development and a restaurant, parking area, and other infrastructure within the botanical gardens. In 2005, a large flood resulted in severe erosion of this infrastructure, collapse of an old diversion structure downstream, and the passage of a major portion of wetland flows out of the extant channel and onto a nearby road. The road surface eroded into a deep channel that thereafter conveyed most of the upstream flows, wreaking tremendous damage during subsequent flood events and perpetuating long-term disturbance to important ecosystems, while droughting the wetland. Interventions considered historical photographs and data as well as modeled flood flows. Implemented in 2018, interventions included a flow diversion structure and flood control berm and had to meet challenges around methods to sustain aquatic ecosystems in the eroded flood channel and control invasive indigenous vegetation in places, while being cognizant of local community concerns and safeguarding existing infrastructure.

Above and below-ground effects of harvester ants in Mediterranean dry grasslands

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Species-rich semi-natural grasslands have drastically declined since the second half of the 20th century all over the world; their conservation and restoration has become a major challenge. In these ecosystems, ants may act as ecosystem engineers, influencing positively or negatively soil quality, plants, invertebrates, and grassland productivity. However, their impacts on these different ecosystem compartments have never been simultaneously considered. In order to improve knowledge about the roles of ants in Mediterranean grasslands and their potential role in maintaining them, Messor barbarus, one of the most widespread harvester ant species in this environment, has been studied. In a semi-natural dry grassland of the Camargue regional nature reserve (southern France), we randomly selected 30 nests of the same age and 30 control zones (without signs of ant activity). In 2018, we analysed, soil physico-chemical parameters, above-ground vegetation (e.g. species richness, plant community, micro-local heterogeneity, plant biomass) and soil fauna (macrofauna, collemboła, mites, and nematodes). Our results show that M. barbarus has a positive and convergent impact. They modify soil physical and chemical proprieties, plant micro-local heterogeneity and affect soil fauna composition and abundance. We
discuss the potential roles of harvester ants as ecological engineers to restore degraded sites in order to accelerate soil, vegetation, and soil fauna resilience.

Monitoring of a long-term, large-scale restoration experiment in the thicket biome of the Eastern Cape, South Africa, using remote sensing

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Intensive goat farming has transformed more than a million hectares of subtropical thicket in South Africa from a dense closed-canopy shrubland into an open savanna-like system. Restoration of the degraded thicket landscapes can be achieved by planting truncheons of spekboom (Portulacaria afra). To determine the efficacy of such restoration, a large-scale restoration experiment comprising 331 quarter-hectare, fenced plots with 12 different treatments (including inter alia different size and spacing of cuttings) was established over an area of ~75,000 km² in 2007. The experiment has only been monitored twice in 12 years, primarily because of resource constraints in collecting data from 331 plots over a distance of more than 1,000 km from east to west. Given that the plots are visible in satellite imagery, we used remote sensing data (NDVI) to derive an index of spekboom growth in each plot over 10 years. We plotted this index against on-the-ground measurements of spekboom truncheons (including stem diameter, canopy diameter, and survivorship) as well as a wide range of soil variables (including pH, sand, silt, clay, stone volume, N, P, K, Ca, Mg, Na, and C). The index was strongly positively correlated with all on-the-ground measurements of the truncheons, indicating that remote sensing is an appropriate, cost-effective way of monitoring the experiment. The quantified relationships between the index and soil properties (e.g. positive correlations with base cations and silt; and negative correlations with stone volume) are of value for restoration practitioners selecting landscapes for restoration using spekboom truncheons.

Prioritisation of catchment areas for improved water service delivery using GIS spatial analyses: A comparison of two South African river systems, the uMngeni and Umzimvubu.

Gary de Winnaar¹, Vere Ross-Gillespie¹, Catherine Hughes², Rosanne Stanway³

As global demands for natural resources increases, so then do the pressures exerted on ecosystems increase. The developing ecological deficit is reaching critical levels to the point where ecosystems are unable to deliver valuable services such as fresh water to meet human demands. This is particularly the case in semi-arid countries such as South Africa, which continues to experience extreme water shortages and periods of severe drought. The uMngeni Catchment in KwaZulu-Natal and the uMzimvubu Catchment in the Eastern Cape both showcase exciting water governance partnerships in South Africa, each unique regarding catchment management and water use. The uMngeni Ecological Infrastructure Partnership is focused on integrating ecological infrastructure solutions to support built infrastructure investments to address water security challenges, while the Umzimvubu Catchment Partnership Programme aims to conserve the river system through sustainable restoration and maintenance of the catchment. Both catchments are important water resources and economic hubs for South Africa, and both are suffering considerable declines in water quality and water supply, coupled with the fast-growing population. This study presents findings from GIS spatial analyses conducted for each partnership. Analyses differed in terms of information inputs but shared the objective of prioritising areas for guiding catchment management and restoration interventions to promote water-related services. Outputs are presented using sub-catchments to represent the flow of services
within catchments, linked to people and ecological infrastructure. Prioritisation maps have provided a pivotal role in decision making by the respective partnerships with the ultimate goal of improving human well-being.

**Wetland restoration policies in the European Union**

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We present an overview of the trend and current status of wetland ecosystems in the EU. In the context of the current pressures/threats and future prospects, the policies for wetland restoration in the European Union are discussed. Some main challenges for the scientific community will be highlighted.

**A dry shrubland restoration within an irrigated farm landscape matrix in New Zealand**

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Within a 7,000 ha plantation forest to pivot-irrigated dairy farm conversion in lowland Canterbury, New Zealand, 187 ha of land has been developed for ecological restoration; 27 new reserves have been integrated into the landscape matrix, with linkages through ecological corridors. The few local remnant benchmark communities consist of Kunzea serotina (Myrtaceae, kānuka, tea tree) with an understory of smaller shrubs and an almost continuous ground cover of Hypnum moss. Our studies have drawn attention to the important functional role of the moss layer, both in moisture conservation and for seedling establishment. Nutrient spillover from farmland favours adventive weeds, but tolerance of native plants to drought stress provides some advantages once they become established. Management of noxious weeds (gorse and broom) and animal pests (rabbits and hares) is particularly critical. Our restoration strategy has been to establish research plots within the reserves, each of which has an established perimeter planting of Kunzea as protective buffer zones. This paper describes the results of experimental trials of soil acidification, mulch amendments, the efficacy of tree guards, how to restore the moss layer, the role of nitrogen fixers, and faunal colonization. Natural colonization by some native plants provides some surprising findings, but the range of species is restricted by a lack of propagule sources at distances that allow native birds to disperse seeds. Current attempts to introduce inoculants and to embed small biodiversity pods within the restoration plots are discussed. We show how the economics of upscaling requires different approaches to ecological restoration.

**Challenges and opportunities of Forest Landscape Restoration implementation in the context of Latin America (20X20 Initiative) and Africa (AFR100)**

**Anita Diederichsen, Pablo Pacheco, Daniel Vallauri, Mark Aldrich, Trevor Walter**
WWF

Both Initiative 20x20 in Latin America and the African Forest Landscape Restoration Initiative (AFR100) support the Bonn Challenge and the New York Declaration. Together the initiatives are aiming to achieve 163 million hectares by 2030. To achieve these ambitious goals it is crucial to consider the specific opportunities and challenges faced in each region and within contrasting landscapes in both regions. This presentation will cover the status for both Latin America and Africa informed by a horizon scanning exercise to better understand the existing social and ecological complexity associated with Forest Landscape Restoration (FLR) across regions. This regional assessment will draw on a global assessment of the future of forests conducted by WWF Global Science and Forest Team. This approach consists of identifying the current and emerging trends shaping the future
of forests and assessing which of those constitute either threats or opportunities. This review allows WWF to inform strategic thinking and planning for Latin America and Africa. This assessment concludes with some reflections on approaches for WWF, which apply also to other organizations for decision making and action, which entail, first, adopting longer-term and system change solutions; second, harnessing the opportunities for achieving impacts at scale; and third, shifting to a more positive agenda for forests. Above all it sets the basis for a solid Forest Landscape Restoration strategy in WWF that is focused on implementation, on the ground results, and achieving impacts at scale.

Advancing Forest Landscape Restoration in Sub-Sahara Africa: Articulating knowledge gaps in interventions' design and in governance challenges and institutional arrangements

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The momentum of Forest Landscape Restoration (FLR) across Africa is increasing with the active involvement of 28 countries in the African Forest Landscape Restoration Initiative. Like other existing environmental mechanisms well-grounded conceptually, the risk of falling short on intended outcomes in line with FLR's ambitious promises are high and avoiding such scenario from the early stages of FLR is paramount. Harnessing restoration science knowledge and its social-dimension to help articulate gaps in design and implementation of FLR interventions/schemes is important, and we present our early research efforts in that direction. We provide a literature-informed synthesis of the socio-institutional factors that influence the outcomes of FLR schemes, and a proposed characterization of FLR interventions as part of scholarly attempts to realign FLR conceptual philosophy and principles to its practical forms. First, early insights on the socio-institutional influential factors operating at multiple scales from the household, community, project/program, and government sector indicate governance and cross-sectoral and cross-scale institutional arrangements as one defining major challenge for successful FLR implementation within a defined landscape. Second, we elaborate ten criteria characterizing FLR in current practice in an attempt to reconcile its divergent discourses, definitions, and interpretations across countries and actors, which have implications on its contextual design. The question is to investigate the extent to which differences between conceptual ideas of FLR and practical investments tagged as FLR can affect delivery of its promises to pre-empt potential differences. Future empirical research aiming at framing context-appropriate polycentric governance system and institutional configurations for FLR is ongoing.

Predicting and alleviating dormancy in challenging species: Insights and innovations from the Millennium Seed Bank Partnership

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The Royal Botanic Gardens Kew (UK) works with countries in the Millennium Seed Bank Partnership (MSBP) to carry out germination tests on locally sourced seed collections of wild plant species from all over the world. Germination tests are conducted after drying seeds at 15% equilibrium relative humidity (eRH) and 18°C prior to hermetic storage at -20°C. Seed dormancy, which functions to ensure seeds germinate at the best possible time for seedling establishment, represents a significant obstacle in monitoring viability in some species. Understanding how dormancy functions in the natural environment is crucial and so climate data are used for choosing dormancy breaking treatments and germination conditions. For instance, Dry afterripening (seeds held at 60% eRH and warm temperatures of c. 20°C) alleviates dormancy by simulating a dry season. In some species dormancy ensures seeds germinate sporadically over several years in nature. It is possible to shorten this time by extracting the embryo from seeds in the laboratory, as in the case
of Galeopsis angustifolia, but this is time consuming and not suitable for large-scale restoration works. Move-along experimental designs, where seeds are moved through a sequence of different temperatures to simulate different seasons, are preferred. This protocol has been successfully used to propagate seeds of Adonis annua. Heat and smoke pre-treatments can also be used for breaking seed dormancy and cuing germination in restoration. Light or darkness may function as an important germination cue, such as photoinhibition of seed germination in some monocots in open, disturbed, and dry habitats.

**Why seed standards matter in the world of ecological restoration**

**Kingsley Dixon, Adam Cross**
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Globally, initiatives in ecological restoration and forest landscape restoration as defined in the International Standards for the Practice of Ecological Restoration are increasing in both number and scale. Native seeds are the foundation of almost every ecological restoration project, and as the scale of restoration projects increases, so too the need for native seed is expected to grow exponentially. Along with the increasing demand for large quantities of native seed there is a global push not only to increase the diversity of species included in seed mixes, but also to improve the quality of seed batches and the delivery of seeds to site to facilitate successful restoration outcomes. Access to, and supply of biodiverse, high quality native seed mixes will underpin major funding and mandatory restoration standards as highlighted in the International Standards for the Practice of Ecological Restoration. In both the agricultural and forestry sectors, seed standards are internationally accepted, and buyers can have confidence in the quality (purity, viability, germinability and genotype) of the seeds that they are purchasing. However, for many countries even fundamental standards guiding the production, collection, storage and sale of native seed are lacking. These standards are designed to provide industry, restoration practitioners and regulators with a guide to science-driven best-practice in the planning, supply, and deployment of native seeds for ecological restoration.

**Evaluating the ability of bivalve facilitation to enhance seagrass bed resilience to disturbance**

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Human-induced degradation of seagrasses has accelerated across the globe. Restoring these productive habitats has proven to be both challenging and costly, particularly once a bed has been entirely lost. Therefore, it is critical to develop and test alternative approaches that promote existing bed resilience to disturbance. One such approach is the incorporation of positive species interactions into restoration design. We hypothesize that facilitation from a mutualist bivalve (the hard-shell clam) could aid in seagrass bed restoration by assisting in a rapid return to favorable environmental conditions for seagrasses after a disturbance. We tested the ability of bivalve facilitation to increase mixed community seagrass bed resilience in North Carolina, USA to two separate disturbance regimes: physical perturbation from propeller scars and excess water column nutrients. We monitored the effect of clam addition and disturbance on seagrass bed characteristics including growth rate, shoot density, epiphyte load, and more. There was no statistically significant effect among treatments for the first summer of the experiment, however we hypothesize for subsequent growing seasons that clam presence will enhance seagrass recolonization into propeller scars and reduce epiphytic loads under nutrient-loading scenarios. These findings would suggest that harnessing ecological facilitation can be an effective restoration technique for degraded seagrass beds. Understanding how
mutualistic plant-animal interactions may reduce seagrass recovery time will allow managers to modify restoration designs to take advantage of natural ecological relationships across a variety of geographic locations and environmental conditions.

**Restoration of structure and function of alpine grassland ecosystems worldwide: Challenges, strategies, and insights**

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Covering about roughly 40% of global land resources, grasslands are vital at local and global scales in terms of ecological functions and the provision of livelihoods for large human populations. Alpine grasslands account for a great share of grassland biomes worldwide. However, widespread grassland degradation in alpine regions such as the Himalayas, Alps, Qinghai-Tibetan Plateau, Central Asian Highlands, and South American Andes has presented dramatic threats to these ecosystem services. This crucial situation has pushed researchers, resource managers, policymakers, sustainable development practitioners, and the people who depend on rangelands to think critically about the future sustainability of alpine grasslands. Here, we will summarize and synthesize the worldwide cases to gain a better understanding of: (1) challenges existing in restoring the structure and function of alpine grassland ecosystems; (2) strategies that can enhance the recovery of degraded alpine grassland ecosystems worldwide; and (3) insights that can integrate new scientific knowledge about the structure and functions of alpine grasslands into restoration and protection management.

**Tracking wildfire driven regime shifts across a biome: Implications for ecosystem restoration**

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Wildfires are implicated as ecosystem-level drivers of regime shifts in vegetated biomes across the globe. Policies and programs abound to mitigate for post-wildfire vegetation responses, encouraging large-scale reseeding campaigns and mitigation of bare ground to restore recently burned areas. In an exhaustive analysis of wildfire-scale vegetation response to large wildfires across an entire grassland biome, we assess the persistence of vegetation change to detect wildfire driven regime shifts. There was no indication of large-scale persistent transitions driven by wildfire in the Great Plains. Immediate wildfire and drought induced signals of functional group response to wildfire were so recurrent within wildfire perimeters that these signals were evident at the scale of the wildfire across the biome. In contrast, a persistent change in functional group abundance indicative of a regime shift occurred for only one of the five assessed functional groups (trees) within one of 11 ecoregions assessed. Traditional perspectives of wildfire driven collapse were restricted to the 30-meter pixel level of analysis, suggesting that many of the transitions described in policies and land management frameworks are localized and represent extreme cases within larger wildfires. Rather than driving undesirable regime shifts, large wildfires may help restore grassland biomes at a large scale where fire suppression has altered fire regimes. Our results support that restoration of ecological processes like wildfire can assist rather than hinder large-scale ecosystem restoration goals.

**What is preventing oak forest regeneration in human-modified landscapes? Evidence from a multi-site experiment in central Mexico**

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Oak forests are climax forest states with an elevated associated biodiversity and complex ecological interactions, and they provide a wide range of ecological services and goods. In spite of their importance, deforestation and expanding agricultural frontiers threaten oak forests worldwide. In México alone – where one third of the world’s oak species grow - more than 20% of its oak forests were lost in the last 50 years while the remaining forests are often heavily impacted by human activities. Seedling establishment in these landscapes is often hampered by a lack of seed-dispersers and harsh micro-environmental conditions. As a result, current regeneration rates are often insufficient to replace older individuals. We set up a field experiment in semi-arid Central Mexico to assess oak regeneration in a human-modified oak forest. We sowed over 8,000 acorns of eight different species in 130 experimental units distributed over five sites (eroded landslides, abandoned cattle pasture, and forest relicts). We tested the impact of five different ecological barriers on seedling establishment: compaction, full sun exposure, enhanced seed predation, poor soil, and absence of litter. We also tested the effectiveness of restoration interventions to overcome these barriers, such as artificial shade or soil transference. Particular barriers or restoration interventions had varying effects according to species, life stage, and site. Furthermore, artificial shade and top-soil transference promoted seedling establishment individually, but not when applied in combination. Our results shed light on oak forest succession in human-modified forests and provide a practical restoration guide to enhance oak seedling establishment.

**Transitioning from carbon offset to optimised biodiversity: The Buffelsdraai Reforestation Project**

**Errol Douwes**

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ETHekwini Municipality, (Durban, South Africa), embarked on a Community Reforestation project at its Buffelsdraai Landfill site in 2009. At that time, the intention was to offset ex-ante 42 000 tons CO2 equivalent over a 25-year period through tree planting. The project was catalysed through Durban’s hosting of several 2010 FIFA World Cup™ soccer matches and the opportunity to deliver a carbon neutral event. The project transitioned from early targets (set in 2009) that focussed on planting of easy-to-access, fast-growing local tree species, to a new focus on climate change adaptation and socio-economic development through optimising on-sight biodiversity. In 2015, a decision to increase floral species richness and diversity was initiated. This was achieved through targeted propagation and planting of selected species, following comparisons made with a reference site, namely Kenneth Stainbank Nature Reserve. Propagation of desired species was achieved through training community members to find and grow plants on the new ‘target list’. On-site propagation of some ‘difficult-to-grow’ species was also done. Active shaping of species richness and diversity targets helped ensure closer alignment between the newly restored forest and the reference ecosystem. The timing also allowed for successful introduction of understory plants, which have thrived under established trees that were planted early on. High on-site plant biodiversity is expected to bolster the diversity of faunal species, improve storm water attenuation and filtration, and reduce soil erosion. The propagation skills gained by local people ensure long-term business opportunity benefits and an appreciation for local biodiversity.

**Preventing plant invasions by using botanic gardens and arboreta as sentinels**

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Invasive plant species continue to significantly impact ecological restoration projects throughout the world. Many woody invasive species in North America have a historical or
present horticultural use. In order to reduce the impacts of these species in future restoration projects, they need to be identified as early as possible – preferably before any widespread commercial release occurs. One approach to prevent future invasions is to harness the expertise of botanic gardens and arboreta, which plant and monitor non-native species within their plant collections. These institutions collect species from around the globe, display them in their collections, and maintain them with expert horticultural care. They also collect data on growth, survival, and reproduction of species over time. Furthermore, many public gardens also maintain natural areas and have management plans to control invasive plant species. Since 2016, a working group of several North American public gardens and affiliated nonprofits have been working together to create a communication network to share information about non-native plants that may be escaping from cultivation on their sites. In this presentation, we present non-native plant species classified as problematic by six different gardens, share how gardens create individual watchlists, and provide an update on the overall effort among North American gardens to work together to help prevent future plant invasions. This project signals that public gardens have significant potential to help prevent the introduction of invasive species in North America while benefiting ecological restoration projects of the future.

**Community-based restoration of degraded landscapes: Developing a training model for sustainable land management at Machubeni, Eastern Cape**

*Monde Duma, Charles Chakoma, James Gambiza, Rebecca Powell*  
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Land degradation is a global environmental problem, especially in the smallholder farming sector in rural areas. Restoration is a key response strategy of Sustainable Development Goal 15, particularly under the land degradation neutrality target 15.3. By recognising that top-down restoration programmes have generally failed, we present a sustainable land management project of the Global Environment Facility 5, which implements participatory approaches to foster restoration in South Africa. The project is based on self-determination theory, under which the success or failure of restoration are understood through the socio-contextual conditions that enhance or forestall buy-in. Collaborating with local leaders and stakeholders, identifying passionate volunteers (called Land Conservation Activists (LCAs)) and exposing them to training opportunities, is a project’s imperative. Researchers, LCAs and the community are integral to the project’s approach, which entails peer-to-peer training, learning exchanges, and continuous sharing of knowledge and skills. For example, in Machubeni’s site the local community has championed the project’s restoration programme. However, a range of contradictions are revealed when working with communities. Particularly, there are trade-offs between the time spent on restoration activities and the fulfilment of basic human needs. Lessons learnt indicate that a simultaneous improvement of grazing management and rangeland restoration can only be achieved through farmers’ collaboration on grazing control. Further government and project investments in building skills and knowledge are needed to achieve win-win restoration across natural and social dimensions. Building trust with communities is a long-term process and the project is still in the initial stage of developing a common understanding.

**Why nurseries are successful and why nurseries fail**

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The need for ecosystem restoration continues to increase, and worldwide, many ambitious initiatives, ranging in scope from local to global, are in place to contribute in response to this need. Reaching these restoration goals will require implementing a broad palette of
techniques, spanning from passive to active restoration. Actively outplanting seedlings can be an important aspect of restoration, especially on the more disturbed sites. Ensuring that nurseries produce the highest-quality plant materials and that those plants become established in the field is a paramount concern. Unfortunately, all too often nurseries fail in their ability to deliver quality plants in a timely manner. The reasons for failure are numerous, but successful nurseries often share common traits, including a passion for growing plants, an understanding of the nursery’s role in the local community, an eagerness to communicate with the public as well as clients, and a management philosophy that encourages and nurtures a learning environment toward increasing plant production expertise. In particular, successful nurseries engage with their clients using the tenets of the Target Plant Concept, especially the realized need for client–nursery sharing of expectations and results that are continually reassessed and modified based on field results. Working together, clients and nurseries are most successful when biological and societal needs are assessed and satisfied.

**Leveraging institutional scale investment in ecological infrastructure: Challenges and opportunities for South African institutional investors**

*Jon Duncan*
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The presentation will explore, from the perspective of institutional investors, some of the challenges with respect to mandates, risk/return, benchmarks, performance measurement, and regulations. Similarly, the paper will explore some of the opportunities with respect to long-term systemic risk mitigation, uncorrelated returns, and diversification.

**Using harvester ants for restoring Mediterranean dry grassland vegetation and soil after a petroleum leak**

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Located in southeastern France, the plain of La Crau is a species-rich Mediterranean dry grassland of 11,500 hectares. In 2009, a petroleum leak totally destroyed 5 hectares of this protected ecosystem. In 2011, 72,000 tons of the same type of soil were transferred from a nearby quarry. 169 founding queens of a common harvester ant (Messor barbarus) were also transplanted to speed up the restoration of the soil and the pre-existing dry grassland. For evaluating this restoration technique, we analysed different soil parameters, the soil seed-bank, and above ground vegetation in patches with and without ant activities in 2017 and 2018, both in the restored area and in the surrounding undisturbed grassland. Our results clearly show that harvesting ants have positively impacted soil fertility, soil seed-bank density, above ground plant cover, plant biomass and species-richness of the restored area plant community. Ant engineered patches in the restored area are now more similar to those of the reference grassland than the control without ant activity. Messor barbarus appears, therefore, as a key component of the restoration of Mediterranean grasslands and soils in the middle term. We will continue the survey to measure long-term impacts of ant activity on the evolution of the restored plant community at the restored area scale.

**What is to be restored? Contribution from landscape sustainability science to landscape restoration**

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Landscape sustainability science (LSS) can make a profound contribution to a better understanding of the concept of landscape restoration (LR) and its application. Diverse global and national initiatives and agreements seek to promote ecological restoration at the landscape scale. The Global Partnership on Forest and Landscape Restoration is a network based on a landscape approach and responds to the Bonn Challenge to restore 150 million hectares. However, we believe that little consensus exists on the definition and methodological approaches needed to apply LR. The objective of this work is to discuss a definition of LR from a landscape ecology perspective and discuss some implications and practical challenges. LR can be defined as the planned process of recovering the capacity of a landscape to consistently provide long-term ecosystem services essential for improving human well-being. In other words, LR seeks to improve key attributes of a landscape including composition, configuration, and dynamics that are spatially interacting with ecosystem processes, biodiversity (at different levels of organization), and ecosystem services. We present a case study to discuss implications of this definition and exemplify practical challenges of how to deal with LR by integrating these key attributes. The study landscape is located in the core of a biodiversity hotspot, with a substantial loss of natural ecosystems, a landscape profoundly transformed by economical drivers, and an explicit need from local community and relevant stakeholders to recover essential ecosystem services in order to improve their well-being.

Hand weeding after direct seeding overcomes competition from high weed loads in riparian zones

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Riparian zones are vulnerable to high levels of weed invasion by a wide diversity of species, due to their location in the landscape and the impacts of human activities. Restoring indigenous vegetation communities is challenging in riparian sites dominated by weed species. We asked whether intensive pre-sowing weed control was sufficient to protect establishing native seedlings from weed competition, and if not, what technique of post-sowing weed control was most effective. At several sites in south-eastern Australia we tested management techniques to promote direct seeding outcomes in riparian zones with high weed loads. Our study found that intensive pre-sowing weed control, involving multiple herbicide applications and physical removal of weeds, was insufficient to protect native seedlings from weed competition during establishment. At one site, native plant numbers were four times lower in plots receiving pre-sowing weed control only than in plots which received pre-sowing and post-sowing weed control. At two other sites, hand weeding in the months immediately after sowing was more effective than spraying a broad-spectrum herbicide at the same frequency, with twice as many native plants establishing in the hand weeded plots. Despite the high cost of manual labour, it may be more cost-effective to hand weed than to not hand weed after direct seeding, due to the higher rates of plant establishment. These results indicate that direct seeding in riparian zones with high weed loads can be successful, but only if effective post-sowing weed control is undertaken.

How the characteristics of non-perennial pans in semi-arid conditions can inform their ‘re-creation’ using the substrate from intact pans

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The creation of wetland habitat can allow for the restoration of ecosystem services within transformed landscapes. The question that arises – can depression wetlands/pans be successfully recreated in the landscape using the material from systems that would be lost? A mine, located within a semi-arid region of South Africa, is expanding its footprint, resulting in the loss of pans. In order to investigate opportunities to mitigate impacts, the
feasibility of creating pans within the surrounding landscape is being investigated. The formation of endorheic, non-perennial pans is considered to be through a process of “erosional control”, i.e. the deflation of the systems. These systems are greatly influenced by the climate, biotic factors (herbivores and vegetation), underlying geology, and local topography. Six potential relocation sites have been identified, using a combination of desktop modelling and fieldwork, in which three scenarios will be recreated. These systems are rainfall-driven, and therefore the underlying substrate of the relocation sites is a major consideration, i.e. sand, clay, or bedrock. Thus, the type of approach adopted per site will differ, e.g. use of liners in sandy soils. The materials will be sourced from the intact systems to be lost in the post-mining landscape. Moreover, the created pans will have to provide suitable habitat for the diverse invertebrate species within the region that will be harvested from intact systems and relocated to the created pans. The characteristics of the pans, including the abiotic and biotic aspects, and the proposed approach to the pan creation will be presented.

Review on land restoration training in eastern Africa: Case studies from Uganda

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Land is an important resource for humanity as livelihoods depend on it. Humans utilize land to sustain livelihoods, but it is degraded partly because of the increasing human population and climate change, among other factors. Land degradation is thus a threat that needs to be addressed globally, partly through restoration. Within Eastern Africa, as is indeed the case in developing countries globally, there is a scarcity of professionals in land restoration. This paper evaluates an effort undertaken by the United Nations University Land Restoration Training Programme partnering with Makerere University and the National Environment Management Authority in Uganda, to offer training in land restoration. We compare this to other land restoration training initiatives in East Africa. We examined curricular of training institutions, including universities, to understand the inclusion of land degradation and restoration issues. We also interviewed practitioners involved in land management to assess their knowledge and skills. Two trainings have so far been conducted in Uganda, targeting district local officers in the Natural Resources Sector, which is a novel approach for spreading skills in land restoration. Case studies of participants in the trainings are used to show that they are causing change. Aroused interest in land restoration issues following the trainings shows that the existing capacity (knowledge and skills) in land degradation and land restoration is inadequate. This study provides basic guidelines to training institutions regarding strategies for re-aligning their programmes to enhance their contribution to addressing land degradation, demonstrating benefits of the north-south collaboration.

Linking Traditional Ecological Knowledge (TEK), native grassland and soil health, and human health on Indigenous traditional lands

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For millennia, Indigenous people have created more productive, healthy ecosystems by modifying them with fire and by altering the movements of important wildlife species such as bison. These practices, part of Traditional Ecological Knowledge (TEK), created healthy, productive soils, increased biodiversity, ecosystem resiliency and vigor, and sustained human health. Globally, colonialism, defined as a foreign polity seeking to extend or retain its authority over other people or territories to develop or exploit them to benefit the colonizing country and help the colonies modernize in terms defined by the colonizers, has created extensive ecological degradation. We illustrate this global problem—and solution—with a case study from an EcoHealth Network founder site in southwest Alberta,
Rewilding with keystones: Using bison and fire to restore North American grasslands

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Native grasslands have been declining in North America since the 1880s, attributed to elimination of bison (Bison bison) and wildfire, introduction of non-native agronomic grass species, and suppression of fires set by Indigenous people. Since less than 3% of historic grasslands remain in North America, restoring a keystone species linked to grassland resiliency is a conservation priority. Restoring native grasslands (also called prairies) is a powerful climate-change adaptation strategy, because native grasslands sequester more carbon more rapidly than non-native, agricultural grasslands. Extensive paleoecological evidence of bison use of North American prairies and Indigenous burning exists. Bison, primarily grass-eating species, increase prairie ecological resiliency and biodiversity. Bison are a keystone species and an ecosystem engineer because their grazing patterns, which include several hundred-mile seasonal migrations, intensively alter the biophysical environment. Bison fertilize the soil with their urine and horn-up saplings and shrubs, keeping prairies open. Bison presence improves soil resources, changes plant and animal composition, and increases biodiversity and energy cycling, thereby creating communities more resilient to climate change. However, to be ecologically effective, bison must be wild and free-ranging. Captive bison have similar impacts as domestic cattle, producing over-grazed, ecologically degraded pasture conditions, damaging even large ranges. Fire improves native grass communities’ vigor, including their resiliency to climate change. While Indigenous people long have seen the bison as central to their world, Euro-American scientists and managers only recently acknowledged this species’ full importance. Subsequent management and legislative actions, including bison reintroductions and prescribed burning, may facilitate prairie restoration.

Social dimensions of the SER Standards: Traditional Ecological Knowledge and Local Ecological Knowledge and their importance to ecological restoration

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Restoring ecosystems and improving ecological resiliency in our rapidly changing world can best succeed by using a multi-disciplinary approach in which researchers, practitioners, and communities find common ground and innovative solutions. Traditional Ecological Knowledge (TEK) and Local Ecological Knowledge (LEK) are incorporated in the International Standards for the Practice of Ecological Restoration as a way to tap into deep, place-based wisdom about historical ecological relationships in order to restore degraded ecosystems. LEK is local, place-based knowledge of the land and its processes applied by humans to create more productive lands and healthier ecosystems, increasing biodiversity and ecosystem resilience. TEK is knowledge and practices passed orally from generation to
The capacity of urban restored forests to support native birds: Ecological or social restoration?

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Urban restoration can perform the dual role of creating refugia for native flora and fauna, and greenspaces where city residents can benefit from daily interaction with nature. Our research combines ecological and social science to evaluate the contribution that restored native forests in New Zealand cities can make to native bird conservation and reconnecting urbanites with nature. Birds were monitored at 43 sites in two New Zealand cities. Sites represented three types of urban forest: unrestored (n = 6), restored (n = 26), remnant (n = 6), and rural forest remnants nearest to each city (n = 6). Restored sites formed an age gradient of 1 to 73 years since initial planting. Using qualitative interviews, we explored city residents’ experiences of urban nature in parks and gardens. Results reveal that native bird species’ richness and diversity increases with time since restoration. Avian communities shift from being dominated by introduced finches to supporting a greater number of native birds as the forest matures. Results suggest that habitat is a primary limiting factor for native birds, demonstrating the potential of restoration to increase bird numbers in cities. The social study findings suggest that we cannot rely on urban gardens to support native biodiversity in the short-term and stress the need for local authorities to invest more time and resources in urban restoration. As the number of people living in cities continues to rise, our research offers renewed evidence for the importance of reserving a space for nature in cities.

Rethinking wetland restoration by considering natural dynamics: Evidence from the Krom River unchannelled valley-bottom wetland, Eastern Cape

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Wetland restoration in the global and South African contexts traditionally considers the hydrological regime as the primary driver of physio-chemical processes that influence wetland ecosystem structure and function. However, in a dryland situation such as South Africa that is dominated by weathering over timescales of tens of millions of years and erosion processes as a consequence of sub-continental uplift over the last 30 million years, geomorphological processes governed by flowing water play a key but largely unrecognised role in shaping the landscape to host wetlands, fundamentally influencing wetland structure and function. As such, the geomorphic work of flowing water and its benefits for wetland formation and maintenance has not before been incorporated into wetland restoration efforts. The Krom River wetland highlights the range of processes in an erosional landscape that contribute to creating a landform well suited to host wetlands. Erosion events happen at intervals of hundreds of years, which leads to both longitudinal
slop reduction and valley widening. Erosion is associated with deposition of a gully-fan at the toe of the gully, which happens over timescales of years to decades. It is proposed that this variation in hydrodynamic and geomorphic processes, operating over different time scales, have contributed to the limited success of the large-scale engineering structures that have been put in place as part of wetland restoration activities in the area. It is argued that restoration activities need to incorporate hydrodynamic and geomorphic processes that work with, rather than in opposition to, the natural dynamics of the system.

**Integrated scientific approaches to rare species restoration: Lessons learnt from Western Australia’s Kings Park and Botanic Garden**

**Carole Elliott** ᵃ, **Siegy Krauss** ᵃ, **Shane Turner** ᵃ, **Ben Miller** ᵃ, **Wolfgang Lewandrowski** ᵃ, **David Merritt** ᵃ, **Eric Bunn** ᵃ, **Belinda Davis** ᵃ, **Bob Dixon** ᵃ, **Jason Stevens** ᵃ

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For many threatened plant species in Western Australia, the lack of knowledge about their ecological behaviour and requirements has been a critical impediment to effective restoration. Over the past 20 years, applied research at Kings Park and Botanic Garden has focussed on many aspects of the ecology and biology of rare and threatened native plants and their requirements for restoration. The aims of this research have been to: (i) determine impacts of planned developments on rare and threatened plant populations, (ii) develop methods to support translocation and restoration of species, and (iii) to assess functional attributes within restored/translocated populations to determine their establishment and long-term sustainability through comparisons with natural populations. We present case studies of rare flora from across Western Australia, including those species impacted by mining (e.g. Androcalva perlaria, Caladenia leucochila, Darwinia masonii, Eremophila resinosa, Lepidosperma gibbonii, Ricinocarpos brevis, Tetratheca erubescens, T. paynterae) and anthropogenic disturbances (e.g. Grevillea scapigera, Symonanthus bancroftii) that highlight how an integrated scientific approach builds upon traditional core functions of botanic gardens (i.e. ex situ conservation and propagation). These demonstrate how understanding species habitat and distribution modelling; population genetics; pollination requirements; mating systems; seed biology and ecology; ecophysiology, and population ecology can be used to inform and improve translocation and restoration outcomes. We also present how delivering successful translocation programs requires significant collaboration with research providers, conservation agencies, and other stakeholders.

**Application of restoration science to threatened species translocation: Insights from a short-range banded ironstone species**

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Restoration or translocation of short-range endemic plant species that occur in highly specific habitats in semi-arid environments is particularly challenging. We used controlled studies to develop a restoration ecology profile for Ricinocarpos brevis, a threatened species of the Goldfields region of Western Australia, to identify efficient translocation protocols. Since 2013 significant investment has been directed into optimising the establishment of plants on mining waste rock landforms using direct seeding and the planting of tubestock. Unsurprisingly, water availability is a major impediment to translocation success, and we have defined the thresholds of water stress through laboratory germination trials coupled with field emergence observations and plant establishment. The potential recruitment window where soil moisture and temperature conditions in the field were optimal to support germination, equated to an envelope of just 21 (non-continuous) days in 2013 and resulted in <2% seedling emergence. In subsequent years, further field trials showed that implementing seed enhancement technologies of
priming and translocation technologies of shading and irrigation increased seedling emergence, but the application of seed pelleting technologies did not improve seedling emergence. Translocations using older tubestock (+1 year) propagated from seed and planted with shading and irrigation increased survival. The use of biodegradable pots, which decreased initial root disturbance during planting, showed improved establishment and growth of tubestock over 12 months. A mix of unusual ecological attributes defines the restoration requirements of Ricinocarpos brevis and consequently the conditions required for its establishment in the field.

Evidence for contrasting functional groups of lianas in restored and reference tropical forests.

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Functional traits are important predictors of species distributions and abundance, and their response to the environment. During community assembly, species that colonize the newly established habitat must be able to adapt to contrasting environmental conditions, in comparison to the undisturbed forest, and thus belong to contrasting functional groups. Although functional groups are well described for trees, this is not always true for other life forms of the tropical forest. For climbers, compositional differences between restored and reference forests have been observed, although this pattern is yet not completely understood. We assessed some functional traits (specific leaf area [SLA], stem density [SD], seed dispersal syndromes, climbing mechanisms) of the 10 most abundant liana species of 20-yr-old restored forests, versus a well conserved, neighboring forest fragment. We found higher SLA and lower SD for the restored forest species in comparison to the reference forest. While anemochory and leaf tendrils were predominant in both habitats, the proportion of zoochory and autochory were higher in the forest fragment, as well as the proportion of scandic bushes. Within the reference forest, liana abundance was strongly associated with the proportion of canopy deciduous trees and tree density, while in the restored plots the main factor was the level of canopy openness. Differences in predominant functional traits and habitat preferences support the evidence for contrasting functional groups of lianas able to quickly colonize restored forests, in relation to groups adapted to well conserved forests. For colonizing lianas, light availability seems to be the main ecological filter.

Working with the mine rehabilitation industry to develop large-scale seed enhancement technologies and restoration solutions

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Depending on the level of impact and degree of active intervention, degraded ecosystems may recover to pre-disturbance conditions by achieving representative levels of species diversity, structure, and cover metrics. However, sites that have experienced longer-term, higher-impact disturbances, such as mined lands, may not be able to return to their pre-disturbance state without significant economic, biological, and technological inputs. Achieving successful plant establishment for a wide range of species requires the development of techniques to overcome various biotic, abiotic, and dispersal filters. Seed enhancement technologies that include precision flash flaming, hydro- and osmo-priming, polymer-based seed coating, and extruded seed pelleting are one approach that has gained recent attention in dryland restoration. For instance, combined with optimised dormancy break treatments, hydro-priming and applying a polymer seed coat to seeds of Triodia pungens (dominant Australian desert grass) increased seedling emergence to ca. 35-40%. This represents a 4-fold increase in global seedling recruitment averages. To apply seed enhancement technologies at scale, however, we are faced with the difficulty of transferring these findings to large-scale operations. It is with this complexity that we
introduce and discuss several knowledge gaps and emerging biological, technological, and precision-engineering solutions that have been developed between a diverse team of researchers to increase the overall species pool available for use in restoration programs. We use examples from seed-based dryland research in Australia and the United States of America. This evidence-base represents a solid example for how multi-disciplinary rehabilitation programs can offer (seed- and engineering-based) solutions to the global restoration challenge.

**Restoration-engineering and seed enhancement technologies offer new solutions for use in dryland (mine) rehabilitation**

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Improving seed use efficiency through seed enhancement technologies is one approach that has gained recent attention in dryland restoration. For instance, our international research team has been working together to advance our knowledge on seed enhancement techniques that include precision flash flaming, hydro- and osmo-priming, polymer-based seed coating, and extruded seed pelleting. These techniques all aim to improve the germination and establishment potential of seeds under sub-optimal conditions. When combined with modifications to existing mechanical seeders or with new-builds, these technologies are one potential solution to overcome major inefficiencies in dryland seeding efforts (i.e. >90% of seeds failing to establish). For instance, ‘flash flaming’ is a technique that removes unwanted hairs and appendages of bulky and fluffy seed batches (e.g. winterfat / *Krascheninnikovia lanata* [Chenopodiaceae] in the USA, *Triodia wiseana* [Poaceae], and *Ptilotus exaltatus* [Amaranthaceae] in Australia). After removal, seed batch volume is vastly reduced, while the flow properties of seeds through cleaning equipment and mechanised seeders are vastly improved. This recent Australian invention allows many species that are historically hard-to-handle, and/or deliberately avoided, to be used in large scale restoration programs. In this presentation we will highlight some key findings from our international projects that include the benefits of flash flaming, polymer-based seed coating combined with priming of seeds and discuss the engineering modifications and machine builds that are assisting with precision delivery of seeds across large-scale, high-impact mine restoration sites in Western Australia. Outcomes of these programs are applicable to degraded lands requiring restoration across global dryland regions.

**Riparian restoration in fynbos catchments**

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Invasive alien plant species are a primary cause of ecosystem degradation in semi-arid South Africa, and their control and management is a legislated priority in the country. Here, ecological restoration has developed as a complementary research stream to invasion biology, primarily because strategic water providing catchment areas that also conserve the country’s rich biodiversity are faced with an escalating threat posed by alien plant invasions. Restoration interventions, through direct removal of alien trees, increase water flows, improve groundwater infiltration and water quality, and reduce disaster risk. Much restoration work has therefore occurred in riparian zones, where there has been the overriding assumption of post-clearing passive recovery of the system (i.e. self-repair). Positive biodiversity outcomes are assumed, but not always evident. Frameworks for restoration of these dynamic and linearly connected systems require an understanding of biogeographical processes at different spatial scales and the relationship between the...
invasion process (and species), resilience, and ecosystem function. Due to legacy effects, management interventions themselves may influence restoration outcomes, and where biotic or abiotic thresholds have been passed, interventions may require also require active restoration. We present an overview and synthesis of recent research in this regard.

Unconscious evolution on a native seed farm reduces the fitness of restoration material

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The high demand for native restoration seed has led to an increasing dependence upon commercially grown sources rather than wild populations. Although this shift away from wild-collected seed may protect natural population demographics, it may have unforeseen consequences at the restoration site. During native seed farm propagation, populations are subject to sampling effects as well as unconscious artificial selection. Both processes can constrict genetic diversity and change the type of genetic variation present in the populations resulting in phenotypes that may contrast sharply with those found in wild populations. Here we test this possibility by comparing Clarkia pulchella plants grown from seed collected from the original wild populations that established plant beds at Native Ideals Farm (Arlee, MT, USA) to plants grown from seed harvested after eight generations of commercial propagation. Plants were also subjected to a watering treatment to determine whether wild and farmed plants differed with respect to stress response. Compared to plants that had been cultivated on a native seed farm for eight generations, wild plants were 4.5x more likely to flower, flowered for five days longer, had larger floral display sizes, bigger flowers, and greater fruit production. Moreover, for many traits, wild plants were less severely impacted by drought. Overall, the relative fitness of the wild plants was more than twice as high as farmed plants in either watering treatment. These results strongly suggest that unconscious selection on native seed farms can undermine restoration success. This seminar will conclude with suggestions to avoid such inadvertent evolution.

Integrated Catchment Management in Lesotho

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Water is Lesotho’s most important natural resource. Due to its unique geographic location, Lesotho is considered the ‘Water Tower’ of southern Africa. Its contribution to the Orange-Senqu basin’s annual run-off is 40% with only 3% of the basin area. A third of the water supply to Gauteng Province – South Africa’s economic centre and home to 12 million people – comes from Lesotho. Additional water transfers, e.g. to Botswana, are under development. However, Lesotho is facing alarming levels of catchment degradation. Erosion leads to an annual topsoil loss of 2%. About 66% of households live on degraded land, as poverty and population growth force people into previously uninhabited areas like wetlands and mountain slopes. Overgrazing, encroachment of sloping rangelands, firewood harvesting, conventional farming and insufficient law enforcement threaten natural assets. Climate change presents an aggravating factor by increasing rainfall variability and extreme climate events. Prior conservation efforts have shown promising results but could not be taken to scale. The root cause is regarded to be inadequate governance of natural resources, including absence or insufficient enforcement of laws and policies, lack of coordination between ministries and poor capacitation of local authorities. The Government of Lesotho is now developing an ambitious multi-stakeholder partnership for integrated catchment management. It aims to bring rehabilitation efforts to national scale through a multi-level approach that includes policy harmonization, strengthening of institutions, capacity building for land and water users, implementation of local watershed development measures, and a natural resource monitoring system.
Spatial prioritisation of invasive alien plants clearing on La Réunion Island

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The largest area of intact vegetation in the Mascarene archipelago is found on La Réunion Island. However, biological invasions are one of the main threats to the biodiversity on this island and globally worldwide. This study aims to spatialize, coordinate, and prioritize conservation issues and invasive alien plants clearing on the island. For this, our approach involved three steps based on existing data and expert knowledge. First, thanks to collective work between researchers and managers, we combined existing data on natural environments, endemic species, and invasive alien plants species. These data allowed us to identify the spatial distribution of biodiversity and threats and to realize the first map of invasion level at the island scale. Secondly, we used a spatial prioritization software, Zonation, for identifying different scenarios of conservation issues. These conservation issues were selected to maximize biodiversity representativeness in lightly invaded areas. Finally, the conservation issues and some operational criteria were used to prioritize clearing of alien plants. Almost 40% of the remaining natural habitats on La Réunion Island are moderately to heavily invaded. We identify 58,500 ha as conservation priorities areas of which 30% are considered as non-invaded. We will discuss how this will influence future alien plant clearing programs at La Réunion.

Mapping the rewilding potential

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The escalating and widespread impacts of human activities on biodiversity urges for the adoption of more ambitious approaches for large-scale biodiversity protection and restoration. Rewilding is emerging in recent years as one such approach that pursues the recovery of self-sustained ecosystems while tapping into opportunities for reconciling nature restoration in socio-ecological systems. Rewilding focuses on the recovery of trophic interactions, natural disturbance dynamics, and dispersal processes as three key ecological axes determining the integrity and resilience of ecosystems. Building on this process-oriented definition, we will present a novel assessment of the ecological integrity of European landscapes and analyse opportunities for rewilding while reconnecting landscapes with high biodiversity value. We mapped biodiversity degradation and the degree of human control on ecosystem processes across Europe by combining indicators of trophic downgrading, landscape fragmentation, and the human dominance on ecosystems. The results were used to identify possible configurations of connected networks of priority areas for rewilding. Building on predictive species expansion models, land use projections, and optimisation analyses, our assessment aims to support green and blue infrastructure goals through identifying the opportunities and limitations for advancing in each of the three axes of rewilding. Furthermore, the framework presented here can accommodate conservation objectives at multiple spatial scales and across different socio-ecological contexts.

Ecological restoration 30 years later: Which priorities should we focus on?

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Since 1987 ecological restoration (ER) has evolved from a technical discipline to a trans-epistemic one in terms of its socio-cognitive organization. It became a transversal space for knowledge production and degradation solution. Multiple approaches and research/management subjects coexist under a common umbrella that harbors scientists, practitioners, and, especially, stakeholders directly linked to decision making. Colleagues from government agencies, NGOs, private companies, or international banks are also regular members of the restoration community. Although science and technology are still the core of the discipline, current major challenges are (1) to integrate political, cultural, and economic interests; (2) meet local, regional, and global targets of ER, and (3) prevent new degradation processes. Such challenges require strong social agreements to solve key issues (e.g. land planning and tenure). In order to investigate which questions should be addressed from now on, we did a critical review of the literature, national plans, and international policies. In particular, we tested whether the major conclusions and recommendations from SIACRE-2015 (4th conference of the Latin American and the Caribbean Society) could be applied worldwide. We established 63 statements pooled into nine thematic subjects: epistemological, degradation causes, principles, land use planning, governance, social-cultural, scientific, technological, and standards. We also found that efforts and approaches are related to cultural values and welfare conditions. In conclusion, restorationists should devote efforts to other priorities: “how well was this hectare restored” or the nice “before-and-after picture” of a rehabilitated site, are no longer enough.

Environmental recovery as a possibility for coping with social vulnerability in the Doce River Basin, Brazil

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After the 2015 Fundão mining tailings dam collapse in the Mariana municipality, the environmental and social problems generated in the Doce River Basin gained international visibility. This event required a complex scientific and institutional arrangement to build strategies to minimise the impacts caused by the disaster and decades of environmental degradation in the Basin. In this process, besides the physical and environmental variables, the Social Vulnerability Index (SVI) was used as an indicator in the study of prioritisation of areas for forest restoration. The SVI makes it possible to analyse the resilience of communities that have experienced crises caused by disasters or extreme weather events. The IVS delineated for the Doce River Basin involves 4 analytical groups: 1 - Infrastructure, 2 - Human Capital, 3 - Income and Labor and 4 - Agricultural Production, considering the particularities of the hydrographic basin. Groups 1, 2 and 3 had the same weight in the composition of the SVI and Group 4 was used with a vulnerability reducer considering the potential of agricultural activities in changing the socio-economic conditions of the communities. Official data from 7,063 census tracts were used in 228 municipalities. The results show sectors with very high SVI, evidencing, however, that the majority of municipalities have a medium vulnerability. Rural sectors have the greater social vulnerability, reflecting the specific characteristics of the Doce River Basin where decades of environmental degradation make agricultural activities fragile in terms of job generation, income, and food security.

What are the challenges for tropical grassland and savanna restoration using fire?

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Tropical grasslands and savannas are ecosystems that are resilient to disturbances and thus, exclusion of disturbances can lead to drastic changes in vegetation structure, composition, and dynamics. In areas excluded from fire for several years, one can find a decrease in plant species and at the same time, changes in belowground biomass and bud bank dynamics. Moreover, biological invasions are changing vegetation dynamics and affecting fire regimes, leading to states that are difficult to reverse. Although fire could be used in restoration, the presence of invasive species and long-term fire exclusion may be some of the challenges to overcome during the restoration process. Invasive species (C4 tropical grasses) increase the amount of fuel load, leading to more severe fires, thus hampering the use of fire as a restoration tool to assist native vegetation regeneration. The presence of invasive grasses homogenizes the local plant community and the soil seed bank. Long-term fire exclusion also leads to a higher accumulation of fuel load, and at the same time, a decrease in local plant species, both above and belowground, where they are represented by the local bud bank. A decrease in belowground reserve organ diversity is observed and is detrimental for vegetation regeneration after fire. Therefore, the use of fire in areas where invasive species are present and where fire was excluded for long periods would be a challenge for local managers. Thus, understanding invasive grasses’ responses to fire and the bud bank dynamics in target areas is crucial to establish good management policies.

Applying machine learning in the mapping of land use and land cover in focusing priority areas for environmental recovery of the River Doce Basin

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The mapping of land use and cover (LULC) is a tool of great importance for planning actions for environmental planning and restoration. In the present study, the LULC was applied in the Doce River Basin (83,400 km²) aiming to provide subsidies to the prioritisation modelling of areas for reforestation in 45,000 hectares, as one of the environmental compensations for the environmental disaster of Mariana, caused by Rupture of an iron mining tailings dam. For this purpose, scenes from satellite Landsat 8, sensor OLI were selected. The predictive variables were the spectral bands together as vegetation indices, climatic data, and a digital elevation model. Samples were collected for training and validation of the model, and the Random forest algorithm was used to classify the LULC. All the processing was done in the software R. The mapping reached an accuracy of 0.91 measured by the Kappa concordance index. The grasslands areas occupy 52.5%, forest areas 29.9%, areas with monodominance of Myracrodruon urundeuva occupy 5.5% of the entire territory. Planted forests and coffee growing areas occupy 8.8%, the non-vegetated spaces represent 3.85%. Most areas with soil degradation have a direct link with livestock and the monodominance of Myracrodruon urundeuva. The results obtained were used in some stages of the modelling of priority areas for reforestation.

Pine savanna plant community patterns after fifteen years of biennial fires in different seasons

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Fire regimes that deviate from inferred historical norms are a management concern in biodiverse, fire-prone regions. Plant communities are considered to have been historically filtered by a specific fire regime, generating a community of species with life history traits linked to that regime. If the filter (i.e., fire regime) is changed, specialized or endemic species would presumably be lost, and/or species that are not harmed by this alternate fire regime would become more frequent. Our objective was to test this assumption in southeastern USA pine savannas, a biodiversity hotspot of North America. We compared
groundcover plant community composition in wet-mesic and dry pine savannas in north Florida before and after fifteen years of biennial prescribed fires in different seasons. We classified fire seasonality as: (1) phenological (occurring in the dormant or growing season), and (2) wet/dry (occurring during the early dry, mid-dry, late dry, or wet season). Based on species frequencies, fire season did not change community composition in dry or wet-mesic pine savannas, regardless of season classification. Species composition only changed significantly over the 15 years in the dry pine savanna. Our results suggest a degree of resilience in these communities to different fire seasons (at high fire frequency) over at least two decades.

**Associations between hydrology, tree growth characteristics, and regeneration in a temperate swamp forest**

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Riparian forests are structured and maintained by their hydrology, and woody perennials ensure their longevity in these dynamic habitats by adjusting allocations to growth, survival, and reproduction in response to the disturbance regime. However, growth and regeneration responses of woody vegetation to water dynamics are complex and require further investigation to inform restoration planning and counter global wetland forest degradation. To yield insights into the regeneration ecology of three riparian keystone species, 298 individuals of Eucalyptus camphora, Melaleuca squarrosa and Leptospermum lanigerum were surveyed randomly across a flooding gradient in an area of 1.7 km² within the Yellingbo Nature Conservation Reserve, Australia. Characteristics of growth shape (DBH, height, number of stems, inclination), and evidence of vegetative (epicormic growth) and sexual reproduction (buds, flowers, cones) were recorded. A hydrological model built in TUFLOW enabled identification of local flooding history for each tree and examination of the impact of flooding regime on tree architecture, condition, and reproduction (mode and intensity). Extended periods of inundation compromise plant growth and result in individuals with a higher tendency to multi-stemmed growth and stem-leaning, while dryer locations favour taller individuals and single-stemmed growth. In general, trees experiencing frequent inundation displayed increased resprouting, whereas indicators of sexual reproduction were more even across the hydrologic gradient. These findings highlight the central role of the hydrologic regime in determining tree growth architecture and, therefore, the shaping of wetland forest structure. Hence, restoring and maintaining appropriate flooding regimes is imperative to sustaining ecosystem integrity and functions, such as habitat provisioning.

**Monitoring outcomes: Transitioning from local restoration projects to regional restoration of pattern and process**

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Transitioning to appropriate restoration styles (e.g., command and control to adaptive management) under conditions of decreasing controllability and/or increasing uncertainty is a key challenge for sustaining ecosystem services in a changing world. Understanding when to transition to a new restoration style requires knowledge of management outcomes and the scale(s) at which undesirable environmental changes are occurring. Our objective was to develop a framework for: (1) monitoring restoration outcomes, and (2) providing recommendations for restoration styles based on levels of controllability and uncertainty associated with the scale(s) of undesirable environmental change. We apply this framework to tree invasion management programs in grassland landscapes of Nebraska, USA, where tree invasion is managed using a command and control restoration style. We used remotely-sensed tree cover data (Rangeland Analysis Platform) to model tree cover trends from 2000-2017 (restoration outcomes) at multiple, nested scales for 21 landscapes. These results provided a systematic basis for identifying an appropriate
restoration style based on the level of controllability and uncertainty associated with the scale(s) of invasion. Tree invasion outpaced restoration in 17 of 21 landscapes and was associated with low controllability and high uncertainty in all landscapes. Command and control styles emphasized pattern restoration using tree removal projects, but largely ignored preventative processes. Given the scale-specific challenges of pattern and process restoration, our framework identified scenario planning as the most appropriate restoration style for all landscapes. Our framework provides a systematic basis for understanding when to transition between restoration styles and has potential to improve broad-scale restoration outcomes.

Using dispersal and germination life traits of native vegetation to promote ecological restoration in southern New Caledonia

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New Caledonia is considered to be one of the main "hotspots" of biological conservation. Its exceptional level of endemism is increasingly threatened by the expansion of human activities. One of the most important threats is habitat fragmentation due in part to fires and mine exploration on ultramafic massifs that erodes habitat quality. Natural environments affected must be restored to maintain the ecosystem services they provide. Over the past 40 years, revegetation techniques have aimed to reduce the impacts of erosion. However ecological restoration has only been pioneered in the past 15 years. Present research compliments previous studies and aims to (1) characterize dispersal and germination of plant species found in early successional maquis and forest mosaics on the Goro plateau in southern New Caledonia, (2) evaluate the trajectory of mine revegetation plantations based on the life traits of the species used from surrounding vegetation. A database was constructed and presents data dealing with 41 life-traits of 407 taxa found in the vegetation mosaic. In addition, an assessment restoration progress using the five-star recovery system developed by SER was conducted from surveys and measurements of both planted and colonizing vegetation. Finally, inventories of surrounding natural vegetation provided details of their structure and composition that highlight the ecological succession and permitted establishment of a local indigenous reference ecosystem. Recommendations based on results were provided to managers to assist in implementing ecological continuities projects including a list of candidate species to prioritize in future restoration programs.

Shifting baselines in the restoration ecology of Renosterveld

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Ecological baselines are important in informing restoration targets. Baselines can shift, however, depending on the timescale of observation. Using observations from the past few years or decades can give a misleading impression of the historical range of variability, and the extent of recent human transformation. Palaeoecological techniques can track interacting effects of climate change and land-use on vegetation composition and fire regimes over decadal–millennial timescales, thereby informing ecologically possible conservation management options and restoration targets. In the Cape Floristic Region, South Africa, European settlement and subsequent land transformation led to dramatic changes in land-cover. Ninety-six percent of Renosterveld, a highly diverse indigenous shrubland, has been transformed. Thus, appropriate management of remaining fragments is critical to biodiversity conservation. However, we know little of the Renosterveld landscapes before the mid-17th century. This study used fossil pollen, coprophilous fungal spores and charcoal to track vegetation, herbivory and fire at centennial timescales in one
of the few remaining Renosterveld fragments. Results showed that the current landscape is atypical compared with the long-term history of the site, with higher abundance of Renosterbos (Elytropappus rhinocerotis), local fires, and herbivory that reflect intensive utilisation beginning in the mid-20th century. To accommodate uncertainties in future environmental change, we recommend an adaptive management approach, which incorporates palaeoecological analyses, burning and grazing experiments, and long-term monitoring. Managing the integrity of Renosterveld at this site according to a pre-colonial baseline requires lower levels of herbivory and fire.

**Scaling up - practical challenges and solutions**

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The scaling up of ecological restoration is essential if we are to arrest the continued degradation of our ecosystems and rebuild critical corridors. We know increased funding and efforts are required in all aspects of ecological restoration including planning, implementation, monitoring, and innovation, but how do we scale up using current best practice standards? Moreover, how can we ensure good standards are applied to maximise our efforts and truly demonstrate what is possible, ecologically and economically? This presentation focuses on two larger-scale projects and illustrates some of the challenges and successes with scaling up. The first project demonstrates how a number of restoration approaches were applied to maximise the recovery of vegetation to support koalas and other local and migratory fauna across 205 hectares of a 969-hectare site. The second project required the development of a practical ecological restoration plan that balances the rehabilitation and possible relocation of threatened fauna, nature-based recreation, agriculture, fire, and other competing priorities across 4,800 hectares. A key challenge was developing a plan that follows current best practice restoration, is easily understood by a range of stakeholders, has a long shelf life, and contains sufficient detail to guide on ground works. While restoration works have commenced, numerous challenges remain for this site and the broader 750 square kilometre corridor. Some of the solutions explored in this presentation include good planning backed by sound science, training, and the utilisation of a multi-disciplinary workforce of scientists, farmers, landholders, land managers, and experienced practitioners.

**Sleeping threats to biodiversity conservation: Extinction debt in global plant communities**

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The ability to identify ecosystems suffering delayed impacts of human activity poses a significant challenge for biodiversity conservation. Extinction debt measures the time lag of species losses in ecosystems and as such can be used to predict the magnitude and timing of future species losses without management intervention. There is an urgent need to quantify the extent and magnitude of extinction debt given we are in the midst of the sixth global extinction event. Here, we review and quantify evidence of extinction debt in the literature on plant communities, applying a formal meta-analysis of species-area relationships and extinction debt magnitude estimates. Comparing current richness with past and present habitat characteristics was found to be the most common method, but inadequate to identify species and species groups suffering extinction debt. With extinction debt detectable between 10- and 110-years following habitat fragmentation for communities with short to moderate species longevities, there is an expectation that long-lived communities have longer time lags. Our review revealed a large knowledge gap for long-lived communities and subsequently, we tested for extinction debt in a rapidly urbanising woodland system from south-west Western Australia. To test for extinction debt, we used re-measurement of plots spanning 1991–2016. For the effective management
of ecosystems into the future, we discuss how a predictive restoration approach could be used to prevent future extinctions.

**Options for the remediation of fine-grained, organic-rich sediments in a subtropical estuary**

**Austin Fox**  
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Benthic fluxes of nitrogen (N) and phosphorus (P) from fine-grained, organic-rich sediments contribute 30 to >40% of the annual inputs of N and P to the central and northern Indian River Lagoon (IRL), an estuary along the east coast of Florida, USA. As part of multifaceted remediation efforts, this internal source of N and P must be decreased. At present, dredging is the only generally practiced method for muck remediation in the IRL. We investigated aeration and subaqueous sand capping as potential complements or substitutes for environmental dredging. These other techniques may be useful, especially in harbors and canals where dredging is limited by proximity to docks and seawalls. Results from aeration showed 50% lower benthic fluxes of N and P in an aerated canal relative to a control canal, when atmospheric oxygen was effectively delivered to the sediments. Subaqueous sand capping helped to consolidate sediments, decrease benthic fluxes of N and P and raise the bottom to depths within the photic zone.

**TEK, natural resources, and adaptive management**

**Kansie Fox**  
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Blackfoot methods of preserving and transferring traditional ecological knowledge through stories, songs, and ceremonies are continually practiced and relationships with the land are being renewed. But with historical changes in policy and increasing threats from climate change, invasive species, and resource development, these relationships are changing at a rapid pace. Kainai has recognized the need to prioritize building grassland ecosystem resilience in order to adapt to these changes. Blood Tribe Land Management (BTLM) and the Kainai Ecosystem Protection Association (KEPA) are utilizing Blackfoot traditional ecological knowledge, or Blackfoot science, to restore important relationships with the grassland ecosystem. Preserving and continuing to use Blackfoot plant knowledge is vital to the health of Kainai members and in maintaining connection with the land. In addition, plant knowledge offers opportunities to observe the land to predict and monitor climate change effects, preserve knowledge that could contribute to economic diversification, and collect information (such as plant vulnerabilities) that could positively impact physical wellness and food security in the context of a changing environment. A participatory approach is being taken that involves co-designing the processes for data collection, training, and data storage. This included working with Elders and Kainai members in methods of plant science and database management to produce a Tribal-owned plant database. An integral part of grassland restoration is the reintroduction of linnii, or Buffalo, a cultural and ecological keystone species and a vast source of traditional ecological knowledge. Linnii brought about knowledge of the landscape, behavior of animals, and seasonal rounds.

**Restoring ecosystem services provided by ant communities in a savannah-like ecosystem**

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Ants have a key role in drylands, where they provide important ecosystem services such as seed dispersal. However, human activities may change the equilibrium in ant communities towards the increase of invasive species and may disrupt important ecosystem services mediated by ants. This is particularly relevant where livestock is overgrazing and there is an increase in aridity, such as in Mediterranean drylands, which are savanna-like ecosystems. In a dry-subhumid ecosystem, we measured ant responses to passive restoration, selecting sites with 18, 12 and 8 years of grazing exclusion and a grazed control. We assessed ant recovery through passive restoration using a taxonomic and functional approach. Then, we compared the interactions between ant communities and four myrmecochorous seeds, in a taxonomically and functionally diverse ant community and one characterized by the dominance of an invasive ant species. Ant functional and taxonomic diversity responded to years of passive restoration; however, ant recovery seemed to be particularly difficult with the occurrence of an invasive ant species. We observed a drop in ant-seed interaction, thus in seed dispersal, in the site dominated by an invasive ant species. These results shed light on the response of ant diversity to passive restoration and on seed dispersal mediated by ants in drylands.

Natural regeneration as restoration strategy to restore functional soils and ecosystems in post-mining sites

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Unreclaimed post-mining sites were reported as hotspots of biodiversity, but less is known about other ecosystem functions of these sites. Here we compare the effect of unreclaimed sites and reclaimed sites planted with alder on provisioning ecosystem services in Sokolov (Czech Republic). In suitable substrates, succession is driven mainly by site topography. In sites that were leveled, grassy vegetation develops. In sites where original wave-like topography was preserved, the ecosystem develops towards shrubs and forest. Reclaimed and unreclaimed forest sites have similar development of canopy cover. Stem numbers gradually decreased with age in reclaimed sites and increased in successional sites, with both reaching the same density after 20 years. Tree biomass was higher in young reclaimed sites. On sites 30-years old or older, tree biomass in successional sites was comparable or higher than in reclaimed sites. The initial rate of soil carbon storage in reclaimed sites, was faster than in successional sites but decreased over time. In unreclaimed sites, the rate of C storage increased and peaked in 20-30 years. The amount of C stored in unreclaimed sites c 50 years old is comparable to alder plantations of the same age. Alder plantations of intermediate age store more water than unreclaimed sites, but the water budget is similar due to the higher water demand of alder. In leveled sites where grassland establishes, reclaimed sites are slightly higher in all studied parameters. In conclusion, development of key ecosystem processes is faster in reclaimed sites but latter on differences disappear.

Understanding changes in biological soil crust’s bacterial communities in rehabilitated sites of phosphate mines in the Negev Desert

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In the Negev Desert, phosphate mining has been practiced for over 60 years, destroying local habitats and fragmenting the landscape. Since the biological soil crust (BSC) layer is a pivotal contributor to desert ecosystem function, it is imperative to evaluate its health following severe disturbances. We have monitored BSCs in four phosphate mining sites and investigated the bacterial communities over spatial (between rehabilitated and undisturbed plots) and temporal (various restoration years between 2007-2015) scales. We hypothesized that BSC communities vary in community attributes on both scales, according to a successional sequence. Forty-eight compositied BSC samples were collected.
and their physicochemical properties and bacterial community composition evaluated using qPCR and deep sequencing of the 16S rDNA. Our results suggest that bacterial total abundance, richness, and diversity in undisturbed plots are significantly higher than in rehabilitated plots across all sampling sites, regardless of their time of restoration. Community composition also varies between undisturbed and rehabilitated plots; whereas the dominant phyla in undisturbed BSC are Cyanobacteria and Chloroflexi, rehabilitated plots are dominated by Actinobacteria and Proteobacteria. We also found a consistent pattern of significantly higher total and relative abundances of Cyanobacteria in undisturbed plots. Along the temporal gradient, we found no significant differences in richness, diversity, or community composition; BSC communities differ significantly from undisturbed areas even 12 years following restoration. These results indicate that BSC communities are altered following the mining disturbance and have slow recovery times with possible ramifications to entire ecosystem health and a need for active BSC restoration measures.

Co-restoring seagrass and bivalves to increase restoration success: Challenges and implementation
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Seagrass meadows and bivalve reefs, along with other coastal ecosystems, are disappearing around the world. Once degraded, these habitats have difficulty recovering on their own without restoration actions. However, restoration success rates have been low in the marine realm, and new strategies are needed to increase success and ensure the survival of these valuable habitats. In a global literature review and analysis of more than 450 studies, we identified the potential for harnessing facilitative plant-bivalve interactions to increase restoration success in marine habitats. Here, we experimentally investigated how to implement interactions between eelgrass (Zostera marina) and blue mussels (Mytilus edulis) in restoration projects across northern Europe. Eelgrass should protect mussels from physical disturbance and predators, while mussels should facilitate eelgrass growth by providing nutrients and filtering water. In aquarium pilot experiments, we found that mussels did indeed fertilise eelgrass and increase growth. We then tested different co-restoration methods in the field. Our first attempts in 2017 involved adding mussels to restoration plots, but these mostly failed because of either mussel loss due to hydrodynamics or seagrass loss due to eutrophication and filamentous algae. In 2018, we added biodegradable structures to create substrate for mussel anchorage, then planted eelgrass in the middle. Early results indicate this method was much more effective in retaining mussels (and attracting new mussel recruits), and that mussels increased eelgrass survival and growth. Further sampling will determine if co-restoration ensures the long-term persistence of plots and facilitates higher associated biodiversity and ecosystem services.

Lessons for improving rural livelihoods through sustainable land management in Macubeni communal land: A landscape littered with skeletons of failed development projects
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Land degradation is a major environmental problem threatening the livelihoods of more than 3.2 billion people globally. Sustainable land management and restoration programs are key strategies for combating land degradation. We review two failed projects implemented in Macubeni in order to draw lessons for future action. The first focused on improving rural livelihoods by applying rotational grazing management practices to reduce overgrazing. Rangeland experts developed grazing management plans that were implemented in 2003. Local farmers were passive participants in the planning and implementation of the grazing management project. By 2010 the grazing management project had collapsed. Most of the fencing was stolen or vandalized. Rotational grazing management ceased when the project ended. Remnant infrastructure such as water tanks and broken water pipes are stark reminders of the failed project. The second project, implemented from 2005 to 2009, focused on clearing the invasive shrub, Euryops floribundus, to improve biodiversity. By 2014 the cover of the invasive species had increased by between 9 and 28% in previously cleared areas, compared to 46-55% in non-cleared areas. Lessons for the design of sustainable land management projects that improve rural livelihoods include: adopting a social-ecological conceptual framework, using a resilience dashboard to assess the implementation of the seven principles of resilience, and implementing participatory approaches where farmers are involved in all the stages of project development (i.e., planning, data collection and analysis, monitoring, and evaluation). We present the concept of participatory hubs as a means of implementing the social-ecological framework to promote sustainable livelihoods.

When restoration contradicts the traditional land use

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The peatlands of Mongolia used to cover 2% of the country and are rapidly vanishing. Peatlands provide unique ecosystem services. Peatlands protect permafrost – the largest current water storage in the country -- from thawing. They store water and carbon and provide habitats for wetland species and productive pastures. The latest assessment (2017) evidenced that peatlands were reduced by 50% during the last 50 years. The carbon emission caused by peatland degradation in Mongolia is estimated at up to 45 million tons per year, which makes Mongolia the seventh largest global emitter of CO2 from degrading peatlands. Mongolia considers including peatland restoration in the NDCs. That demands good pilots which could show the positive effect of restoration. The experiment on mire restoration in Khashat began in 2017 and involved fencing springs, construction of small dams on the flows – natural and originating from cattle paths, and reparation and fencing of the large dam in order to create an alternative source of water for cattle. Restoration is followed by monitoring. In the first years the restoration measures were opposed by a large part of the local community. Traditional land use does not recognise fencing and includes free unlimited grazing, using springs as water sources. The dramatic increase of cattle makes it impossible to maintain this approach. Peatland restoration benefits are not clear for local communities and costs include serious limitations in cattle density and access to water sources. The clear cost benefit analysis is needed to move ahead with ecological restoration projects.

Intraspecific trait variation of species commonly used in southwestern United States aridland restoration at early developmental stages

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In recent decades, quantitative trait-based models have been used to predict how plant communities develop under variable environmental conditions. Trait values obtained from
mature plants are typically used to inform such models. These values may not be appropriate for understanding the development of restored communities for two reasons: (1) trait values from different populations of a species may vary, and (2) trait values of mature plants may not reflect seedling traits important for establishment and survival. We measured traits (e.g., specific leaf area, leaf dry matter content, root length) of grass and forb species commonly used in arid land restoration from several populations at different developmental stages. We used Bayesian point estimates of population trait means and variability at each ontogenetic stage and compared them to one another as well as to trait values from the TRY Plant Trait Database or values published in the literature. We found that mean trait values as well as population-level trait variability differed by population, trait measured, and ontogenetic stage for all species. In some cases, differences in trait values at specific ontogenetic stages resulted in unique ordering of populations within a species and often trait values of young seedlings differed greatly from those reported in the TRY Plant Trait Database or the literature. Because traits expressed during early stages of plant growth are critical to plant establishment, a better understanding of variation in seedling traits will inform seed source selection for restoration and improve the use of trait-based models for predicting re-vegetation outcomes.

Beneficial heterotrophs enhance the effectiveness of cyanobacteria-based biocrust restoration in drylands

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Biological soil crusts (biocrusts) are communities of microbes that inhabit the surface of arid soils and provide essential services to dryland ecosystems. While resistant to extreme environmental conditions, biocrusts are susceptible to anthropogenic disturbances that can deprive ecosystems of these valuable services for decades. Until recently, culture-based efforts to produce inoculum for cyanobacterial biocrust restoration in the Southwestern US focused on the most abundant primary producers and biocrust pioneers, Microcoleus vaginatus and M. steestrupii. The discovery that a unique microbial community characterized by diazotrophs and phosphate-solubilizing bacteria is intimately associated with M. vaginatus, known as the “cyanosphere”, suggests a symbiotic division of labor in which nutrients are traded between phototrophs and heterotrophs. To explore the role and potential of the cyanosphere community for development of biocrust, we performed targeted isolation of cyanosphere inhabitants and used co-cultivation with M. vaginatus under nutrient poor conditions to test for interactions. We found that M. vaginatus grew well when co-cultured with bacteria characteristic of the cyanosphere, while growing poorly or not at all when cultured alone or with non-cyanosphere bacteria. Additionally, co-inoculation of soil substrates with cyanosphere constituents resulted in more rapid development of cyanobacterial biocrusts over inoculation with the cyanobacterium alone. Our findings highlight the hitherto unknown role of beneficial heterotrophic bacteria in the establishment and growth of biocrusts. Future biocrust inoculum production should consider cyanobacteria and their beneficial community to be the true pioneers. Therefore, their inclusion is instrumental for rapid establishment of incipient biocrust, thus rapidly restoring ecosystem services.

Territorial production planning in the Amazonia: The role of ecological restoration in reducing deforestation

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The Department of Caquetá is located in the north-western zone of the Amazon region and is considered the region where the greatest amount of deforestation of tropical forest in Colombia is concentrated. Between 2002 and 2016, close to 429,000 hectares of tropical forest were deforested and to date 2,877,634 hectares are replaced with agricultural
production systems that represent 32% of the total area of the Department. One of the main challenges of the country and of regional development is to reverse the development model based on semi-extensive livestock systems characterized by a loss of biodiversity resources, ecosystem services, land degradation, and concentration of land tenure. This paper presents the main results of a research program aimed at developing ecological restoration protocols consisting of 21 models of restoration practices and the implementation of a pilot area of 1,100 hectares restored by 250 peasant families. Likewise, it is demonstrated how, based on the results obtained, the Department of Caquetá advances the processes of productive and environmental management of the territory, integrating the productive and functional restoration of the landscape as a central strategy to avoid deforestation and propose productive alternatives with low emissions articulated to the environmental potential, as well as the main limitations encountered, and the challenges that are faced to transition to alternative productive models.

**Long-term evidence of wetland change: Accommodating variability in setting restoration options**

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Long term records of wetland change reveal considerable variation in response to climate variability, anthropogenic catchment change, and the natural evolutionary pathways of aquatic systems. For wetland restoration this suggests that there is no single identifiable condition that may represent a target for management actions. Almost fifty years ago nations signed the Ramsar Convention for the protection of the world's most significant wetlands in response to the recognition of the widespread loss and degradation of critical habitat, particularly for birds and fish. Under the Convention, governments are required to identify the natural ecological character of their nominated wetlands. In most instances this condition was that described at the time of listing. More recently the Convention is seeking signatory parties to identify the limits of acceptable change to their listed wetlands. There are many listed wetlands across Australia’s Murray-Darling Basin and the nominated natural character of many is in contrast to that revealed by paleoecological records of their past state. This longer-term view could broaden options for management and allow the drivers of change to be better identified and mitigated and so allow restoration measures to be better targeted into the future.

**Restoring resistance and resilience in droughty ecosystems: Landscape-scale evidence for the benefit of adaptive management**

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Altered disturbance regimes such as increased wildfire are transforming semiarid ecosystems globally and are motivating greater management responses, such as restoration. In the western United States, post-fire restoration efforts, such as seeding and herbicide spraying, have been applied to millions of hectares and comprise one of the largest conservation investments worldwide. However, long-term success of restoration efforts across regions such as the Great Basin has been mixed, particularly in relatively warmer and drier sites that are considered to have low resistance to invaders and low resilience to disturbance and also where droughts are more frequent. Whether an adaptive-management approach that allows for multiple or iterative treatment interventions over longer time frames can lead to greater success in restoring resistance and resilience is a major question. We addressed this using data from 113,000 hectares of cold-desert shrub-steppe on the 2015 Soda Wildfire site, for which the management response became the first adaptive post-fire management effort in the USA. Published and preliminary results from observing traditional “one-off” compared to multiple-intervention restoration efforts reveal substantial benefits to the primary restoration objectives of reducing exotic plant species and restoring key perennial plant species. Although the treatment and monitoring
efforts for the Soda fire are ongoing, there is a clear indication that the unique approach implemented in this postfire response has resulted in a system of learning that has built manager-stakeholder trust, capitalized on the intrinsic flexibility of the adaptive management approach, and one that will serve as a prototype for management responses in the future.

**Restoration for resilience**

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Landscapes change over time in response to multiple interacting drivers, including climate, disturbance, and land-use, which all leave a lasting legacy on ecosystem structure and function. In this review I explore the utilisation of long-term data in restoration ecology, under two main themes:

1) Our perceptions of landscape change are influenced by the timescales of observation. The same change in vegetation cover may elicit different restoration responses, depending on the history of the landscape. Therefore, long-term data is essential to contextualise recent changes and plan appropriate restoration responses.

2) As the dynamic nature of ecosystems is increasingly recognised, there is an accompanying paradigm shift in the ecological restoration community to move from strategies that promote restoration to a prior condition to restoration of process and function. Furthermore, restoring a former ecosystem state may not always be possible or desirable as we approach no analogue conditions, where some ecosystems are showing evidence of new stable states outside of the historic range of variability. Rather than recreating prior reference conditions, in these cases, restoration may focus on restoring ecological processes that support resilience, specifically resistance, recovery, and re-organisation. Long-term data can assist in understanding these processes that form a sound basis for the restoration of resilience. For these reasons, there is a natural synergy between restoration ecology, long-term ecology and palaeoecology that warrants further exploration and the development of new collaborations.

**Development and application of microbial inoculum for biological soil crust restoration in drylands**

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Biological soil crusts (biocrusts) play important roles in improving soil fertility and promoting erosion resistance of arid lands. A variety of human disturbances such as vehicle and foot traffic can quickly damage biocrust communities and natural recovery can take decades. Attempting to enhance recovery rates, we developed a “biocrust microbial nursery” to supply inoculum for restoration. Four locations from different climatic and edaphic origins from the southwestern US were selected as restoration sites, and two restoration strategies were pursued: whole-community and mixed-isolate approaches. Regardless of the approach, our studies indicate that working towards obtaining optimal inoculum is a complex endeavor. We will review these two methods as well as recent advances in strategies for biocrust restoration. Advances include inoculum conditioning to increase biomass viability in the field, seasonality of seeding, inoculum recycling, the development of a unified approach to growing field-acclimated mixed-community and mixed isolate inoculum on native substrates, water delivery approaches, and landscape-scale production of inoculum by operating a “mobile microbial nursery”. This nursery operates as a self-sufficient field research station and can be transported to different sites,
allowing the production of quality-controlled, pedigreed, drought-acclimated and in situ acclimated inoculum of both whole community and cultured isolates.

How to monitor species and population recovery as part of ecological restoration programmes?

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Meise Botanic Garden, Meise, Belgium

Monitoring plays an important role in the conservation and recovery process. Yet many monitoring programmes do not have a sound ecological basis, are poorly designed and do not lead to appropriate management interventions or responses and are disconnected from decision making. Monitoring is often given low priority because it can be difficult and expensive to implement, and monitoring programmes are often inadequately funded and implemented. Monitoring is an opportunity to measure the success of a project’s recovery actions and provides evidence for management decisions. The abiotic conditions necessary for a species can vary greatly during plant development, the adult niche being often wider than the recruitment niche, therefore the population might persist as adults under particular conditions but without any establishment of new recruits. This highlights the importance of performing an integrated analysis, combining the ecological, demographic, and genetic monitoring results. Demographic monitoring will assess changes in population size, dynamics and fitness. It may require frequent measurements or mapping to achieve the level of resolution necessary for an unbiased interpretation of the results. Sufficient contemporary gene flow between individuals, within and between populations, is often a key factor for the long-term persistence of populations. It is therefore a crucial element to consider in genetic monitoring. In this talk, we provide advice on developing a monitoring plan and the different components that should be considered. The various scales for monitoring and the different variables to be measured are outlined.

Diagnostic phytoplankton pigments as indicators for measuring restoration success in coastal waters

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The coastal zones are where more than half the world’s human population lives and this percentage continues to increase. Given the increasing pressure on coastal ecosystems, accelerated by human activity, restoration is needed where ecosystem services have declined, together with the conservation of healthy sites. As key primary producers, phytoplankton are the first link in the conversion of nutrients and sunlight into biomass, and they reflect immediate effects of changes in the input of nutrients in coastal ecosystems. They are therefore excellent indicators of water quality, marine ecosystem change, and the effectiveness of restoration efforts. In this work, we use phytopigments that are diagnostic of phytoplankton functional groups to develop a new phytoplankton composition index (PPCI). PPCI is a multimetric index that integrates group-specific chemotaxonomic indicators (carotenoids) that respond to pressures. The index was initially developed in Mediterranean coastal waters where well-known reference conditions deliver a baseline against which other phytoplankton variables can be anchored. Being very sensitive to human pressures, PPCI detects the effects of anthropogenic disturbances on both quantitative and qualitative phytoplankton community structure over different spatial and temporal scales. PPCI is therefore a useful tool for assessing long-term effects of restoration measures and benefits of nutrient reduction strategies. PPCI is transferable over a broad range of coastal zones (e.g. French Atlantic coastal waters). PPCI is easily implemented, which enables it to be used by environment managers who are not experts in phytoplankton taxonomy. An example of phytoplankton recovery after aquaculture closure is presented.
A transdisciplinary research framework to guide actions along the Great Green Wall for the Sahara and Sahel Initiative

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To meet the environmental and social challenges in the Sahel, the adoption of the Pan-African Great Green Wall (GGW) in 2007 was a step in the right direction. However, the success of the GGW depends on its capacity to gather, generate, integrate, and use knowledge from different sources, taking into account the complexity of socio-ecological systems (SES) along its path. Future Sahel, a French government-funded research program, brings together multidisciplinary scientists and GGW natural resource managers in Senegal, providing a unique opportunity to nudge the GGW along a positive trajectory. Herein, a research framework to guide GGW decision-making that integrates a social ecological systems perspective, multi-scale interactions, and ecosystem service delivery will be presented. To navigate towards “desirable” futures, decision makers must focus on optimizing and innovating actions for immediate implementation, while simultaneously creating a social and institutional context conducive for lasting change. In response to both short and long-term needs, two examples of Future Sahel research will be presented. The first provides data to inform immediate on-the-ground restoration strategies (tree planting vs. natural regeneration) for contrasting SES along the GGW path. The second seeks to operationalize “resilience thinking”, reflecting on both actions and the social context in which actions are implemented. Toward this end, we will share our experience in piloting the “Wayfinder, a resilience guide for navigating towards sustainable futures” (https://wayfinder.earth/), in Senegal. Finally, our GGW research-natural resource management partnership is already being scaled-out to other GGW countries in hope of fast-tracking decision-making at the continental scale.

Multi-sector partnership and collaborative water governance in the uMngeni Catchment

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In South Africa there has been a shift towards managing catchments as integrated socio-ecological systems to address water security challenges. Catchments represent an appropriate level of water resource governance and management. This approach intentionally links water security to ecological infrastructure management and society benefits. This relies heavily on stakeholder engagement and participation to understand the society demands and pressures on natural resources. The uMngeni catchment in KwaZulu-Natal of South Africa is typical of many rapidly developing catchments with the growing population and increase in economic development resulting in water security challenges. The catchment covers more than 4250 km² and occupies less than 5% of the surface area of KwaZulu-Natal, even though it supplies water to approximately 42% of the population of the province. Despite the investment in built infrastructure, the catchment is no longer able to provide sufficient water of adequate quality to people. The uMngeni Ecological Infrastructure Partnership (UEIP), a multi-stakeholder partnership, has focussed on understanding the role that ecological infrastructure (EI) can play to supplement built infrastructure. Multi-sectoral stakeholder governance towards effective collaboration and coordination of activities associated with catchment management has become particularly important for this catchment. The partnership is committed to strategic investment in ecological infrastructure to enhance water security in the catchment. The UEIP has a well-developed research component that improves the knowledge base and contributes to various points along the science-society-policy-practice continuum. This paper provides an overview of the uMngeni Catchment, the UEIP and introduces the key research topics.
Ecological restoration through the management of hyperabundant wildlife: A 10-year review of predation, partnerships, and policies

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In Canada’s National Parks, some forest ecosystems are unable to regenerate due to hyperabundant wildlife, such as moose and deer, which consume and damage vegetation. As a result of this damage, habitat for insects, birds, and small mammals declines. Over time, hyperabundant wildlife can cause a cascading loss of species and ecological processes. Since 2008, reducing wildlife population densities through harvest improved the ecological integrity of national parks in Newfoundland, Nova Scotia, Ontario, and Alberta. Supported by national policies and guidelines, the Parks Canada hyperabundant wildlife management program has also provided opportunities for meaningful partnerships with Indigenous peoples and local communities. Conflicting public values and politics have also presented challenges for these operations. This 10-year review evaluates the policies, engagement, monitoring, and implementation of the hyperabundant wildlife management program in Parks Canada. We found that the strength of the ecological response depended on the longevity and efficacy of the population reduction. Unexpectedly, controversy surrounding the population reductions generally centred around which stakeholder groups were involved in the wildlife management activities, rather than objections to lethal wildlife management in national parks. Key recommendations will be presented including: a) Use Before-After-Control-Impact (BACI) designs to control for the effects of natural variability such as weather and insects, and b) When communicating with the public and stakeholders, focus on ecological restoration outcomes rather than on wildlife management.

From monologue to dialogue: Creating a community of inquiry in online ecological restoration courses

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Universities are offering more online courses in ecological restoration to meet the growing demand for practitioners in this field. Online courses have the potential to contribute to this nuanced discipline by creating an environment in which learners from various backgrounds and locations can co-create knowledge. Unfortunately, online courses are often executed within the traditional educational paradigm of one-way knowledge transmission. In contrast, creating a community of inquiry invites learners to discuss ideas to generate meaning for themselves through collaborative and constructivist learning experiences. We tested techniques to create a community of inquiry in an online course in an ecological restoration program with the aim of shifting learners’ interactions from the transmittal to constructivist model of knowledge construction. We changed three interdependent elements of communities of inquiry: the cognitive, social, and teaching presence. We measured participation and dialogue resulting from changes made to the 2014 and 2015 courses compared to the 2013 course, which served as the control. To quantify dialogue, we developed an index based on the different roles individuals take in a discussion. Results show that participation and dialogue increased, particularly in 2015 when the teaching presence followed a community of inquiry approach by showing curiosity, recognizing multiple perspectives, and by illustrating that knowledge can be co-created. Variability in the results among groups suggested that some learners did not thrive in a community of inquiry. Nevertheless, many learners embraced collaborative knowledge construction, setting the stage for an enduring community of ecological restoration practitioners to emerge.
Good Wood: A business concept for restorative and sustainable tropical forest management

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As the decade of restoration approaches, global aspirations are high—restore 350 million ha, limit climate change to 1.5°C, transition to a bio-economy, and meet the Sustainable Development Goals by 2030—but tangible approaches are low. Both REDD+ (to reduce emissions from deforestation and degradation) and Forest Landscape Restoration have received ample hype, but financing and implementation are lagging. We introduce “Good Wood” as a novel strategy to implement and fund restoration of degraded tropical forests by starting new value chains centered on a new timber processing business concept. This concept contrasts conventional forestry practices—which rely on logging large trees of a few species from relatively pristine natural forests—in that it is adapted to degraded natural forests with small and damaged trees of many species. Utilizing small and medium-sized trees from a wide variety of species allows for management activities such as thinning and liberation cuts to be carried out and be financially viable. It also includes value-adding steps—such as drying and finishing—to improve efficiency, quality, and access to high-value markets. Linking manufacturers directly with customers allows for product development and customized timber products, which maximizes both wood recovery and profit. This new timber processing business concept promotes a new paradigm for restorative and sustainable tropical forest management and enables natural tropical forests to connect to the bourgeoning market for the future of cities built of wood. This concept is highly relevant to the Bonn Challenge and other global agendas—providing a concrete strategy for governments, NGOs, entrepreneurs, and investors.

Restoration and historicity: Practicing the long view with practitioners and communities to lay the groundwork for transformation within restoration

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The transition to democracy saw the emergence of large scale state sponsored and coordinated restoration programmes such as Working for Water in South Africa. Explicitly coupled to socio-economic development objectives, these programmes reflected a willingness by natural resource management (NRM) policy-makers to confront and respond to historical socio-political injustices and their legacies. Translating these social and environmental objectives within individual restoration projects required local level practitioners and stakeholders to additionally confront the unique and nuanced histories of their local contexts within the immediate post-apartheid era. We report on reflections by practitioners on the collapse of efforts to establish the Blyde National Park (in the Olifants Catchment), and particularly the unsuccessful attempts to implement comprehensive and integrated restoration projects within it. Practitioners from an interconnected group of local NRM practices (including restoration, water, forestry, and conservation), highlighted the need to collectively re-define and transform institutional arrangements in collaboration with local communities, especially in relation to changing organizational mandates, capacity, and landownership. This co-enquiry into local pioneering NRM practices, although not fully complete, has supported the emergence of agency and collective action, as well as building a community of practice. Cultural Historical Activity Theory provided a valuable framework for the above process and allowed the re-thinking and re-modelling of the restoration practice as a learning-action space. Finally, we advocate for adequate attention to various social dimensions (including organizational, socio-economic and socio-political) within which the bio-physical and technical aspects of restoration projects are nested, in order to ensure sustainable and just resilience building.
Improving Indonesia’s tropical peat-fire emissions monitoring as a restoration tool

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Indonesia’s tropical peat swamp forests are vast reservoirs of below-ground carbon. Annual deforestation rates, however, range from 3-8% with degradation stemming from drainage, logging, fires, and conversion of land for agriculture, oil-palm, and paper-pulp. Indonesia’s Nationally Determined Contribution is 29-41% reduction by 2030, the latter dependent on international support. This will require reducing peatland degradation rates and restoring several million hectares of already degraded peatlands. One of the key challenges facing peatland recovery is the annual occurrence of wildfires, which upon igniting the peat, create local and international haze crises and release large volumes of GHG. On-the-ground studies for understanding peat fire behaviour and for accurately calculating peat fire emissions remain very limited. To support the Indonesian government, the UMCES-IPB NASA Peat Fire Research Project, established in 2014, developed novel field methods and is collecting nation-wide data on peat fire occurrence, behaviour, and emissions across Indonesia. Nine Indonesian institutes are trained in and applying these methods, with data being collated in a central database. Our recently published paper highlights the importance of accurate field data to support calibration and verification of remote sensing models and calculations on emissions, where assumptions have been shown to lead to large percentage errors. For Indonesia to reach its peatland restoration targets, it is essential that methods, field data, and building local capacity are prioritised to facilitate accurate fire monitoring and efficient management. This project’s goals focus on the scientific capacity building and community-engagement aspects essential in ameliorating this international crisis.

Rebuilding orangutan homes: Community-based, multi-sector, landscape-scale tropical peat swamp forest restoration

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The Borneo Orangutan Survival Foundation’s (BOSF) vision is “the realization of Bornean orangutan and habitat conservation with the community’s participation”. BOSF Mawas Conservation Program, Central Kalimantan, works towards protecting a single hydrological peat-dome area - 309,000 hectares, which is the natural habitat of ~2,550 wild orangutans surrounded by 53 villages. Tropical peatland ecosystems have some of highest rates of degradation world-wide, through drainage, logging, fire, and land conversion to agriculture, oil-palm, and paper-pulp. Tropical peatland degradation results in the annual release of huge volumes of GHG, with devastating local air pollution. The Mawas area has suffered 50% forest cover loss since 1990. BOSF Mawas (established in 2002) has partnered with international peatland restoration efforts, increasing our knowledge capacity, technical expertise, and field activities: canal blocking (177 small canals blocked in 9 villages), community-based fire management (16 villages participated over 13 years), seedling nursery programs (established in 18 villages), reforestation and ANR activities (several hundred hectares), and annual landscape-scale environmental monitoring (120,000 ha peat, hydrology, vegetation, fuel and fire - 2010 to date). Nearer to villages, we prioritise alternative livelihood development (programs established in 22 villages), and community empowerment and education (programs established in 8 villages). With this capacity and knowledge, we have designed a new project – ‘Rebuilding orangutan homes’, which prioritises holistic, integrative restoration efforts. Whilst BOSF’s ultimate goal is to ensure sustainable wild orangutan populations, we are aware that this cannot be achieved
without applying an interdisciplinary, multi-sector, community-based, landscape-scale approach.

**Disciplinary perspectives on timescales of ecosystem formation, degradation, and recovery in wetlands in drylands: What is the natural reference state?**

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One of the defining characteristics of southern African wetlands is the limited to non-existent imprint of recent Quaternary glaciation, such that these systems have much longer morphodynamic histories than those in cool-humid regions. This complicates the definition and assessment of a wetland present ecological state (PES), which serves as a measure of ecosystem degradation relative to some definition of the natural reference conditions. It is argued here that the underlying assumptions inherent in defining natural reference conditions and assessing PES differ by discipline, primarily due to differences in the appreciation and conceptualisation of time. The introduction of deeper-time concepts into an assessment of PES may be viewed as an inconvenience for assessors of ecosystem components that measure controls over short timescales (e.g. hydrology, physico-chemistry), but it is sacrosanct to geomorphologists. For geomorphology, more so than for any other component, the evaluation of natural reference conditions is complicated by the dimensionality of geomorphic investigation (a nested hierarchy of 3D space and time); geomorphologists are compelled to recognise that their subject of study is a product of both the recent and long-distant (geological) past. As such, the PES cannot be evaluated apart from this context. This paper presents a meta-analysis of timescales and rates of wetland morphological change extracted from a large body of literature on southern African wetlands to interrogate the idea of a natural reference state, and to provide a framework through which the value of such context may be better demonstrated to multi-disciplinary teams working on wetland restoration activities.

**What existing wetland classification systems do not tell us: Implications for restoring wetlands in drylands and a proposal for a genetic geomorphic classification system**

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Due to climatic constraints in dryland regions, wetlands usually occur at confluences of flow paths, whether from surface flow, inter-flow, or occasionally at locations of groundwater discharge. Long-term landscape processes that shape valleys and focus the movement of water and sediment are accountable for providing a suitable template with which hydrology interacts to allow wetland formation. Understanding the temporal and spatial scales of these dynamics, as well as the drivers behind them, is key to successful wetland management and rehabilitation. Existing wetland hydrogeomorphic classification systems focus on hydrology, which is an outcome of interactions of geomorphology and climate. These systems typically neglect the role of sediment accumulation in maintaining wetlands in drylands, or potentially shifting the system from one of aggradation to one of erosion by crossing slope thresholds. A classification system is proposed that focuses on mode of wetland formation and is based on the understanding that genetic processes impact on the outcome hydrology, sedimentology, geomorphology, ecosystem service provision, and long-term dynamics of wetlands in drylands. The classification aims to impart understanding of dynamic processes of sediment transport in wetlands, such that restoration plans can be sensitive to long-term landscape processes. The classification system, developed primarily for wetlands in southern Africa, has four wetland macrotypes based on sediment source (colluvial, alluvial, aeolian and geochemical), which may be subdivided into 8 wetland types based on landscape location, shape and the occurrence of
geomorphic characteristics indicative of process (hillslope seep, floodplain, valley-bottom, plain, blocked-valley, alluvial fan, aeolian depression and geochemical depression).

**Could South Africa's environmental legislation better support wetland restoration efforts?**

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The Working for Wetlands Programme was established in 2000 but conceived through pioneering wetland restoration initiatives in South Africa in the late nineties. This government programme, under the Department of Environment, Forestry and Fisheries, Natural Resource Management, pursues its mandate of wetland conservation in a manner that maximises employment and skills transfer amongst vulnerable and marginalised population groups. In the past 18 years, the programme has invested just over R1.1 billion in more than 1,500 wetlands, thereby improving the health of over 70,000 hectares of wetland. Furthermore, 34,000 jobs were created, representing 3.3 million person-days to date. Despite the above, the Programme may have had an even greater impact if restoration projects were more effectively supported by South Africa's environmental policies and law. Current legislation, intended as a catch-net for development projects rather than restoration projects, requires that Environmental Authorisation be obtained from the Department of Environment, Forestry and Fisheries for activities that are associated with the wetland restoration. The mandatory processes for approval are ill-suited to projects with positive impact, and are therefore onerous, costly, and time-consuming in the context of wetland and riparian restoration projects. This paper outlines the current approach to environmental authorization of wetland restoration projects using constructed interventions, present its pitfalls, and explores possible solutions to regulating restoration activities in a more efficient way that does not treat them as development projects.

**Rehabilitation within the KwaZulu-Natal National Botanical Gardens, South Africa: A review of the Kingfisher Lake habitat enhancement, rehabilitation monitoring indicators and citizen science**

Megan Grewcock¹, Craig Cowden¹, Vere Ross-Gillespie¹, Sthembile Zondi²
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The KwaZulu-Natal National Botanical Gardens in Pietermaritzburg, South Africa, is a green escape within an urban jungle. Within the Gardens is Kingfisher Lake, which was built in the 1980s and quickly became overwhelmed by sediment in the early 2000s. This was largely as a consequence of the extensive forestry and urban developments that have mobilised large volumes of sediment within the catchment. GroundTruth, appointed by the South African National Biodiversity Institute (SANBI), created a remediation plan, involving the dredging of Kingfisher Lake and the enhancement of the upstream wetland habitat. The enhancement of the wetland habitat looked to encourage the deposition of sediments to ultimately reduce the frequency of dredging of the Lake. Following the completion of the rehabilitation, ongoing monitoring has been undertaken to measure the response of the system. Indicators such as vegetation response, water turbidity, and Dragonfly Biotic Index (DBI) were used to measure fluctuations in the system's functioning and condition. The location of the rehabilitation site within a publicly accessible area has increased opportunities for public participation. School groups have visited the rehabilitation site and learned about wetland rehabilitation and ecosystem monitoring using miniSASS, DBI, and water clarity tubes. The Gardens include a large number of opportunities for the incorporation of citizens into the ongoing monitoring of the site through the introduction and application of citizen science tools. An investment into public
Large-scale restoration after bauxite mining in the jarrah forest of south west Australia: An ongoing evolution in science and practice

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Alcoa of Australia, Pinjarra, Australia

Alcoa has been mining bauxite in the biodiverse jarrah forest of south west Australia since the early 1960’s. From 1988, the objective of rehabilitation has been to restore a self-sustaining jarrah forest ecosystem, and in 2003 Alcoa was presented with a Model Project Award from the Society for Ecological Restoration International in recognition of its efforts. In the fifteen years since then, an ongoing program of research has identified a range of refinements in the areas of tillage, seed and fertiliser regimes, and in the nursery production of difficult-to-return species, all of which have been integrated into standard rehabilitation procedures. A key aspect of the ongoing evolution is the value of long-term studies and monitoring datasets in understanding longer-term ecosystem development. At the same time, the long-term nature of operations poses a range of organisational and administrative challenges. In this symposium, we will outline the current status of this large-scale restoration project, suggest future areas of improvement, and discuss the lessons learned along the way that may be useful for similar projects elsewhere.

Peatland restoration support from local to national level – case studies from South Africa

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Peatland conservation is not only vital to effective biodiversity conservation but also in mitigating climate change as peatlands are earth’s greatest natural carbon store among natural ecosystems. They are therefore cross cutting areas of natural and social interests where the real costs and benefits of peatland restoration often support local growth points for local economies or have strong impacts on them. While wetlands are globally regarded as one of the most important life support systems, they are in South Africa the most threatened ecosystem type with 62% classified as critically endangered and only 15% in near-natural ecological condition. The Working for Wetlands, a South African government programme, mandated with protection, promotion of wise-use, and rehabilitation of wetlands is often faced with the challenge of prioritising catchments and wetland systems due to financial resource constraints. The programme’s current planning system is based on catchment priorities that have potential for high biodiversity and functional value return, as well as potential for partnerships. Prioritising wetlands of high conservation value such as peatlands in a drier landscape must be weighed up against the restoration of more common drier wetland types. It is imperative therefore that peatland restoration projects must be based on clear formulation of objectives and costs-benefit analyses. This presentation focuses on the ecological and socioeconomic outcomes of a local community-based peatland restoration project compared to that of regional incentive from a national programme.

Peatland degradation: From fire to restoration – southern African case studies

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Peatlands compose 50% of the world's wetlands, host a third of terrestrial carbon, and 10% of fresh water resources. However, the occurrence, functioning, and value of peatlands in drier climates, such as southern Africa, is poorly understood and their conservation status unsure. During the recent extensive regional drought, peat fires were reported from the wetter east in the Kingdom of Swaziland (KoS) and coastal KwaZulu-Natal Province, South Africa (SA), and the drier west in North West Province (SA) with the latest fire reported in 2019 in the southern Western Cape Province (SA). Degraded peatlands turn from carbon sinks to sources. Peatland desiccation results from the draining of peat pores, oxidation of the peat, compaction, hydrophobicity, and eventual collapse of the accumulated peat due to impacts such as drainage, erosion, or water abstraction. Peatland restoration can be complex, and therefore expensive, with varying levels of success. Not only hydrology, geomorphology and vegetation dynamics need be considered, but also a suite of microbial communities and bio-chemical processes must be in place. A peat fire is the (burning of the) last straw resulting in the total collapse of these sensitive ecosystems. Restoration of peatlands should therefore aim to address the impacts first that resulted in the desiccation (e.g. water abstraction upstream from the peatland or an erosion gully draining it). This study focuses on five fire-scarred peatlands in SA and KoS and the success of restoration efforts using various techniques.

Resilience as a background principle of ecosystem restoration projects

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Background resilience is an extremely important component to understand for any restoration project. The key to being able to assess resilience, loss of resilience, and future impacts affecting resilience requires a comprehensive understanding of local ecosystem functions and any external impacts effecting the project area. All sites have tell-tale signs of their resilience, that is their ability to regenerate naturally, or through assisted restoration techniques. To establish the site regeneration potential there are many individual components that need to be considered. These include but are not limited to:

- Stored resilience in the soil through a seed bank
- Connectivity to areas of high resilience
- Changes in hydrology
- Ongoing degrading impacts
- Remnant vegetation
- Ongoing human usage

Once the assessment has been made of the site's resilience, it is then critical to select the correct restoration techniques to ensure that maximum benefits are gained from the retained site resilience. It is also important to understand that there is potential to reduce the sites resilience through the incorrect implementation of restoration techniques or their order of application. A good understanding of your site's resilience and knowledge on how to best use it can often mean a large saving in restoration costs. A poor understanding of resilience in planning stages can focus on fabrication of an ecosystem, which is very costly. The first priority is to always to protect existing site resilience.

Using landscape function analysis as a mine rehabilitation monitoring tool in South Africa

Adrian Haagner$^{1,2}$

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In Africa, mine site rehabilitation is largely still considered an event rather than a process. The 'event' is assessed, post-disturbance, either on purely geotechnical merits or on purely biological development, both of which have substantial shortcomings when considered in
isolation. A landscape ecology approach to evaluating rehabilitation development bridges the gap between the two opposing camps. Landscape function analysis (within the framework of ecosystem function analysis) provides a peer-reviewed, rapid method to assess, analyse and report on multivariate indicators that best describe the recovery of an ecosystem after disturbance and subsequent interventions. We have undertaken landscape function assessments on rehabilitating mine sites across the South African climatic sphere for multiple commodities and on a variety of waste landforms. In this symposium presentation we present the fundamentals of landscape ecology, the theoretical basis for landscape function analysis as a monitoring tool, and a series of case studies highlighting the applications and results of monitoring rehabilitated chronosequences over time. Attendees will receive a detailed overview of techniques and will be provided with reference lists, MS Excel spreadsheets, and a field manual.

The critical importance of nurseries for meeting ecosystem restoration goals

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Global leaders, through the Bonn Challenge, the UN Decade on Ecosystem Restoration, and other programs, have pledged to restore millions of hectares in the near future. To achieve these unprecedented and ambitious goals, millions of established plants are required. Natural regeneration and direct seeding may partially achieve that need, but have limited efficacy in areas with environmental stresses, animal damage, and seed scarcity. Thus, high-quality, nursery-grown seedlings can be critical for providing plant material needed to create healthy, functional, and resilient ecosystems. Well-managed plant nurseries also serve as a hub of local plant expertise, help ensure genetically appropriate plants are used for specific outplanting sites and support sustainable livelihoods in rural communities. In spite of their integral role, however, nurseries often receive inadequate training, resources, or long-term support. Production of insufficient plant quantities or poor-quality plants have considerable economic and environmental consequences and will result in unsuccessful planting programs. To succeed, nurseries need integrated and sustained support from a range of actively engaged stakeholders including communities, policymakers, and land managers to insure they are a priority investment to restore thriving landscapes worldwide.

The effects of land degradation on sustainability of the Lesotho Highland Water Development Project: The need for land restoration

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Lesotho is known as Southern Africa's water engine due to its abundant water and high altitude that allows it to supply water to parts of the region either through treaties or naturally. Lesotho currently supplies 780 million m³ of water to Johannesburg through the Lesotho Highland Water Development Project (LHWDP), thus driving one of the strongest African economies. Lesotho earns royalties that contribute 10% to its Gross Domestic Product and hydropower. Lesotho has also agreed to the envisaged Lesotho - Botswana Water Transfer. The project will benefit communities in Lesotho, Botswana, and South Africa through increased climate resilience and long-term water supply security, revenue for Lesotho, and increased irrigation agriculture. Namibia benefits from Lesotho's water through the Orange River. This talk highlights the importance of land restoration for Highland Water Development Project stability. LHWDP is highly attractive to politicians because of the money generated. However, politicians have no interest in land rehabilitation. Lesotho's highlands are severely degraded, affecting the recharge of underground water. In the long-run water projects will not endure. Restoration brings economic benefits from increased productivity on formerly degraded lands. A healthy land restores biodiversity lost during construction. Land restoration creates recreational
opportunities conducive to ecotourism development. Additionally, restoring vegetation reduces soil erosion and related de-silting expenses. All states benefiting from Lesotho’s water should develop a coordinated land restoration approach for a continued supply of water. Lesotho should also allocate a percentage of royalties for land restoration and urge local water utilities to pledge resources for restoration programs.

**Looking outside scientific literature: What is restored, and which factors decide?**

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We present data from a national survey, covering a major part of all ongoing and completed restoration projects in Norway. This dataset provides a unique opportunity to explore the diversity of restoration projects in one country and to investigate the underlying drivers for restoration and potential for more effective restoration. We demonstrate the potentials and limitations from applied and singleton restoration projects for knowledge sharing, and how this can be further utilized as a contribution for large scale restoration strategies and national programs. Main findings are: 1) In general, other factors than the level of degraded land determine which projects take place. Restoration occurs in most nature types, the majority in freshwater and peatland. Very few projects include forest habitats, despite forest being the most degraded nature type and containing the most red-listed species nationally; 2) Most projects are motivated by local conditions, such as local events or local observations, and very few are part of national strategies. Still, the motivation for restoration can be assigned to the main threats to biodiversity, such as habitat destruction (the most frequent), pollution, and carbon emissions; and 3) The documentation and evaluation of projects is poor, and only occasionally are the results published in scientific journals. The consequence of this is that good experiences are not shared, and bad experiences might likely be repeated.

**Determining optimal germination cues for use in restoration seeding in a lowland Fynbos ecosystem.**

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Invasive alien plants impact ecosystems, which often necessitates their removal. Where indigenous species recovery fails following removal alone, active seed re-introduction of native species may be needed. This study investigated the potential for combined smoke and heat pre-treatment of seeds in breaking dormancy and facilitating increased germination. Selected species represent different functional types in the Cape Flats Sand Fynbos; a fire-prone, critically endangered vegetation type in South Africa. Seeds were exposed to either a heat pulse (temperatures between 60 and 300°C for durations between 30 s and 20 min) or dry after-ripening (1 or 2 months at milder temperatures of 45°C or less). Thereafter, seeds were soaked in smoke solution for 18 h and subsequently placed on agar at 10/20°C for germination. Most species fell into one of two main groups: Seed germination in the first group was greatest following a lower temperature (60°C) heat pulse, an extended period of mild temperatures (20/40°C or 45°C) exposure, or no pre-treatment with heat. Seed germination in the second group was promoted after brief exposure to higher (100°C) temperatures. No germination occurred in any species following heat treatments of 150°C or higher. Species that responded better to higher temperatures were mainly those possessing physical dormancy, but seed morphology did not correlate with germination success. This study showed that heat stimulation of seeds is more
widespread in fynbos plant families than previously known and will enable development of better seed pre-treatment protocols before large-scale sowing as an active restoration treatment after alien plant clearing.

**Testing for evolutionary change in restoration: A genomic comparison between ex situ, native, and commercial seed sources of Helianthus maximiliani**

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North America’s grasslands are one of the most globally imperiled ecosystems and thus need restoration strategies that maintain evolutionary potential for persistence under rapidly changing conditions. However, the maintenance of evolutionary potential requires genetic variation for adaptive evolution. Thus, increasing our understanding for how preservation and propagation may modify genetic variation of material used in restoration will illustrate the important role evolutionary change may have influencing short- and long-term restoration success. A combination of evolutionary factors, including selection, demographic variation, and founder effects will influence the amount and type of genetic variation available in restoration material. Intentional or unintentional selection of restoration material may contribute to the evolution of seed sources, impacting performance and evolutionary potential following restoration. We examined genomic variation in Helianthus maximiliani, a perennial sunflower distributed across the Great Plains of North America that is commonly used in grassland restorations. We use next-gen sequencing (GBS) approaches to evaluate genomic variation within and among a combination of seed sources; including historical ex situ collections, native populations, and commercial seed sources. Our data suggest that genetic differences have evolved across seed source types. In particular, commercial seed sources exhibit significant genetic differentiation from both ex situ and native seed sources. Future work aims to tease apart the impact different evolutionary processes have had on the genomic structure of the different seed source populations. This work will include an evaluation of whether phenotypic variation in traits important to adaptation have evolved over time and in response to propagation.

**Vegetative purification of Oman oil field byproduct water: A case study of the world’s largest constructed wetland and its beneficial ecological offsets**

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The oilfields of Oman, along with others in the Middle East and elsewhere in the world, produce large amounts of ground water as a byproduct of the oil extraction process. This oil contaminated water is often dealt with by return to the deep oil field aquifers. Petroleum Development Oman has established the largest constructed wetland in the world by engaging a German environmental consultant to design and construct a vegetated wetland to purify the oil-laden water to avoid the use of fossil fuel power sources to pump the contaminated water deep underground. The volumes of water are enormous, and the success of the project is demonstrated not only by the water purity of the wetland outfall but also by the wetland supporting extensive wildlife that otherwise would not be present and to offset habitat loss in other migratory zones. This presentation will demonstrate the science and engineering bought together by specialists from around the world to develop an environmentally responsible solution and provide an example of the power of constructed natural processes to address water
pollution challenges. The presentation will include the latest staged addition to the wetland, involving the propagation of wetland species endemic to Oman in a collaboration between international wetland scientists and plant propagation specialists.

Experiences from restoring a degraded forest ecosystem in South India over the last ten years with active involvement of indigenous communities and their traditional knowledge

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Bandipur National Park is an important Protected Area located in the Western Ghats of South India, a global biodiversity hotspot. A number of indigenous communities are at its periphery; mostly relocated from within the national park when it was formed in 1973. Disconnected from the forests, these communities lead a subsistence existence dependent on temporary work in nearby agricultural farms and tourist resorts. Traditional ecological knowledge is fast fading, raising risks of its permanent loss with future conservation efforts suffering as a result. Junglescapes (www.junglescapes.org), a grassroots ecological restoration non-profit, has been working on restoring degraded forest ecosystems since 2009 through a community-participative model involving local communities, both indigenous and non-indigenous. Scientific approaches to restoration were complemented strongly by traditional knowledge of community elders on such aspects as flora, fauna, hydrology, soil, climate, etc., helping to strengthen project design and implementation significantly. Human-oriented and low-cost restoration methodologies were adopted to maximise alternative livelihood creation, with a focus on year-around activities. Around 30 men and 20 women from 5 villages participated on a year-around basis, with indigenous community members showing marked preference for restoration activities over non-forest occupations. Key community-related outcomes included strong reconnect to ecological roots and knowledge, improved custodianship of local ecology, increased self-confidence and sustainable livelihoods. Community teams and leaders evolved naturally, and youth involvement facilitated generational transfer of knowledge. Community members imbibed modern restoration concepts well and also devised innovative solutions to local challenges. Over 800 ha of degraded forests have been restored so far.

Moving beyond traditional restoration with genetics

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A long-standing principle in ecological restoration is “local provenancing,” i.e., using seed that is local to the site being restored. However, anthropogenic-induced changes to natural ecosystems (e.g., land clearing, conversion, and climate change) may have altered environmental conditions so much that local provenances, that evolved in situ over many generations, are no longer adapted to the local conditions. Alternative provenancing strategies, such as climate adjusted provenancing, have been proposed. These strategies advocate mixing non-local provenances, sampled along an environmental gradient, with local provenances, to increase genetic diversity and bolster resilience of plantings in the face of future change. Hence, identifying the geographic extent of a local provenance and delineating seed zones based on adaptive characteristics is important to guide seed transfer strategies. We here demonstrate how quantitative genetic studies of functional traits and genomic studies can be used to delineate adaptive seed zones for guiding restoration decisions. We focus on Eucalyptus pauciflora, a key restoration tree species in Tasmania, Australia. These genetic studies are used to identify climatic drivers of adaptive variation among provenances which are then used to develop a spatial model of the adaptive surface to delineate seed zones under current and future climates. Seed transfers
using predictions from these models are being tested by studying provenance performance in two contrasting multi-provenance common-garden field trials. Our results demonstrate how genetic studies can rapidly inform alternative provenancing decisions in the absence of field trial data.

**What does innovation mean in the context of ecological restoration?**

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Recent research in ecological restoration shows mixed support for, and adoption of, new practices and techniques. Emergent techniques and methods (e.g. genomics, drones, big data, etc.) offer the potential to address restoration challenges, but they also invite debate and controversy. We argue that meeting the velocity of environmental change requires a concomitant increase in the velocity of change in practice. The purpose of this presentation will be to use the literature on the science of innovation to help inform issues in assessing innovation in restoration. Specifically, we: (i) explore the meaning and measurement of innovation – is innovation that which is new to an individual; something previously known in one domain and applied to a different discipline/region/area; the use of technology (e.g., drones) to automate tasks previously performed by people; something that fundamentally alters “nature”; or the perceived riskiness of the novel practice? (ii) evaluate how to measure the degree of innovation in restoration (e.g., is it the percentage of adoption of a new practice and how would data to calculate that percentage be obtained (numerator/denominator)? (iii) discern the dimensions to evaluate viability of innovation (e.g., cost, training, possible efficacy in addressing existing problems, future adaptability, etc.) and how the evaluation of those dimensions differs across categories of adopters. Familiarizing the field of restoration with these challenges in understanding innovation can help inform research and practice not only about innovation itself, but also the debate on the value of these innovations and the potential to “scale up” innovation.

**The critical value for transferring knowledge between restoration projects**

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As the number of restoration projects increases, the potential for knowledge exchange between them becomes more relevant. Utilizing the experiences from one project in others can be challenging and calls for a systematic approach: what is transferable, under what conditions, and how to communicate between projects? We use the restoration of a mountain area in Norway as a case project to illustrate our approach. The project, Hjerkinn PRO, has an aim formulated by the Norwegian Parliament, to restore a 165 km² former military training area into National Park. This is the most prominent restoration project in Norway so far, ongoing for almost 20 years, including stages of planning, implementation, and documentation. The experiences from Hjerkinn PRO have to some extent been adopted and continued in other restoration projects, nationally and internationally. More specifically, we will discuss transferability relative to goal formulation, restoration methods, cooperation between actors during implementation, and system for documentation and evaluation. In this presentation we want to suggest a model for how to identify and separate the relevant and transferable experiences from those that are unique and not relevant to others in more general terms. We will also discuss barriers for transfer of knowledge and from this identify further potentials. Finally, we give examples of how such transfer can improve the quality and effectiveness of future restoration.
Emotion-based restoration planning and communications tool – understanding and removing barriers to restoration collaboration

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Collaboration comes from working together to produce or create optimal ecological restoration outcomes. This process works best when we are able to fully understand the objectives and interests of each party and stakeholder involved. Understanding differences can begin to move us away from often polarized or conflicting positions, towards true, respectful collaboration. This presentation introduces a novel, practical Emotion-based Restoration Planning Tool to support collaboration during the planning, design, and implementation of ecological restoration projects. This tool allows the restoration specialist to more rapidly identify the emotions underlying unwelcome human behaviours and attitudes that create barriers to collaborative success. Key ingredients of the Tool are drawn from various existing emotional guidance scales and from non-traditional classification systems (e.g., Seven Deadly Sins and Cardinal Virtues). Where interests are underlain and defined by negative emotions (e.g., pessimism, envy, anger, fear), outcomes tend to be unbalanced and less effective. Where interests are defined by positive emotions (e.g., diligence, patience, optimism, temperance), outcomes tend to be balanced and optimized. The development of this emotional understanding will be discussed in light of the changes that are continuing globally in various sectors engaged in restoration (e.g., ENGOs, industry, special interest groups, and conservation organizations, the private sector, academia). Collaborating in this period of change requires a deep and respectful understanding of differences and common objectives; it demands better and more effective communications, founded on a clear understanding of emotions, behaviours, and actions.

Long-term change in the biomes of southern Africa: Implications for restoration ecology

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Humans have changed the environment in profound ways. What we see around us today may be nothing like the kind of environment that existed centuries or even only a few decades earlier and, as a result, acceptable baseline conditions might also have changed. This has important implications for the setting of reference points for restoration ecology. Using an analysis of repeat photographs, we summarise the changes that have occurred in the major biomes of southern Africa over the last 100 years. The results show that the Succulent Karoo biome has remained relatively stable over time, although woody plant cover has increased in ephemeral river environments. Woody plants have also expanded into fynbos biome environments on the Cape Peninsula as a result of fire protection policies that are currently in place. The eastern part of the semi-arid Nama-Karoo biome has become significantly more grassy since the mid-20th century while grass cover has also increased in the more arid parts of the Grassland biome. The Savanna biome has experienced a significant increase in woody plant cover over the last 100 years in both the mesic and arid parts of this biome. These results are discussed in the context of changing land use practices in the region. The number of animals utilising southern African environments have declined significantly over time while fire regimes have also changed. Understanding the different ways in which land use has influenced environmental outcomes provides restoration ecologists with the tools to influence particular trajectories of change.
Complete disruption of rehabilitation succession on a minesite in northern Australia by fire exclusion and invasive ants

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Rehabilitation progress was assessed at the Rio Tinto Gove minesite in 2012 and 2016 at 27 sites ranging from 2 – 42 years of age, and at six representative unmined sites. Ant species richness at rehabilitation sites displayed a humped trend with rehabilitation age whereby rehabilitation progress was stalling after approximately 12 years due to fire exclusion. Native ant abundance declined with rehabilitation age. The invasive yellow crazy ant was found in nine sites spanning almost the entire age-range of sites. Where yellow crazy ant occurred, other ant abundance and species richness was lowest, and its abundance was up to 257 times higher than that of all native ants combined. Sites where yellow crazy ant had undergone eradication treatments were recovering quickly and rehabilitation was progressing well. The work highlighted the ongoing issue of fire exclusion for rehabilitation progress in this fire-prone landscape, but particularly highlighted the devastating consequence of an invasive species in the area. Rehabilitation success at this minesite will require the implementation of a fire regime and the eradication of the invasive yellow crazy ant.

Alien tree invasions, fire, and restoration in the Cape Floristic Region (CFR)

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The CFR is dominated by fire-adapted fynbos shrublands. Invasive alien trees cause major fynbos degradation, and fire is recognized as an important restoration tool. Serotinous invaders (Pinus, Hakea) can be managed using “Fell & Burn”: felling releases seeds after which seeds and seedlings are killed by fire. An alternative for serotinous species is short rotation burning, but this risks eliminating native serotinous species. More challenging are long-lived, soil-stored invader seed banks, a feature of Acacia: in dense or long-term infestations fire stimulates germination, resulting in extremely dense recruitment which overwhelms recruiting native flora, and is difficult and prohibitively expensive to control. Postponing fire may simply delay the problem, but granivory can reduce invader seed banks after clearing. At lightly invaded sites, or in subsequent follow-ups of denser invasions, clearing must be integrated with fires – whether planned or accidental – to prevent invaders outcompeting the local flora. Fire successfully suppresses germination of secondary invaders, such as weedy annual grasses, that otherwise benefit from Acacia’s legacy of increased soil nitrogen. Indigenous grasses also benefit from nitrogen and may suppress recruitment of other species, creating an undesirable alternative state dominated by herbaceous species. Post-fire timing of fynbos re-introduction is critical as exposure to wind and sun may kill seedlings where resprouter species have been lost. Sowing of fast-growing forbs and shrubs may partially counter this. Management authorities remain reluctant to burn and prescribed fires are generally cool fires that are more easily managed and seldom the intense, summer fires ideal for restoration.
The potential for passive restoration in alien plant-invaded ecosystems in the Cape Floristic Region (CFR)

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Invasion by alien woody species is one of the greatest threats to the conservation of fynbos ecosystems in the CFR. This degradation impacts negatively on ecosystem services, such as water provisioning, as well as biodiversity. Fire is the main ecological driver in fynbos but also provides a window for invasion by fire-adapted alien trees and shrubs. Many fynbos species are killed by fire - termed obligate reseeders – while the remainder may resprout from lignotubers and other below-ground storage organs. Dense stands of alien trees shade out fynbos so natural recovery potential depends on the persistence of native soil-stored propagules and their germination following alien clearance. Few fynbos species can disperse far, thus colonization of highly degraded sites from intact remnants is slow. Density and duration of invasion are key to understanding thresholds to natural recovery. Other factors that influence recovery potential include the dominant invader species, vegetation type, quality of initial alien clearance and proximity to sources of fynbos and secondary invader species' propagules.

Resilience measures for the social-ecological systems of closed mines

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The number of coal mines in China has decreased from nearly 100,000 in 1990 to 5,800 in 2018 due to resource depletion and a policy of mine closure in favor of renewables. The key problem is whether the social-ecological system can provide the transformative capacity for the changes required. We focus on transferability of system resilience as the key for ensuring durable restoration outcomes. Firstly, this paper analyses the effect of the disturbance on the socio-economic-ecosystem fabric. The system faces disturbances in the form of land pressure, land use change, soil, water and air pollution, rural population exodus, worker unemployment, industrial succession (where one industry replaces another), policy planning, etc. Secondly, the surrogate index method was used to construct the evaluation index system of social-ecological system resilience of closed mines from the three dimensions of ecology, society and economy. Finally, a three-dimensional evaluation model of resilience was constructed and evaluated with examples drawn from the massive Dahuangshan mine in Xuzhou, China. The transformational development of closed mines is the transfer and reorganisation of the social-ecological system, corresponding to the release and updated phases of the adaptive cycle towards closure. The Dahuangshan Mine was closed in 2001, and its resilience increased from 2.7188 in 2001 to 4.4606 in 2017. The social resilience increased from 1.53 to 2.58. The economic resilience increased from 1.29 to 2.83, and the ecological resilience increased from 1.53 to 2.29. In order to improve resilience, the function of ecological indicators needs to be progressively improved and enhanced.

Alignment of biodiversity and ecosystem service benefits under Forest and Landscape Restoration

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The success of Forest and Landscape Restoration (FLR), the world’s guiding framework for the restoration of forest ecosystems, demands multiple co-benefits. This task is particularly pressing for biodiversity conservation, which often is side-lined by ecosystem services in FLR’s agenda-setting and fails to benefit when tree plantations are deemed sufficient for FLR goals. The key to enabling multiple co-benefits under FLR lies in understanding their synergies and trade-offs with each other, but such knowledge has been severely limited by the narrow focus on the biodiversity-carbon co-benefit and their geographical overlap, leaving out the major ecosystem services of soil erosion control and water provisioning that are also major FLR motivations worldwide, and failing to inform what tree covers FLR should restore. Focusing on biodiversity, carbon storage, soil erosion control, and water provisioning, we conducted a global meta-analysis to address these knowledge gaps by asking: of the tree covers FLR can restore, which ones deliver more desirable performances when considering all four environmental outcomes, and does the same answer hold across the world’s forest biomes? We found that native forests had clear advantages over tree plantations as the target of restoration, and that these advantages aligned among all four environmental outcomes. Moreover, the additional benefits of restoring native forests, instead of monoculture plantations, are higher for regions closer to the tropics. For FLR, these findings make a strong environmental case for restoring native forests for the world’s biomes but particularly for regions closer to the tropics.

Avoiding further degradation by supporting locally important functional ecological infrastructure for improved land-based livelihoods

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The Tsitsa Catchment is a grassland-dominated, summer rainfall area in the northern-Eastern Cape Province of South Africa. The majority of the catchment is degraded, which has implications for land-based livelihoods in communal areas. Due to the livelihood challenges and planned water infrastructure developments, restoration efforts have been intensified in the area through the Tsitsa Project. The Tsitsa Project strives to restore functional (but threatened) landscapes to the benefit of local and downstream users. It prioritises limited resources for the maintenance of functioning, but threatened, ecological infrastructure over severely degraded systems. This requires detailed spatial and functional information on ecological infrastructure. National datasets are limited and do not provide sufficient information to support catchment wide prioritisation. High resolution mapping identified ecological infrastructure (e.g. wetlands and rangelands) and threats (e.g. alien invasive vegetation and erosion) to natural ecosystems. Community-based spatial priorities were captured and include locally important rangelands, fuel-wood, security risk areas (dense stands of alien vegetation) and wetlands. The high-resolution mapping and community inputs were combined to prioritise socially and environmentally important ecological infrastructure that is still functional but in need of intervention. This presentation will show how scientific and local knowledge can be integrated to support both land-based livelihoods and avoid further degradation of ecological infrastructure.

Promoting rangeland restoration and climate resilience through case studies

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Rangelands occupy over a third of the ice-free land on Earth. Domestic livestock operations are a primary user of this grazing resource and will have to adapt to climate change effects on rangelands. Management directed toward current rangeland stresses that may be amplified under a changing climate—including fire risk, invasive plants, and variable forage production—is beneficial under every future scenario. And although climate change discussions have become highly politicized, our experience suggests that U.S. ranchers support management strategies and practices that provide ecological and economic benefits in addition to benefits relating to climate change. Our goal is to foster adoption of these “no-regrets strategies” by sharing individual success stories of rangeland restoration and sustainable management. Successful ranchers are already experienced at considering economic, ecological, and social risks in decision-making. They can identify and implement practices that increase resilience to climate change and support wildland restoration while balancing the other risks they face. Forward-thinking ranchers can provide insights into their resilience management practices, enabling others to join them. Farmer-to-farmer communication is known to be more successful than “expert” outreach. Our multi-media case studies are designed to encourage other ranchers to make management changes toward promoting rangeland restoration, resilience, and economic sustainability. Each case study consists of a short documentary film highlighting an innovative rancher and a peer-reviewed written factsheet with descriptions of the rancher’s ecological context, innovative practices, and a discussion of challenges and benefits of adopting restorative practices. These innovations apply worldwide in regions with semi-arid plant communities.

Applying an adaptive management approach to a wetland rehabilitation project using an urban South African wetland as an example

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The uMhlangane River, located in Durban, South Africa, is a highly polluted system that has a significant impact on water quality within the downstream estuary and Durban’s swimming beaches. For this reason, the portion of the uMhlangane River Floodplain located within an area of private open space owned by the Riverhorse Valley Business Estate, was chosen for a wetland rehabilitation project pilot study. The aim of the rehabilitation was to improve the hydrological and vegetation components of the wetland in order to enhance the overall integrity and ecosystem service provision of the system. An adaptive management approach was adopted during the implementation phase of the project, whereby regular ongoing monitoring and implementation support was undertaken by wetland ecologists and engineers. This provided a mechanism for the wetland engineers and ecologists to identify unanticipated enhancements to the rehabilitation plan that were not identified during the rehabilitation planning phase of the project. After completion of the rehabilitation activities, Ezemvelo KZN Wildlife identified suitable habitat at the Riverhorse Valley wetland for the release of Pickersgill’s Reed Frogs that were captive-bred at Joburg Zoo. This frog species, listed as ‘Endangered’ by the IUCN, is endemic to central coastal KwaZulu-Natal. The introduction of these frogs to the Riverhorse Valley wetland and other sites will contribute to achieving the aim of increasing population size and connectivity between populations, and ultimately leading to the frog species being listed as Least Concern.

A good start but a slow dynamic: Hopes and disappointment of a Mediterranean steppe grassland restoration experiment

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The spontaneous recovery of plant communities after severe anthropogenic disturbances has often to face two main obstacles: the reduced propagule pressure of target species and the high dispersal and establishment potential of unwanted species, particularly due to the increased soil fertility. An experiment was carried out 10 years ago to address the question: what are the most efficient restoration treatments to restore such plant communities? After the rehabilitation of an herbaceous sheep-grazed habitat in a formerly intensively cultivated orchard in a Mediterranean steppe in France, four experimental techniques were applied to restore the plant community: i) topsoil was removed to lower ruderal species seed banks and soil trophic levels, ii) nurse species were seeded to rapidly occupy niches, and then to provide safe sites for target species once sheep grazing has been reintroduced, iii) hay was transferred to provide local species seeds and iv) soil was inoculated to provide local species propagules with associated microorganisms and to lower soil trophic levels. Four years later, above-ground vegetation physiognomy was rehabilitated, and some treatments had great results: species richness was restored and community structure was half restored by soil transfer and topsoil removal. Ten years later they did not improve more but the other treatments, including the control, have greatly improved in diversity and structure, reaching the restoration level of the latter treatments. These results will be discussed, as well as the merits of having good results at the very beginning of a restoration project but with no better dynamics after.

A vibrant Junior LandCare Project in the Western Cape Province

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The Junior LandCare programme can be seen as the cornerstone for youth development to provide for sustainable resource management for future generation. To ensure that the Junior LandCare programme promotes development of youth with regards to natural resource management, three themes were created: SoilCare, WaterCare and VeldCare. The various themes entail:
- SoilCare: Soil life, erosion, horticulture, and composting.
- WaterCare: Water cycle and water life.
- VeldCare: Indigenous and alien plants and trees.

The Junior LandCare programme promotes food security for homes and schools as food garden competitions are held on a regular basis to create awareness regarding LandCare and sustainable agriculture. Furthermore, the programme also improves leadership skills of the youth as various leadership facilitators are kept consistently in the province. It developed and creates business for local service providers that specialise in environmental education. The main aim of the presentation is to explain the Junior LandCare programme and its various success stories in the province.

Optimising water and financial flows to guide investment in catchment protection and restoration

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This paper forms part of a workshop focussed on sharing findings from the uMngeni Ecological Infrastructure Partnership. Through this initiative, a range of catchment stakeholders have committed to investment in restoring, maintaining, and managing the natural landscape to deliver water supply services and other benefits such as job creation, improved agricultural productivity, securing cultural benefits, reduced flood damage, and increased adaptive capacity to climate change. This component seeks to identify sites in the uMngeni catchment where investment can provide long-term and sustainable returns. In essence, “what to do and where to do it” in the catchment to provide optimal benefits. This seemingly simple question encompasses complexity in time, space, and in the
connections between different biophysical, social, political, economic, and governance actors as well as uncertainty regarding the most appropriate way of estimating return on investment. Based on an analysis of 10 years of water supply data, we present and test methodologies to consider the returns on investment using the cost to provide 1 m³ of water from restoration activities as a basis. Drawing on analysis of ten years of water and financial flow data supply in the catchment, we consider appropriate discount rates and ROI methods and compare these to the volumes provided and costs associated with traditional forms of infrastructure investment. The methodology adopted, results obtained, and recommendations provided are particularly appropriate for rapidly developing landscapes but are also applicable in a wide range of other restoration studies.

Benthic infauna abundances are driven by sediment organic content and impacted by benthic restoration via dredging

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Estuaries worldwide are plagued by the accumulation of organic sediments from eutrophication. High levels of organic sediments smother benthic life, foster anoxia, and flux nutrients into the water column. One mitigation approach is legacy organic sediment removal via ecologically-focused dredging. Dredging for navigational purposes is common, but environmental dredging impacts are not well known. This study reports on three years of benthic population data in association with environmental dredging, including a baseline, pre-dredging period and continuing for a year after the cessation of dredging. The study estuary is the Indian River Lagoon (Florida), a diverse shallow subtropical estuary. Organisms tracked include invertebrates collected in benthic grabs. Sites sampled include stations within dredging areas, immediately adjacent, and away. Sediment organic content had inverse correlations with species richness ($R^2=0.74$), diversity ($R^2=0.80$) and overall densities ($R^2=0.72$). Considering major taxa separately, population densities of crustaceans ($R^2=0.55$), molluscs ($R^2=0.64$), and polychaetes ($R^2=0.60$) had inverse correlations with sediment organic content. Organic content correlates closely with silt-clay ($R^2=0.93$) and porosity ($R^2=0.88$), and the dissolved oxygen of the water column immediately above the sediments ($R^2=0.54$). All correlations had significance of $p<0.001$, except polychaetes, $p<0.016$. Organisms absent from muck prior to dredging, but appearing in dredged sites during or afterwards, included polychaetes (Glycera americana, Alitta succinea, Pectinaria gouldii, Paradiopatra hispanica, Ctenodrilus serratus, and Hypereteone heteropoda) and amphipods (Cymadusa compta, Cerapus tubularis, Corophium sp., and Grandidierella bonnieroides). Environmental dredging improves conditions for benthic infauna when muck is removed, but the benefits of removing intermediate organic sediments are less clear.

Long-term effects of ecological restoration on soil seed banks in urban forest patches

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Forest restoration is increasingly being employed in temperate zone cities to provide environmental benefits to people and support biodiversity. Goals of these ecological restoration efforts often include restoring a self-sustaining trajectory of vegetation development that resembles regional flora, while urban environments are sites of frequent exotic species introductions. Effects of urban conditions on the response of forest community change to restoration actions are not well understood. Dormant plants living as seeds in and on the soil – soil seed banks – serve as a means of species dispersal through time, and the abundance and composition of the seed bank may be altered by management interventions. To understand effects of ecological restoration and urban
conditions on the regenerative capacity of urban forest patches, we compared the soil seed banks of forest patches dominated by non-native vines and shrubs, patches that had been restored by invasive species removal and native plantings, and an urban old-growth forest in New York City, USA. A two-year germination experiment indicates that restoration treatments resulted in lower abundance of seeds of non-native species (particularly targeted woody vines) and greater abundance and richness of native trees compared to sites similarly dominated by introduced vines and shrubs and not restored over 20-25 years.

River diversions as coastal restoration tools: Plausibility, trade-offs and ecological consequences

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River diversions have been increasingly used in estuarine and coastal systems worldwide to restore hydrologic connectivity, provide sediment subsidies, control salinity, or mitigate harmful algal blooms. Freshwater and sediment diversions on the Lower Mississippi River play a central role in the proposed $50 billion, 50-year strategy for restoring the Louisiana's coast. The key objective is to mitigate the loss of coastal wetlands and achieve ecological and socioeconomic sustainability of the State's coastal resources. The State is currently operating several freshwater diversions, including the Caernarvon Diversion (~ 220 m³/s), the Davis Pond Diversion (~ 300 m³/s), West Bay Sediment Diversion (~ 700 m³/s), and several smaller siphons. Under the proposed 2017 Coastal Master Plan, four additional large-scale sediment diversions are being considered that would convey an order of magnitude more water compared to existing diversions. The effects of existing and proposed diversions on hydrodynamics, biogeochemistry, and water quality were investigated using a high-resolution, three-dimensional, coupled hydrodynamic-biogeochemical model. The numerical model domain covers most of the northern Gulf of Mexico and includes high-resolution nested grids in Barataria Bay and Breton Sound estuaries where the diversions are located. A number of different diversion scenarios were assessed, including a concurrent operation of all existing and proposed diversions with a combined flow of ~ 6,000 m³/s. Numerical modeling results indicate that while the diversions provide valuable sediment subsidies, they are subject to significant ecological trade-offs associated with estuarine freshening, alterations in nutrient transport pathways, proliferation of harmful algal blooms, and development of hypoxia.

Equity and social inclusion in land restoration interventions in Ghana: Considering the ‘by whom’, ‘for whom’, and ‘how’

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The pervasiveness of land degradation in Africa carries far reaching socio-political, economic, and ecological impacts. Land restoration interventions are therefore critical for strengthening the resilience of livelihoods and landscapes. Nonetheless, restoration interventions have far too often omitted community participation in favor of top-down approaches. Moreover, they have often narrowly concentrated on the biophysical aspects of restoration, thus diminishing the significance of socio-ecological, political and economic dimensions. This paper is based on qualitative research from 2018 and 2019 in the Talensi district in Ghana, an area with both active and completed Farmer-Managed Natural Regeneration (FMNR) interventions. We draw on interviews, focus group discussions, and other participatory rural appraisal methods carried out in four communities in Talensi (the selected communities represent a mix of active and former project sites) to analyse how effectively FMNR interventions have incorporated equity and social inclusion in their approach to regreening. While most land restoration interventions seek to strengthen the
resilience of livelihoods and landscapes, the critical questions of resilience ‘by whom’, ‘for whom’, and ‘how’ are often inadequately addressed in development projects—something that carries important implications for equity and social inclusion. We focus particularly on how former and current beneficiaries of FMNR in Talensi perceive the anticipated and/or actual distribution of benefits, costs, and risks within their communities. Our analysis of equity draws on a multidimensional framework developed by McDermott, Mahanty, and Schreckenberg (2013), which is structured around three dimensions to equity: distributive, procedural, and contextual.

A conceptual framework for exploring social and institutional dimensions of landscape restoration: The case of four market-based approaches in Kenya

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In an era where the socio-economic dimensions of landscape restoration can no longer be ignored, emphasis on equity is increasingly being placed on initiatives such as market-based conservation (MBC) schemes. Despite this emphasis, little attention has been devoted to understanding how and why the interplay between institutional and social dynamics influences the design of MBC programmes and their outcomes. This study begins to address this knowledge gap by developing a conceptual framework which guides analyses of MBC initiatives through two areas of inquiry that explore and interrogate the: i) historical and institutional contexts within which actors emerge and interact to influence equitable socio-economic outcomes, and ii) underlying factors for gender in/exclusion in such programmes. Conducted across four case studies in Kenya – two payments for ecosystem service schemes and two Reducing Emissions from Deforestation and Forest Degradation schemes - the study adopts innovative qualitative approaches including Process Netmap, the participatory secret ballot and intra-household in-depth interviews to uncover the multi-faceted drivers and constraints associated with MBC approaches. The results reveal that: i) power imbalances condition socio-economic and environmental outcomes and are both relational and multifaceted, ii) women are excluded from equitable participation in decision-making processes and from receiving direct benefits while men incur unremunerated costs on their labour. The study therefore encourages critical reflection on the extent to which the overall neglect of non-technical aspects in market-based approaches limits their potential to address the very same socio-economic inequalities that are linked with the restoration and degradation of critical landscapes.

Restoring habitat and hope: The Sagebrush in Prisons Project

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The Sagebrush in Prisons Project, a collaborative effort between the US Department of Interior Bureau of Land Management, Institute for Applied Ecology, and state Departments of Correction engages multiple prisons across seven western states (CA, ID, MT, NV, OR, WA, UT) in the United States. Working with prison systems to engage inmates in habitat conservation and ecological science is an innovative approach to increase our ability to reestablish habitat and at-risk species, while simultaneously providing people in custody with opportunities for reciprocal restoration, vocational education, therapeutic activities, safer conditions, and lower costs of imprisonment. Adults in custody contribute to the conservation of Greater Sage-Grouse and its habitat, the Sagebrush Sea, by growing sagebrush plants in prison-run native plant nurseries. This distributed network of nurseries produces locally sourced sagebrush seedlings for habitat restoration on public lands, primarily in response to wildfires in priority habitat for the grouse. The quality of these sagebrush seedlings is exceptional, and first year survival is very high (>80%). Since 2014,
the program has engaged over 3,500 adult and youth inmates who grew and planted over 1.1 million sagebrush seedlings. Adults in custody also receive training in horticulture and nursery production, lectures in science and conservation, and certificates for their accomplishments. Including incarcerated people in conservation and science taps into the positive potential of over 2 million inmates at over 4,000 prisons and jails in the United States and creates new partnerships for educating an underserved community and supporting large scale ecological restoration and research.

Rehabilitation of Tailings Storage Facilities by re-seeding: A review of 10 years of research

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Tailings Storage Facilities (TSF) developed after mining operations are characterized by different shapes, sizes, and growth mediums, depending on the ore that is mined and the use of top-soil. TSF are generally rehabilitated by grass species to stabilize the surface (reduce erosion and pollution) and for aesthetic reasons. Research carried out by scientists and post-graduate students at the North-West University in collaboration with AGT Foods over 10 years will be presented. This includes results from the rehabilitation of mainly gold and platinum TSF that have been re-seeded by different coated and non-coated grass seed types as well as natural soil conditions characterized by different clay textures as the control. Data from laboratory, nursery, glasshouse, and field trials in different ameliorated soils will be compared. Results indicate that the soil-, climatic- and other environmental conditions, as well as the slope geometry of the TSF, the amelioration technique, seed type, and the pre-seeding conditions (such as seed traits, storage facilities including temperature and moisture contents, harvesting and coating techniques) will influence the rehabilitation success. It is evident that no single recipe exists and that all attributes have to be considered per specific site before making sound decisions for the rehabilitation of TSF.

Managing temperate grassland and developing and restoration enterprise in Victoria, Australia

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The process of developing a restoration enterprise based on funding through biodiversity offsets though purchase and restoration of land containing threatened temperate grassland on the Victorian Volcanic Plains of Victoria, Australia will be described. Eighty ha of land was purchased and permanently protected as it contained a high-quality example of threatened temperate grassland, albeit with significant weed cover, of which less than 1% remains in Victoria. Funding was obtained through offset funds from developers and came with six separate management plans demonstrating that the available offsets were adequate to compensate for the losses from development. The six management plans for different portions of the site had varying requirements that were integrated into a general management and monitoring plan. Site-wide procedures were developed to ensure that the requirements of each individual management plan are met while implementing effective management for the entire site. Biomass control is essential in temperate grasslands for maintaining flora and fauna diversity so regular fire or grazing is essential. The management process primarily requires regular burning cycled through the site and weed control is focussed on targeting weeds after burning because it is then most efficient and effective. An overview of the management and monitoring plan will be presented to illustrate the complexity of obtaining offset funding for protecting and restoring threatened vegetation and habitats. The long term aim of being a significant and reliable source of seed for direct seeding of new temperate grasslands in the local area will also be discussed.
Dynamics and management of invasions, re-invasions, and secondary invasions in Great Salt Lake wetlands

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Wetlands are highly prone to invasions but even after extensive management, they often experience re-invasions and secondary invasions. What are the best approaches to manage invasions, re-invasions, and secondary invasions? We address these questions in Great Salt Lake wetlands, the most important wetlands in the Intermountain West of the U.S., which have been invaded by the non-native grass Phragmites australis. In a field experiment at two Phragmites patch scales (0.2 and 1.2 ha), we investigated the response of Phragmites, secondary invaders, and native plants to various herbicide treatments. We found that Phragmites cover was greatly reduced overall with herbicide, but there was some Phragmites reinvasion, particularly at the large patch scale, relative to the lowest Phragmites covers reached in the first two years post-herbicide application. At both patch scales over the five years, as the cover of native emergent plants increased, the cover of Phragmites decreased substantially. We saw a similar relationship with Phragmites cover declining over time as a secondary invader, Typha, increased in cover. These findings highlight the importance of native plant communities for minimizing reinvasions. Thus, in two outdoor mesocosm experiments, we looked at competitive dynamics between Phragmites and native emergent plants. We identified which species (Schoenoplectus acutus) and which native seeding rates (2, 3, and 5x the standard restoration seeding rate in the region) were most effective at limiting Phragmites invasion. Taken together, these studies highlight how invasions, re-invasions, and secondary invasions can be managed more effectively in wetlands through native plant biotic resistance.

Determining the scale of local adaptation: What can we learn from a large-scale reciprocal transplant study of an important restoration grass species?

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Using locally adapted seed sources is fundamental to the long-term success of plant community restoration. However, the scale of local adaptation is not well understood, and has been determined only at a cursory level in a handful of species. Reciprocal transplant studies are the gold standard for measuring local adaptation, but the majority of these studies are based on a few populations and common garden sites, due to severe logistical challenges. Here we present a large-scale reciprocal transplant study of an important restoration grass to determine the scale of local adaptation across a significant portion of its range, and how that affects seed sourcing decisions now and under future climates. Bluebunch wheatgrass (Pseudoroegneria spicata) is a keystone species in the grasslands and shrublands of the interior western United States and is the most heavily used native grass for restoration in that region. Nearly all of the available commercial varieties of bluebunch wheatgrass are sourced from a small area of southeastern Washington State, despite strong evidence of distinct lineages across the region. In 2014 we established 15 bluebunch wheatgrass common gardens across four U.S. states, representing a wide spectrum of environments, using 15,400 experimental plants sourced from 78 locally collected populations and three commercial varieties. Our data show that the pattern of local adaptation in bluebunch wheatgrass is a complex mosaic, with some environments and populations showing stronger or weaker signals. We discuss consequences of this pattern for restoration in the context of the interior western U.S. and global restoration efforts.
Positioning scientists as relevant and respectful partners in forest restoration

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Scientists can play different roles as collaborative partners in the process of ecological restoration, two of which are building knowledge of ecological dynamics and developing tools to support land stewards' decision-making. In each role, the positionality and mode of engagement between scientists and stakeholders will shape the outcomes of the process. We describe an ongoing collaboration between an interdisciplinary team of scientists and a group of stakeholders who are all stewards of globally rare Maritime Live Oak (MLO) forests in the southeastern United States yet have different stances on the appropriateness of various forest restoration strategies. Invoking principles from structured decision-making (SDM) and participatory action research (PAR), we focus on our methodologies for appreciating stewards' perspectives and values, which were adopted to strengthen the relevance of our contributions while also avoiding a hegemonic position in the partnership. We have used interviews, workshops, and field research partnerships to engage stakeholders as sources, co-producers, and target recipients of ecological knowledge. To build a decision-support tool for MLO forest restoration, we first sought to understand stewards' multiple restoration objectives and specific decision contexts to help ensure that the tool would deliver the kind of information and support they would value. With that established, together we compiled a suite of foreseeable management options and assessed the data needs and uncertainties associated with each. SDM and PAR offer complementary notions for building relevant and respectful partnerships, yet require creativity, humility, and intentionality on the part of scientists in crafting engagement activities with stakeholders.

Integrative restoration protocols for temperate mesophotic reefs: The case of the Mediterranean coralligenous habitats

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The temperate coralligenous habitats are considered hotspots of Mediterranean marine biodiversity. These coralligenous bioconcretions are built primarily by the accumulation of encrusting coralline algae growing at low irradiance levels that host numerous long-lived macroinvertebrates with prominent ecological roles. Several pressures, such as fishing activities, invasive species, and recurrent warming-induced mass mortalities, affect coralligenous assemblages and lead to dramatic loss of habitat complexity and biodiversity. One aim of the EU-funded project MERCES, dedicated to marine ecosystems restoration, was to develop innovative active restoration protocols with a focus on coralligenous habitat-forming macroinvertebrates from three key taxonomic groups: Cnidaria/Anthozoa, Porifera/Demospongiae and Bryozoa. These protocols combined transplants from donor organisms and recruitment-enhancing devices, taking into account the life-history traits, population dynamics, and genetics of targeted habitat-formers. Our results show that transplantations require low initial effort due to high survival of transplants, but decades will be needed to fully recover habitat complexity.
because targeted species are slow-growing. In order to speed up recovery, we explored the potential influence of facilitation processes, i.e. positive species interactions. In order to guide the choice of transplant donors, we also aimed to identify thermo-resistant populations and specimens. We thus combined a transregional common garden and whole-genome sequencing to unravel the eco-evolutionary processes driving the differential responses to thermal stress. The outcomes of these works will implement the EU directives and contribute to the strategic planning of restoration initiatives for temperate marine ecosystems in the context of global change.

Theoretical basis for restoration of humid grasslands

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Humid grasslands in South Africa comprise diverse assemblages of grass and forb species typically growing on relatively infertile soils and are maintained by regular defoliation. Temporal species turnover appears low in undisturbed grassland, with plant longevity strongly influencing both grass and forb species dynamics. Recruitment of new seedlings is rare in the face of severe above- and belowground competition for resources. Long-term research focused on defoliation and soil nutrient addition has revealed that increased soil nutrient levels severely impact species richness, while reduction in defoliation frequency has a similar effect. Nitrogen addition, on its own and in conjunction with phosphorus, increases productivity at the expense of richness. Likewise, reduction in fire frequency and/or defoliation in the growing season reduces richness in the presence of increased aboveground biomass. Species loss in the presence of increased soil nutrients and/or reduced fire and defoliation frequencies can be rapid (2-5 years). Studies and observation of abandoned crop lands and revegetated opencast mines reveal an extremely low recruitment of indigenous grasses and forbs, with secondary succession commonly stalling at a stage dominated by grazing resistant tall grasses that resist invasion by other species. Contrary to common perceptions, many indigenous grasses exhibit high seed viability, raising the possibility of reseeding to accelerate the secondary succession process, provided post-seeding management is geared towards facilitating species richness, including optimum (low) soil nutrient status and optimum defoliation frequencies (fire and/or mowing and/or non-selective grazing). Management should be geared towards avoiding dominance by grazing resistant species that resist invasion.

Improving biodiversity and related ecosystem services by sowing high-diversity seed mixtures of native plants in vineyards

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Wine is one of the most intensive forms of agricultural at present. In Germany, inter-row vegetation usually consists of 90% perennial ryegrass and 10% white clover with every other inter-row left open to reduce evaporation, but this increases erosion risk and desiccation. Biodiversity in these vineyards is low. Within the LIFE-project ‘Optimizing Ecosystem Services in Viniculture facing Climate Change’ we tested the suitability of multifunctional native seed mixtures, aiming to reduce erosion and provide feeding habitats for wildlife. A block trial was implemented in mid-August 2016: two variants were sown with high-diversity seed mixtures (48 native species each), and one variant sown with a conventional ryegrass-clover mixture with every second inter-row open. Surveys were carried out from 2017-2019, comprising vegetation development, quantification of nectar and pollen sources, and abundance of wild bees and butterflies. Percentage of bare soil was used as proxy for erosion risk. Leaf-water-potential was measured with a Scholander-Pressure Bomb. Establishment of sown native plants was about 70%, even after three years. After the extreme drought in summer 2018, native plant variants recovered more rapidly than the ryegrass-clover variant. In autumn 2018, vegetation cover reached 45-50% on native
plant variants compared to 25% on conventional variants. Measurements of vine leaf-water-
potential revealed no significant differences between variants. Inter-rows sown with native
plants developed copious nectar and pollen sources and, therefore, significantly more wild
bees and butterflies were recorded. We concluded that sowing high-diversity mixtures of
site-adapted native plants is most useful to increase biodiversity and related ecosystem
services in vineyards.

Land use, ecosystems, and fire in the Mediterranean Basin

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Ecosystems and landscapes of the Mediterranean Basin (MB) have been deeply modified
and degraded for millennia through intensive and extensive exploitation. Over the last 50
years, extensive rural abandonment and land use changes in southern European
landscapes have led to dramatic increases in fuel load and continuity, and periodic
outbreaks of large forest fires. By contrast, the incidence of large fires is much lower in the
southern rim of the Mediterranean (North Africa) where rural areas are highly populated
and exploited. Burned area has actually been reduced during the last two decades in the
EU Mediterranean countries, except Portugal, but increased fire risk due to climate
warming and increasing forest fuels may reverse this trend. The MB has a long tradition of
afforestation to combat desertification and for timber production, especially using native
pine species. MB post-fire management tends to be proactive, often oriented to control soil
erosion and excessive runoff, and to promote forests. Extensive land abandonment has
favored the expansion of fire-prone shrublands and pine woodlands, often generating
short-term fire degradation loops. Canopy fires in serotinous pines usually result in
overstocked stands that may transition to shrubland if a new fire occurs before pine
maturity. In open woodlands dominated by oak species, where fires are less frequent, pine
trees have been introduced or invaded in recent decades. This development changes the
fire regime and increases fire risk. New pre- and post-fire management approaches are
discussed to face these land-use-change driven fire risk challenges.

Planning and implementing restoration projects from a social-ecological systems perspective - which aspects should be included on the “social” side, and when to consider them?

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Ecological restoration encounters in its practice a diversity of social, economic, cultural, and
political aspects that can be decisive for project efficiency and success. All restoration
activity takes place in a larger socio-economic political context, constituting, for example,
drivers and barriers for its realization. Using an encompassing social-ecological systems
(SES) perspective has been suggested in order to improve restoration planning and
implementation, and to promote ecosystem and community resilience. However, taking
such a SES perspective can add up to a very complex picture with a high level of
uncertainty about which aspects to include on the “social” side of this framework and
when to give them ample consideration in the restoration process. We will build on
different kinds of quantitative and qualitative data to shed more light on these questions: 1) data from a national online survey of all restoration activities (in all habitats) in Norway
since the year 2000; 2) case studies on river restoration projects in Switzerland, alpine
heathland restoration in Norway, and grassland restoration in Germany; and 3) a national
survey on river restoration in Switzerland. Based on this data from Europe and
international research literature we propose an SES framework with explicit social, cultural, political, and economic aspects that can help to address them in the respective planning and decision-making phases for projects in different contexts.

**Inspired by nature: Using wild populations to inform rare species translocations and evaluate success**

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Translocations are an increasingly utilized tool for rare plant conservation, as habitats continue to be fragmented or degraded. However, knowledge gaps in a species’ basic ecology can lead to failed attempts at translocations. Wild populations provide a priori knowledge of a species’ basic biology and ecological requirements to help inform translocations. In the heavily fragmented Florida scrub, translocations are recommended as a key step towards recovery for many listed species, including the federally endangered Dicerandra christmanii (Lamiaceae). In 1994, we began monitoring the only protected wild population in permanent plots. Using 16 years of a priori information from ~ 3,300 plants, we designed two experimental translocations (an augmentation and introduction). Here, we determine if translocations share similar vital rates and trajectories as wild sites. Mean annual survival was similar among wild (76%), augmented (74%) and introduced (76%) cohorts. Mean relative growth rate of wild and augmented cohorts were 0.556 and 0.599, respectively, but 0.922 for introduced cohorts. A significant interaction between site and plant age for both survival and relative growth indicates differing patterns in these two demographic metrics. Recruits in the introduction flowered earlier (1.67 years) and were larger (mean branches 28.9; flowering branches 10.1), compared to augmented (age 2.11; branches 19.9; flowering 5.7) and wild (age 2.37; branches 22.8; flowering 5.0) plants. These data suggest vital rates of translocations are comparable or higher than wild sites. Translocations may be viable options for species recovery but continued monitoring and analyses will add insights into the mechanisms for translocation success.

**Monitoring, evaluation, reflection, and learning: Transforming M&E into reflexive learning and adaptive management within restoration**

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Restoration programs in complex social-ecological systems face a conundrum in terms of monitoring and evaluation (M&E). On the one hand they need to report to donors or higher-level structures using indicators and targets. However, targets are notoriously difficult to set because of the unpredictability inherent in these contexts, so people ‘play the game of numbers’ and approach M&E as a quantitative tick-box exercise which does not encourage learning or, even worse, is met with resentment. Despite good intentions, M&E systems often end up being focused on accountability or compliance at the expense of learning. In this talk we present our experiences with transforming M&E to enable, rather than stifle, learning and adaptive management within restoration practice in the Olifants and Tsitsa catchments in South Africa. Innovations include the use of mixed modalities (including quantitative and qualitative monitoring, case-based evaluations, and conceptual work), promoting ongoing reflection through multiple means (including reporting processes and various kinds of learning events), and linking ongoing learning to planning processes so as to build in change as appropriate. We conclude that it is not only specific features of the M&E design that enable learning, but also the disposition of the people who animate the system. Our work provides evidence for the value of adequately resourcing the monitoring, evaluation, reflection, and learning function at catchment or landscape levels - to support scientists and managers to expand their roles, develop new relationships, participate in sense-making and engage in transformative social learning.
Mountain Catchment Area restoration as an extreme sport: A case from South Africa

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Despite major investment in state-funded clearing, IAPs (Invasive Alien Plants) continue to spread in South Africa's Mountain Catchment Areas (MCAs) posing considerable threats to biodiversity and water resources. There is need for both improved monitoring and evaluation of clearing operations as well as for strengthened involvement of MCA stakeholders, including those who use MCAs for leisure. One of the ways for the leisure stakeholder group to contribute is in cutting down IAPs, commonly referred to as “hacking”. Building on the decades-long hacking tradition of the Mountain Club of South Africa, hacking is being explored as an adventure sport in its own right, with the thrills, challenges, and fulfilment of other adventure sports such as sky running and wild fly fishing. The satisfaction in ascending a mountain, reaching a difficult-to-access tree, and making a clean cut compares with the satisfaction of landing a fish for which you have had to work hard to catch. Hacking also offers an all-over body work out. A case example in the Klein Swartberg Mountains, Western Cape, South Africa, is described, where three hackers participated over a one-year period in hacking as a weekend leisure activity. The hackers cleared over 1000 ha, while at the same time keeping records of location, species, and size class of the cleared trees. The case demonstrates that sport hackers have a potentially very useful contribution to make in clearing areas with low IAP infestation levels and assisting in identifying higher infestation areas for the focused attention of state-funded clearing teams.

Restoring degraded tropical forests through watershed management: A case study from Lokkere Reserve Forest

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Degraded ecosystems are deficient in both biotic and abiotic elements, including soil and hydrologic elements. These ecosystems have low vegetation cover and high soil exposure, leading to poor soil quality and water absorption capability. Water run-off during monsoons causes soil erosion and loss of topsoil impacts plant recruitment. This adverse cycle impacts resilience of the overall ecosystem and makes natural recovery difficult. This presentation discusses a watershed management approach to address these issues, implemented over the last five years in a scrub forest ecosystem adjacent to a major tiger reserve in South India. The project site covers 100 ha with a mix of hilly terrain and valleys, characterised by low vegetation cover, high soil erosion, and annual rainfall below 900 mm. Restoration objectives were to arrest and reverse soil erosion, improve water holding capacity, and revive grass and shrub cover. Mapping of the watershed at the landscape level helped to understand hydrological flows. Erosion control measures included gully plugs and contour trenches. Additional ground water enhancement was through check dams across streams. Innovative methods included saucers for grass revival and short trenches for naturally recruited juvenile plants. Seed dispersal and sapling plantings were also conducted. Main outcomes are a reversal of erosion, increase in grass and shrub cover, and revival of pioneer tree species. Vegetation monitoring is done against reference plots. Soil analyses indicate improvement in quality. Insect and bird surveys and monitoring of other fauna indicate good rewilding success. Involvement of indigenous community members enhanced project success significantly.

The decade of ecological restoration: Plans for required urgent synthesis of restoration across ecosystems and treatments

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113
The recently declared ‘Decade on Ecological Restoration’ by the United Nations represents a timely opportunity to develop a strong and integrative path forward for ecological restoration. One of the most effective ways to do this is to create a living data repository where restoration successes (and failures) are collated and made freely available to researchers and practitioners alike. Restoration has been taking place for decades across ecosystems, in every part of the world, with millions being spent. Different types of restoration ‘action’ have been taking place, depending on the definitions and targets of individual projects and their context. Data collected are used for monitoring, the results of which are sometimes published in academic journals, sometimes not. Projects and investment will continue, the results of which will affect legacies for decades more. We are in the process of developing a large, cross-cutting and collaborative effort to compile data from across the world, across ecosystems and across restoration efforts and types. We plan to publish an open-access data paper, maintain and grow the database as other efforts join, and lead the syntheses of these data in order to move forward into this dawning decade with an idea of what works and doesn't, what constitutes success, and major lessons learned. We invite anyone involved in restoration, in any corner of the world to join us on our mission and donate existing data to be a part of an effort to quantify success and synthesize the future of ecological restoration.

Prioritization of the restoration species pool to maximize restoration outcomes

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It is worth thinking critically about which plant species are appropriate to use for restoration treatments and why. Can we restore targets for not only diversity, but also for supporting ecosystem services and function? Can we be more effective in selecting species for particular targets to maximize desired outcomes and minimize inputs? Our study suggests we can. Here for the first time, we applied decision support software, to prioritize plant species by maximizing the provision of plant traits that enable ecosystem functions in order to compile optimized selections of plant species for restoration treatments. Using European alpine grasslands as a case study, we identified and prioritized plant species to meet restoration objectives that support and may accelerate regeneration. We compared the prioritized species selections to that of selecting plant species for biodiversity (systematically selecting one plant species of every taxonomic family or genera), for dominant species, and for selecting species completely randomly. Our results suggest that the functional identity of plant species matters more for ecosystem function than the number of species. This novel framework transcends that of a case study, and may be applicable to any initiative, in any habitat, seeking to apply quantitative decision making to ecological restoration objectives so as to optimize the provision of desirable ecosystem functions or targets. You can prioritize anything that can be measured, and this approach has an exciting range of potential applications to restoration and conservation. We present a simple proof of concept but suggest approaches to practical situations.
African Forest Landscape Restoration (AFR100) Initiative: An introduction to the commitment to restore 100 million hectares in Africa by 2030

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Degraded land has a cost both to local people and national economies, contributing to the escalation of natural disasters such as flooding and erosion and exacerbating social conflict as people seek better access to food and water. Restoration of productive landscapes in Africa can help lift people out of poverty, stabilize food production, protect biodiversity, help African economies grow, and contribute to adapting to and mitigating climate change. The African Forest Landscape Restoration (AFR100) Initiative is a country-led effort to restore 100 million hectares of deforested and degraded landscapes across Africa by 2030. The initiative seeks to build on field support, capacity building and policy advice to restore forests and landscapes on the ground, promote large-scale FLR, and leverage additional resources for FLR, share FLR experiences and monitor FLR results. Since its launch in 2015, AFR100 has successfully catalyzed political will for restoration, with half of the African continent now committed to the initiative. A network of 28 technical and 12 financial partners supports this effort. Impact investors have earmarked USD 481 million in private finance for restoration and USD 1 billion in development finance has been committed. As AFR100 nears its goal, strategic and streamlined implementation is the path forward. The presentation will provide an overview of the Initiative with special focus on outlining the FLR principles and engagement with various stakeholders. A few examples will be provided to illustrate how, FLR, when supported, improves livelihoods and boost economies in Africa.

The land ethic, restoration, and me

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Ethicists and conservation biologists have long debated the role of humans in nature. One extreme holds humans as outside the natural realm while the other extreme considers humans one with nature. In this talk, I argue for the latter, simply because I see no juncture during evolutionary history when humans made a jump from being part of their ecosystems to being an outsider that merely uses ecosystem services (though the dawn of agriculture is a possibility). Restorationists especially must grapple with the question of if and/or how to take humans into account when locating and designing ecological restorations. Aldo Leopold’s essay, “The Land Ethic”, provides direction through its emphasis on the interdependence of biotic (including human) and abiotic actors, but leaves unanswered the larger question of landscape: where is ecological restoration appropriate? Some argue that it is a waste of resources to restore parcels that are too small to be self-sustaining, but this excludes human participation and ignores the societal role in sustainability. Also sacrificed in this view is the reciprocal value of restored areas to humans. City planners have long understood the value of trees and parks in urban landscapes and such refuges from agricultural pesticides may also prove valuable for imperiled insects, such as the US endangered Rusty Patched Bumblebee. Increasing the opportunity for interactions between humans and other aspects of nature, including making humans active participants in restoration within their communities, can produce feedbacks that heighten appreciation for our shared environment.
Patience or intervention? Identifying the best strategy for weed control during grassland restoration

Diane Larson1, Pauline Drobney2, Sara Vacek3, Jennifer Larson4

Most practitioners of grassland restoration realize that the first few years of a new reconstruction on former cropland are fraught with anxiety-producing, vegetative manifestations. We can be certain that many weedy annuals will be outcompeted in short order, but what about species that are known to be troublesome in the long-term? When is it reasonable to trust in the power of the species we are nurturing to fend for themselves, and when should we intervene? We addressed these questions with a geographically extensive, long-term experiment. Results of nine, experimental, tallgrass prairie reconstructions initiated in 2005 and monitored through 2015 on U.S. Fish and Wildlife Service land in Minnesota and Iowa, USA, have suggested that patience pays with respect to most invasive forbs (e.g., Cirsium arvense, Carduus acanthoides, Sonchus arvensis, Daucus carota) that quickly invaded new reconstructions but declined within the first five years. The same cannot be said for cool-season, invasive grasses (e.g., Bromus inermis, Poa pratensis), which invaded more slowly but were still increasing 10 years after reconstruction. The ratio of forbs to grasses planted during reconstruction can influence secondary invasion. Plots with highest planted-forb richness were most likely to compete well against invasive forbs but were also the most susceptible to the invasive grasses. Knowing when to expect various benchmarks of invasion resistance can help managers and practitioners better judge when to have patience, and when to intervene.

Utilising quarries to propagate threatened species and promote agroforestry strategies towards enhancing biodiversity, ecosystem services and community resilience in Ghana

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Quarry activities can potentially have both direct and indirect impacts on biodiversity and habitat. They can also provide a good opportunity to restore critical habitats or create new ones. Broad landscape restoration has often-recognised habitats as a special mechanism for maintaining ecosystem services. Even in protected areas, where sometimes special protection is required for populations of endangered species, artificial regeneration and other agroforestry tools can assist conservation efforts. This is important in sustainable agriculture and building resilience for communities that depend on these resources. The Ghana Wildlife Society has been working in partnership with the Ghana Cement Manufacturing Company to secure ex-situ conservation of the remaining stands of Talbotiella gentii, a critically endangered leguminous tree species in the Yongwa Forest Reserve, within proximity to one of Ghana Cement's operational quarries. In Ghana, T. gentii is highly threatened with extinction due to anthropogenic activities such as cutting for charcoal and wildfires. In the past, propagation trials conducted with T. gentii yielded minimal tangible results on the ground. This paper presents the results of propagation trials of T. gentii towards raising seedlings to promote species recovery in the extant tree populations in the Yongwa Forest Reserve. To explore the optimum conditions required to raise healthy seedlings for forest restoration activities, propagation trials were conducted under different biotic and abiotic regimes. This paper further sheds light on lessons learnt from agroforestry strategies conducted in engaging communities and the public sector to increase their participation in forest restoration activities and building their resilience.
A decision framework for restoring kelp beds: A case study in eastern Tasmania
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Kelp beds are among the most productive and biodiverse habitats on earth and provide a raft of products and other services to humans. In many parts of the world kelp beds are declining or being lost due to climate change and other anthropogenic drivers, however whether it is sensible to attempt kelp-bed restoration depends on the nature of drivers causing their loss and the magnitude of hysteresis in the ecological dynamics of these systems. We present a workflow to guide decision making for kelp bed restoration in which recommending not to attempt restoration is a possible outcome. As a case study we apply this decision framework to the possibility of restoration of kelp beds in eastern Tasmania, Australia. This region has experienced ~95% loss of giant kelp (Macrocystis pyrifera) forests, primarily as a result of climate change, while extensive destruction of beds of the common kelp (Ecklonia radiata) is the result of overgrazing by sea urchins (Centrostephanus rodgersii) to form ‘urchin barren grounds’. Restoration of giant kelp depends on identifying warm-tolerant genotypes and establishing ‘seed’ populations of minimum threshold size. Rehabilitating urchin barrens to kelp beds includes a range of management responses to reduce urchin numbers on barren grounds, but because of the magnitude of hysteresis in the ecological dynamics it is critical to use expensive interventionist technologies to remove the urchins at scale, e.g. deployment of ‘smart’ robots (autonomous underwater vehicles).

Feasibility and limitations of passive restoration
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As the result of analysis on landscape change occurring in the Korean DMZ where human entry has been thoroughly restrained for more than 60 years, we found that most of the former rice paddy areas recovered to form riparian forests. The result of stand ordination-based vegetation data obtained from riparian ecosystems of the DMZ, rural areas, and urban areas showed that riparian ecosystems of the DMZ have different riparian vegetation types from those of the other areas. Similar processes were found in the abandoned rice fields as well. Establishment and development of plants introduced for reforestation in tree planting projects to reforest mountains denuded due to excessive use and war contributed to erosion control and thus led to development of soil. Further, such improvement of environmental conditions caused vegetation to become more similar to natural vegetation and increased species diversity. Those plantations were monocultures and composed of rows of planted trees. In this respect, the project achievements could be recognized as passive restoration. As the results of analyses on the forest vegetation around the Yeocheon industrial complex, Korea, grassland and/or shrubland began to appear by the mid 1970’s when the industrial facilities began operation there. These vegetation types increased their occupied area until the mid- 1990’s. But the vegetation has shown a reverse trend since the 2000’s. Woody plants and trees began to appear in the grassland and shrub-land, respectively, and thereby passive restoration is in progress. But the speed of recovery was very slow compared to actively restored sites.

Prioritising restoration measures to protect ecosystem services in the Western Cape
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The Western Cape Department of Environmental Affairs and Development Planning commissioned a study aimed at guiding investments in ecological infrastructure (EI) so
that they increase social-ecological system resilience. This presentation reports on one component of this study which prioritised EI for investment in restoration and protection. Stakeholder workshops were held to identify the key EI and to prioritise the threats to the delivery of benefits from that EI, including alien plant invasions, inland water ecosystem degradation and rangeland degradation. The workshops formulated a vision for this investment: By 2040, people of the Western Cape live and organise themselves in a way that promotes healthy and resilient ecological infrastructure, so that it yields goods and services that support physical, psychological and spiritual well-being in the face of population pressure, rapid urbanisation and climate change. The prioritisation focused on the biophysical factors, identifying catchments where high yields of benefits are coupled with societal demand for those benefits and where degradation of EI places those benefits at risk. The study divided the province’s catchments into 6 clusters based on their biogeographical characteristics and how these determine the suites of benefits. A multi-criterion modelling system was used to identify priority areas for different benefits within each of the 6 clusters and for the province as a whole, with a strong emphasis on water and livelihood security.

Collective exploration of the impact of restoration in the Baviaanskloof through the lens of the Water, Energy, and Food Nexus

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The Baviaanskloof catchment in the Eastern Cape of South Africa encompasses the Kouga and Baviaanskloof mountains and is comprised of private farms surrounded by the largest wilderness area in South Africa. The catchment is a source of water for the agriculturally significant Gamtoos Valley as well as the Nelson Mandela Bay municipal area. As part of the Cape Floristic Region, it boasts an enormous botanical diversity and forms a meeting place of different biomes. Decades of overgrazing from goat farming has led to massive vegetation loss and soil erosion. We employ the 4 returns framework for large scale ecosystem restoration: each restored area provides inspirational, social, and natural returns to bring down the risks for a sustainable financial return. This transformative model combines ‘restoring’ people’s inner drivers and purpose seeking to concrete ecosystem restoration on the ground, based on business cases, using a landscape zoning approach and the Theory U (Otto Scharmer) as a stakeholder management tool. We aim to address ecological challenges such as water retention, social challenges such as effective governance and economic challenges such as diversification of income. Through participation in this session we will further explore the impact of our work in the Baviaanskloof through the Food, Energy, and Water Nexus lens. We will share examples illustrating the benefits and avoided the costs of restoration interventions, highlighting the interlinkages we have observed within the Food, Energy and Water Nexus.

Strandveld restoration within a complex mosaic in the absence of large herbivory

Zurelda Monique Le Roux
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The Atlantic Beach Conservation Area (ABCA) comprises of 36 ha of Cape Dune Strandveld within a high-income residential area and a golf course mosaic and is an important ecological corridor between two nature reserves. The site is extremely fragmented, consisting of strips of Strandveld alongside the golf course and in between houses. Ecological drivers of the system, such as large herbivores, are no longer in action and as a result the vegetation has come to be dominated by certain bush species that impact recruitment of annual plant species, reducing overall biodiversity. Furthermore, the spread of alien vegetation such as kikuyu grass (Pennisetum clandestinum) influences the natural vegetation cover. In order to mimic herbivory, manual clearing of dead, overgrown, and
Alien vegetation is done as part of the regular management interventions. Whilst illegal activities by people who wander into the conservation areas are deemed unacceptable, such activities may mimic minor disturbance activities. The Strandveld system has evolved with local disturbance events caused by the action of indigenous mole rats (Bathyergus suillus), which displace up to 6 tonnes of soil in a year. However, both natural and anthropogenic activities can be detrimental to the active restoration areas where disturbance is undesired. In line with an international shift by golf courses to reduce the expanse of fairways as cost and water-saving measures, there is potential to expand the buffer between the golf course and the conservation areas and the dilemma exists as to what these areas should be used to vegetate these areas.

**All roads lead to Rome: Convergence in the woody community assembly of different tropical forest restoration systems after 20 years**

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The capacity of planted species for promoting the natural regeneration of native species during restoration of tropical forests has been emphasized in many studies over the last few decades. It is believed that differences in the composition and structure of the canopy will lead to different assembly trajectories in the regenerating community by changing biotic and abiotic filters. We compared the woody vegetation (trees, shrubs and lianas) colonizing seven different active restoration systems (ranging from 5-40 tree species being planted), in two sites with contrasting soil fertility and landscape characteristics, established 20 years before. A reference forest fragment near each experimental site was also surveyed. We included all individuals with DBH (diameter at breast height) ≤ 5 cm for trees and ≤ 3 cm for climbers. After 20 years, the restoration system and sites showed differences in forest structure, yield, and species diversity for the canopy species. Nevertheless, restoration systems had no effect in the structure and composition of the natural regeneration community, either for bush/tree species and lianas. The number of tree species regenerating within the plots ranged from 93 to 126, plus 40 species of lianas. We found remarkable differences for trees and lianas only between sites and between restored x reference forests. We concluded that site and landscape effects are stronger than restoration design for community assembly, and planted trees might have a major role in changing abiotic filters. These findings have implications for the design of restoration systems for tropical regions that might accomplish multiple services.

**Community asynchrony rather than climate change determine the temporal stability of plant community biomass: A 20-year experimental study in eastern Qinghai-Tibet Plateau**

Shuai Li

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Climate changes have the potential to influence the temporal stability of plant community biomass in Qinghai-Tibet Plateau, but most studies were based on short-term field climate manipulation experiments, the response of biomass stability of natural alpine meadow remain largely unexplored. We conduct a 20-year experimental study in eastern QTP with linear regressions and a path analysis of annual temperature, annual temperature range, annual precipitation, annual precipitation distribution, biomass stability of grass, biomass stability of forb, community asynchrony to assess the influence climate change and biological factors on the temporal stability of plant community biomass, we find that it was community asynchrony rather than climate change determine the temporal stability of plant community biomass and alpine meadow ecosystems are resistant to climate change. Our findings suggest that future climate change may have considerable uncertainty about
the temporal stability of plant community biomass in the alpine meadow and we should combine with both field climate manipulation experiments and long-term observational experiments to assess the influence of climate change on the temporal stability of plant community biomass.

Grassland conservation and restoration in China: Achievements and outlook

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China's grassland area is nearly 400 million hectares, which is the largest green ecological area in China. The Chinese Government pays high attention to grassland conservation, makes it an important part of building ecological stability, and has continuously increased its support. In accordance with the requirements put forward by Chinese President Xi Jinping to coordinate the management of mountain, river, forest, farmland, lake, and grassland systems, we have taken a series of measures to strengthen grassland conservation and restoration and have achieved obvious results. The tendency toward ecological deterioration of grasslands in China has been initially curbed, the grassland ecological environment has gradually improved, and the utilization of grassland resources has become more reasonable. But at the same time, the grassland ecosystem in China is still fragile, and the situation of grassland degradation in some places remains grim. We need to continue to maintain strategic confidence and continue to strengthen grassland conservation. Next, we will take the following measures: first, enhancing top-level design by improving policies, amending laws, and conducting long-term planning; second, strengthening the management of grassland resources according to laws; third, implementing more grassland restoration projects; fourth, promoting rational use of grassland resources; fifth, strengthening grassland monitoring and improving grassland statistical systems; and sixth, increasing the investment in grassland science and technology. Meanwhile, we will strengthen cooperation with relevant countries, share and exchange successful experiences in grassland conservation and restoration, actively participate in global ecological governance, and jointly build a better home for mankind.

Pursuing sustainable land management through community development: UNDP/DEA GEF 5 Sustainable Land Management project in South Africa

Lehman Lindeque
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Arresting degradation across 1.5 million hectares of degraded land in South Africa is critical for ensuring ecosystem integrity, productivity and continued benefits to livelihoods. Through the project “Securing multiple ecosystems benefits through Sustainable Land Management (SLM),” funded by the Global Environment Facility 5, we aim to reduce the costs of ecological restoration in South Africa and increase land productivity. An innovative approach is adopted to sustain long-term SLM solutions that foster community development. We note that project staff must go through huge efforts to build trust with communities, understand the underlying social ecological systems that characterise the landscape, and identify the reasons for system failure that lead to vulnerabilities towards SLM. Based on project implementation between 2016 and 2019, we highlight two important lessons learned towards achieving interconnectedness between SLM and community development. Firstly, the importance of buy-in. Understanding community dynamics allows us to avoid a potential disconnect between technical project staff and local community members and land users. This is key to achieve real and sustained impacts on the landscape. Secondly, the use of the “Champion Farmers Model”, where farmers participate in a peer-to-peer learning environment. This model allows us to make the most of local knowledge, which in turn is used to mobilise communities towards
collective SLM action in the project's landscape. Ensuring sustained project impact on the landscape and on people's livelihoods is a key challenge of development agencies. This project demonstrates that interconnectedness between SLM and community development is a key and achievable pre-requisite for success.

The new generation plantations social learning curve

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Improving governance is the first step in any restoration, because poor governance is driving degradation. People are therefore at the heart of both degradation and restoration. Any transformation designed to tackle the drivers of degradation requires a meaningful social process to support it. Over the past 10 years, NGP has used the social learning approach to bring different people together with different values, beliefs, ideologies, and world views. Through running week-long study tours in the field, it has taken participants on dialogue-based learning journeys. This has changed HOW participants work with their own staff, with other organisations on non-competitive sustainability issues, and importantly with their external stakeholders. This has resulted in improved landscape stewardship with a positive impact of how plantations are managed and natural forests restored. Social learning is a type of informal adult learning, suited to working with multiple stakeholders with different opinions and world views, which form the context of the complex world we live in. It is an approach that develops human agency – the ability and power people have to think, reflect, and act – that is critical to tackling the drivers of degradation. Social learning can be an approach to collaboratively bring together all landscape stewards to develop a common understanding of the causes of degradation, and co-construct stronger governance solutions. NGP is using its social learning experiences in Africa, South America, and Asia by supporting landscape stewards to develop their agency to collectively improve forest governance and accelerate forest restoration.

Selection of suitable plant species for alpine meadow protection near an open-pit copper mine in Tibet

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The open-pit mining of copper mines has brought tremendous economic benefits to Tibet while seriously damaging the local alpine meadows. This study describes an effective approach to select suitable plant species for reducing interference from mining in the Qulong copper mine in Tibet. We compared soil variables, vegetation structure, and floristic composition along different gradients (10, 50, 100, 150, 200, 250, 300, 400 m) from the mine. Soil variables showed a general trend over the gradient of increasing soil organic matter, total carbon, and nitrogen, but a reduction in soil pH, Cu, As, Cr, Ni, and Pb. Most of the heavy metal content exceeds the background value of the region, which means that all the samples have been contaminated with heavy metals from mining activity. It also suggested that the impact of copper mining on the surrounding ecological environment is over 400 m. Non-metric multidimensional scaling analyses revealed that great differences in vegetation community composition existed in the sampled plots, even those at similar distances from mining areas, which indicates that disturbance distance was not the only factor to determine the vegetation community. The results of Canonical Correlation Analyses showed that Cu was the main soil variable affecting the vegetation diversity in this region. Malva sylvestris, a perennial erect herb, had the highest tolerance to Cu. The use of Malva sylvestris to isolate the mining area from the fragile alpine meadow area is an effective method to reduce the damage of mining to the regional ecosystem.
Incorporating community participation and native plant resource conservation with degraded subtropical forest restoration

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Forest degradation is a global issue and occurring at a rapid pace, especially in subtropical and tropical regions. Therefore, much effort is needed to restore the degraded forests by a multidisciplinary perspective including biology, socioeconomics and policy-making with participation of all stakeholders. Recently, a program was launched in Heshan County, located in subtropical China, financially supported by Botanic Gardens Conservation International. The program aimed to restore the degraded subtropical forests through local community participation and native plant resource conservation. Participatory Rural Appraisal can be used to identify problems and constraints to forest rehabilitation. The major causes of forest degradation in the study area are intensive disturbance caused by human activity and simplification of the forest community and species composition. This problem can only be addressed by reducing the farmers’ economic dependence on the forests and restoring the degraded forests with native species of high ecological and economic values. We developed three restoration strategies: (1) Restore the seriously degraded abandoned hilly land by establishing fast-growing plantations; (2) Rehabilitate the degraded ecological forests with native rare tree species of high economic and conservation value; (3) Develop “understory economics” with native understory species of high economic and conservation value in degraded commercial forests. The degraded forest rehabilitation with the above strategies can improve local community's understanding about the importance of forest ecosystems and wild plant resources from the ecological and economic perspective and raise their awareness of environmental protection and plant resources conservation.

A cost-benefit analysis of river restoration in Switzerland

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River restoration is gaining momentum worldwide despite the high investment costs involved. While the economic valuation of river restoration has received substantial attention in the literature, cost-benefit analyses of river restoration are rare. Switzerland plans to restore 4000 km of rivers by 2090. Such an ambitious objective has put Switzerland at the forefront of river restoration efforts. Despite the immense investment costs, river restoration benefits have not been valued in monetary terms, and a cost-benefit analysis (CBA) does not exist for any river restoration project in Switzerland. We apply stated preference methods (choice experiments and contingent valuation method) to elicit public preferences and willingness to pay for restoring two specific but representative river sites. The benefits of restoration are compared with its costs. Upscaling the results to the national level shows that the government budget allocated for river restoration (CHF 1200/m) is insufficient to cover the costs of local restoration projects. However, the surveyed local populations are willing to pay substantially more for restoring rivers in their area of residence than they are legally obliged to do. The CBA results demonstrate that the benefits outweigh the costs in the two case studies, and hence that restoration efforts are justified from an economic point of view. A sensitivity analysis shows that the main results and conclusions do not change when we change some of the key assumptions underlying the CBA. We believe that these findings are also relevant in the international context.
Methods for estimating the total economic values of accelerating restoration: Results for Washington's Elwha River after dam removal

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At an increased cost, ecologists can increase the rate and spatial extent of restoration and thereby accelerate the provision of ecosystem services. In order to justify the increased costs, we estimate the Total Economic Values of ecosystem services (TEVs of use and passive/non-use values) associated with alternative rates of restoration after dam removal on Washington’s Elwha River. TEV was estimated for two distinct restoration projects of: (1) native salmon; (2) riparian forests with associated wildlife. TEV of both projects is measured at three different restoration rates: (a) baseline recovery at no added cost; (b) moderate habitat restoration at medium cost levels; (c) extensive restoration actions at the highest cost levels to households. Washington households would pay a one-time $283 to moderately increase and $332 to substantially increase native salmon restoration beyond the baseline rates. Oregon’s households would pay a one-time $236 to moderately increase and $321 to substantially increase native salmon restoration. This pattern demonstrates that households in both states value increasing the rate of restoration. In addition, the Oregon results demonstrate that there is significant value of restoration even at substantial distances away from Washington’s Elwha River. Lastly, to increase the rate and spatial extent of riparian forest/wildlife habitat restoration, households in both states would pay an average one-time $257. This research demonstrates that the public values and would pay for accelerated restoration. In addition, measuring the full benefit of restoration requires that surveys not be limited to population centers immediately adjacent to the restoration site.

Curbing inexorable attrition of Albany Thicket: Working towards coordinated approaches and solutions

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Avoiding degradation is the preferred approach towards meeting the Land Degradation Neutrality (LDN) targets of the UNCCD. In South Africa’s Albany Thicket Biome, the inability to control illegal transformation of the thicket and poor understanding of the thicket’s value has resulted in >50% transformation and severe degradation. As it is a threatened ecosystem, avoiding degradation and transformation is a key responsibility of national and provincial governments. However, lack of resources and institutional capacity continue to limit effective action toward rapid and illegal land use change within the agricultural sector. After a desperate plea for assistance and the injection of funding from the national government, coordination between researchers and environmental law enforcement focused attention towards addressing activity on the ground. A three-pronged approach was developed and implemented in three landscapes. This included: 1) sub-catchment regional fine-scale mapping of thicket cover and change, 2) providing land owners with maps and surface area values of thicket extent as a baseline against further transformation, and 3) quantifying illegal transformation at farm-level to assist law enforcement with compliance and prosecution. We believe that along with combination with conservation planning, future real-time thicket monitoring and hosting workshops with landowners and the agricultural sector, the rate of thicket loss can be reduced. However, while effective in meeting immediate needs of law enforcement and highlighting a seemingly inexorable problem, addressing governance issues, resource constraints, sector demands, and the
perception and value of the thicket are crucial to establishing sustainable solutions toward securing persistence of the Albany Thicket Biome.

**Restoration as biocontrol: Mass-ratio or diversity-invasion theory as the guiding principle?**

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Climate change and invasive species present significant barriers to restoration. Contrasting evidence from investigations into how diversity and species abundances influence invasion processes raise the question of whether land managers should restore for diversity or monocultures of high biomass species. In this study, we assessed the effect of restored perennial grassland species richness and composition on invasive species re-establishment in a calcareous, savannah ecosystem in central Texas, USA. The study also became a test of the effectiveness of restoration with climate change, as during the establishment phase (2010-2011), 88% of Texas experienced “exceptional drought” conditions. We hypothesized that invasive species re-establishment would be slowed at higher levels of restored species diversity and in plots with species with high initial biomass. We employed a two-way factorial experiment in a randomized complete block design where richness (1-4) and native species composition were manipulated in 1 x 1 m plots. All possible species combinations were included at richness levels 2 and 3 with four replicate blocks. We found that suppression of the invasive species was greatest in monocultures of the dominant native species but that suppression at the four-species treatment level was on par with this monoculture. We also found that complementarity (diversity-invasion hypothesis) operates to reduce invasive species re-establishment and that the abundance and suppressive effect of the dominant species may be reduced at intermediate levels of richness (i.e. 1 and 2 species). For each system, optimal monocultures and richness levels need be assessed.

**Biological responses to aeration in an estuarine canal with fine-grained organic-rich sediments**

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Fine-grained organic-rich sediment (FGORS), referred to as “muck”, is detrimental to the overall quality of estuarine ecosystems. One potential restoration technique is aeration, which generates fine bubbles to create overturning circulation. This process could increase dissolved oxygen concentrations, facilitating decomposition of organic matter and neutralization of toxic hydrogen sulfide. A pilot aeration experiment was carried out in a canal containing thick layers of FGORS in the Indian River Lagoon estuary (Florida, USA) to examine ecosystem outcomes. Biological responses (both phytoplankton and benthic infauna) were monitored throughout the aeration process and compared against control conditions in a separate canal to evaluate the feasibility and effectiveness of aeration for muck mitigation. The water columns were primarily composed of nanophytoplankton with the lowest algal density of $1.8 \times 10^4$ cells per ml during the non-bloom period and the highest algal density of $3.5 \times 10^6$ cells per ml during the brown tide (Aureoumbra lagunensis) in both canals. The water column was highly stratified during the summer, fall, and spring, as evidenced by distinct assemblages of phytoplankton near the surface vs. near the bottom regardless of canal site. With regard to the water column communities, depth distinctiveness persisted, apparently unaffected by aeration. In contrast, a benthic community developed in the aerated canal during cooler months and was significantly different from the depauperate un-aerated benthos (S-W Diversity index comparison, $p<0.05$ between the aeration and control canals in February 2018).
Assessing, with limited resources, the contribution of wetland restoration to ecosystem services supply

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Resources for evaluating the ecological outcomes of investments in ecological restoration are often limited. In order to rapidly assess the contribution of wetland restoration to the functionality of a wetland for supplying ecosystem services, a method has been developed based on the WET-EcoServices method. A set of indicators (e.g. hydraulic roughness of the vegetation) are rated on a five-point scale. Indicator scores are then combined in an algorithm that attempts to reflect the relative importance and interactions of the attributes represented by the indicators. In addition, the extent of the affected wetland area is recorded. Furthermore, supply is placed in the context of the demand for the ecosystem services, based on the number of beneficiaries and their level of dependency. Thus, the greater the increase in functionality over the wetland area for which there is a high demand for the ecosystem services, the greater will be the contribution of wetland rehabilitation in terms of ecosystem services. This provides a currency for comparing different wetland rehabilitation sites or scenarios within a site. Application of the method is illustrated by comparing five different wetland restoration sites in South Africa’s Working for Wetlands program, encompassing a diversity of land use contexts. At some sites the contribution to supply was much greater both in terms of the spatial extent of the wetland and the level to which the functionality of the positively affected area had been raised. However, this was often not accompanied by a correspondingly greater demand for the services at the site.

Dryland degradation as a social-ecological regime shift: A Sub-Saharan case study

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Drylands globally support over two billion people as major providers of critical ecosystem goods and services. However, drylands also represent places where the human population is growing most rapidly, biological productivity is least, and poverty highest. These ecosystems are therefore particularly fragile and vulnerable to shifting into a degraded state. This change in the structure and function of an ecosystem can be seen as a regime shift, impacting on the provisioning of vital ecosystem services as well as human wellbeing. In this study we identified the main drivers and impacts to identify leverage points to intervene in order to increase the resilience. We extracted information from the Regime Shifts Database and used Sub-Saharan Africa as a case study to identify the susceptibility of this world region to dryland degradation. Drivers related to harvesting natural resources and their consumption, vegetation conversion, and habitat fragmentation were the most common causes of regime shifts resulting in dryland degradation. Primary agricultural production and biodiversity are the most common cluster of ecosystem services affected along with provisioning ecosystem services such livestock and wild animal and plant products. This affects human wellbeing in terms of nutrition, livelihood, and economic activities. Maintaining the structure and function of the dryland system and increasing the resilience of this ecosystem relies on preemptive restoration and a better understanding of the social and ecological drivers. Using a systems-thinking approach will help us to understand these underlying patterns and prevent further dryland degradation.

Restored ecological infrastructure supports livelihood: Research provides the evidence

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The SDG: 2030, the Aichi Biodiversity Targets, Africa Agenda 2063, the NDP (2011), are just some of the high-level plans meant to tackle ecosystem degradation, thereby securing the services they provide to society. In-fact the World Economic Forum lists climate change resilience, water crisis, extreme weather events, biodiversity loss, right at the top of highest world risks. Unless these high-risk issues are dealt with sooner, the world population, particularly in developing countries will remain in abject poverty, unemployment, and inequity into the future despite the “ambitious” targets. The targets are driven by the extent of degradation which can no longer be tolerated, such as soil erosion, dam siltation, and alien and invasive plants. These targets can be met; however, a lot of resources are required to achieve the targets, especially those due in 2020! Ecological infrastructure (EI) is a concept which has not been taken up by policy and society, including business. Amongst the reasons is proof or evidence that it can secure water at catchment level if cared for. The Water Research Commission of South Africa in partnership with more than 30-organizations funded research projects in uMgeni and uMzimvubu catchments in order to establish facts behind the value played by the EI in water security. One of the key reports highlighting the evidence will be launched at the end of the ecological infrastructure symposium. This is a key policy document which should lead to Government recognition and uptake of the EI, similarly by business and society.

Use of seed enhancement technologies for overcoming abiotic and biotic limitations to native plant establishment

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Rangeland degradation and desertification is a global problem with many regions of the world experiencing declines in ecosystem goods and services and biodiversity. Often the only means of restoring these lands involves seeding with native species. The sagebrush steppe ecosystem of western North America is an example of a dryland system that is undergoing rapid ecological change as wildfires and other disturbances remove native perennial plant communities and convert the system to an exotic annual grassland. Land practitioners currently do not possess the tools needed to consistently reestablish native plants in these degraded landscapes. In this presentation, we will examine limiting factors impairing seedling establishment and show how seed enhancement technologies have the potential to overcome these identified barriers to restoration success. We will specifically share how seed enhancement technologies have the potential to improve seed delivery, protect seeds from predation and pathogen attack, improve seed germination timing, minimize mortality from freezing soils, preserve seed energy levels, and enhance seedling vigor to promote survival under drought conditions. These seed enhancement strategies have the potential to dramatically improve the effectiveness of seeding treatments that are intended to protect or restore the diversity and productivity of dryland ecosystems.

Incorporating biodiversity priorities in Natural Resources Management (NRM) prioritization at a national scale

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The Natural Resource Management (NRM) programmes of the National Department of Environment, Forestry and Fisheries are a series of different intervention programmes namely: Working for Water, Working for Wetlands, Working for Ecosystems, Working on Fire. A need to prioritize spatial areas for interventions was highlighted as an important exercise in order for the programme to efficiently focus and direct NRM investments. In response to this, a more integrative approach of addressing environmental challenges across the NRM programmes has been applied and spatial priorities have been identified.
for each of the nine provinces. The prioritization process was done at a quinary catchment scale, where all quinary catchments in a province were assigned a score based on their biodiversity importance. Catchments with high biodiversity importance were identified as priority areas for intervention. Areas of high biodiversity importance are also referred to as biodiversity priority areas. These are natural or semi-natural areas in the landscape that are important for conserving a representative sample of ecosystems and species, for maintaining ecological processes, or for the provision of ecosystem services. Incorporating these areas in the prioritization process not only aligns with the aims of the NRM programmes but it also ensures that priority is given to areas with high biodiversity importance. The presentation will highlight how biodiversity priority areas have been used systematically in identifying priority areas for NRM investment.

Stakeholders in Forest Landscape Restoration

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Understanding the diversity of stakeholders involved in large scale forest restoration is essential to success. Stakeholders may be categorised in many different ways, recognising that categories hide unique differences. In forest landscape restoration, each stakeholder may understand the approach differently, engage with it in diverse ways, be motivated by different benefits, and may use it for different outcomes. The purpose of this contribution is to better understand how different stakeholders can be categorised in forest landscape restoration (FLR), and what motivates them to engage in restoration. When dealing with landscapes or large scales, stakeholders can be found at many different spatial scales, and those involved in the restoration action may not necessarily be the ones benefitting or losing the most from restoration. Tools to incentivise restoration may be employed in the short term while failing to address fundamental governance issues. Power dynamics are an essential component in decision-making related to large scale forest restoration. Exploring some of the specificities of FLR helps to better understand the full range of issues associated with stakeholders. Examples from projects led by different sets of stakeholders (private sector, NGO, government...) will be examined as a starting point to highlight some of these challenges related to FLR implementation.

Back to the field! Open lesson learning is required to meet global FLR targets

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Lesson learning generates new knowledge that is particularly important in the context of recently developed approaches, processes, and complex systems with much uncertainty. One such approach is forest landscape restoration (FLR). Although grounded in a number of disciplines (e.g. conservation biology, landscape ecology, restoration ecology), FLR has remained very fluid and moulded to suit different stakeholders, from local to global. Today, many countries or organisations commit to implement FLR. Global commitments, especially following the Bonn Challenge on FLR (2011), aim to up-scale FLR to achieve social, biodiversity, and carbon benefits. However, the FLR approach is relatively new (less than 20 years), complex due to its multifaceted nature, and long-term field experience is still limited. FLR practitioners mainly learn by doing. That makes lesson learning particularly urgent. Combining learning theory and field studies from WWF's portfolio of long-term FLR projects worldwide, the paper proposes here a framework for lesson learning in FLR that can serve to ground both practice and policy in field experiences to date.
Palaeoecology as a valuable source of information for restoration practices in globally endangered habitats: A case study from a Mediterranean seasonal wetland

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Seasonal wetlands are small, shallow water bodies that are usually waterlogged during the rainy season only. They develop as a consequence of high phreatic levels, almost exclusively in areas under Mediterranean climate. Here, they represent highly diverse habitats, delivering important environmental services such as water provisioning and purification. This is key in areas undergoing summer drought. They are globally threatened by human impact and environmental change, making their restoration a priority. Seasonal wetlands represent potential palaeoecological archives and consequently are valuable records of environmental and land-use change capable of revealing their long-term ecological history. Here, a high-resolution multi-proxy case study from a seasonal wetland in the Western Mediterranean (Doñana National Park, southwestern Spain) is presented. The palaeoecological analyses (palynological, microcharcoal, magnetic susceptibility, loss on ignition and diversity analyses) reveal the intermittent development of ~300–500-year-long wetland phases along the last ~6900 years. The development of wetlands is linked to dune immobilization during humid periods, whereas during arid periods mobile dunes cover them. This suggests that geomorphological dynamism is the baseline state for this system, ultimately controlling wetland development and biodiversity. Restoration efforts here should focus on the management of Pinus pinea, (a keystone species associated to substrate dynamism) to promote the development of landscapes capable of maintaining wetlands under the current aridification trend. In conclusion, palaeoecological reconstructions, as here exemplified, can provide a link between long-term historical data, present landscape intervention, and future scenario projection for these endangered but yet of utmost importance habitats.

Spatially mapping target areas for planting trees to guide forested wetland restoration for optimum ecosystem services provision in the Wairarapa, New Zealand

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Wetlands are important flood control tools that store excess flood waters. Restoration of these ecosystems is critical to the maintenance of this key functional role. The restoration of formerly forested wetlands involves the re-establishment of trees (the main vegetation component), which is followed by a change in soil hydrology and the flood dynamics of the wetland. Trees generally increase water storage within the canopy, soil, and across the soil surface. This is important for flood mitigation in that it lowers the runoff rate and flood peaks. This role, can be determined by spatially and temporally varying factors, including antecedent soil moisture and topography, among others. Therefore, where trees are placed during restoration is critical for the success of wetlands as flood management tools. Information on the appropriate siting of trees becomes useful for the design of restoration strategies. A scenario-based modelling exercise using the Land Use Capability Indicator (LUCI) framework was carried out to support the analysis of the flood mitigation impacts of tree planting on areas of varying micro-topography in wetlands undergoing restoration in the Wairarapa, New Zealand. Areas that could potentially benefit from intervention for storage of excess flood waters are spatially delineated. This is important for guiding restoration of wetlands for optimum provision of ecosystem services.
Ecological restoration on large scale commercial Solar Development: Opportunities for habitat restoration and agriculture

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Renewable energy sources, including large scale commercial solar development, are quickly becoming integrated into electrical energy networks world-wide. Many of these solar projects are sites on degraded lands, sanitary landfills, former quarry and mine sites, or other degraded habitats that offer opportunities for ecological restoration and restoration as agricultural sites. This paper describes opportunities and the methods we and others have used to provide ecological restoration and improved stormwater management on large scale commercial solar renewable energy projects. We also provide examples of how solar energy and agriculture may be integrated to provide dual uses of energy and food production. When feasible, it is preferable to site new solar projects on previously developed or degraded locations. Within these previously developed sites, both internal and external restoration of grasslands and ecosystem habitat may be incorporated into the solar restoration plan to improve ecological conditions. For instance, a solar project was built on a former airport. The paved runways were removed, and planted with native grasses, thereby creating new habitat. Solar projects may be seeded with a combination of native grasses and wildflowers to control erosion, promote pollinators, and to provide habitat for wildlife. The inter-cropping of agricultural crops may be compatible with solar projects, as is the ability to graze livestock or maintain bee colonies. Examples of agricultural intercropping with solar projects is provided using examples from the United States and other parts of the world. Worldwide examples are provided of ecological restoration of degraded habitats at commercial solar sites.

Coastal bank and salt marsh restoration: Examples of low impact and soft engineering strategies

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This paper describes soil bioengineering techniques, living shoreline construction, and coastal marsh restoration techniques to stabilize eroding coastal shorelines and marshes. Although the examples provided are from North America, the innovative techniques described may be used to restore coastal shorelines worldwide. The use of native vegetation to stabilize eroded shorelines, in concert with soil bioengineering techniques, is well adapted to withstand sea level rise and high-intensity storm events, while allowing landward migration of coastal vegetation and the critical habitat it supports. We describe new methods and innovative uses of soil bioengineering installation to restore coastal shorelines, coastal dunes, and salt marshes. The case studies described in this presentation demonstrate that after 20 years of installation, the use of soft engineering and native vegetation may be considered a long-term solution for addressing coastal erosion without the use of stone armour, revetments, or other hard structures and the negative environmental impacts associated with traditional hard armouring of shorelines. Strategies such as high-density coconut fiber rolls and geo-lifts are proving to be adaptation design strategies to stabilize our coasts, which are facing increased rates of erosion due to sea level rise and more frequent storm events.

Unpacking Ecosystem-based Adaptation in the Western Cape in the context of existing nature-based projects and programmes

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Ecosystem-based Adaptation (EbA) advocates that well-functioning ecosystems are critical for building resilience and supporting society's adaptation to the adverse impacts of climate change. Ecological/green (as opposed to built) infrastructure can help mitigate the effects of climate extremes, while many ecosystem services are important in supporting adaptation to new risks. The National Department of Environment, Forestry and Fisheries in South Africa has taken the decision to mainstream EbA into its climate response actions, developing a strategy and set of guidelines to steer implementation. However, there has been little work to grasp different actors’ perspectives and understandings of EbA, its implementation, and how to link it to existing related projects and programs that focus on natural resource management and ecological restoration. This research presents findings from a study in the Western Cape that sought to unpack what EbA means ‘on the ground’ and how it can be actioned. In-depth interviews were conducted with 19 government officials. Some initial findings suggest that: 1) there is still uncertainty as to what EbA is and how to engage with it; is it a concept, framework or a set of guidelines to apply to current work, or does it require something new?; 2) there are concerns related to what successful EbA is and what this means for repurposing existing projects and for monitoring and evaluation; and 3) multiple barriers to EbA implementation exist, with one frequently mentioned example being the difficulties in collaborating across sectors and ensuring communication and coordination between relevant actors.

Natural resource management capacity building and advocacy program for traditional and community leaders in rural areas

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The black people migrated from Central Africa and settled throughout Southern Africa. Social communal systems without individual land tenure were the accepted means of land ownership. The Western idea of socio-economic competition, profit motive, and enrichment were foreign to traditional black society. Age-old customs, culture, and traditions determined the position, duties, and responsibilities of everyone in the community. Natural resources such as water, grass, wood, and wild animals were common property of the community. South Africa's land surface is 121.9 million hectares, 80 percent of which is used for agriculture. Black South Africans, about 80 percent of the population, were limited to 13 percent of the country's land which amounts to about 23 million hectares. This situation had major environmental impacts on ecosystem services in communal lands such as overgrazing, soil erosion, bush encroachment, water scarcity, unemployment, and abject poverty. The threats to biodiversity and natural resources outside protected areas is well documented, yet there is no clear breakthrough in finding sustainable solutions acceptable to all stakeholders. The behaviour of a community towards natural resources is a manifestation of values and principles and practices at a family level, which is a basic unit of a society and community within a village. Traditional leaders and their system of governance survived through all the phases of land management changes, and they are by definition natural resource managers in the same way as farmers, foresters, enviromentalists, and conservationists.

Cultivating camas connections

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Camassia quamash (common camas) is a facultative wetland hydrophyte with significant cultural ties to many tribes and first nations across western North America. It was particularly important due to its edibility and abundance. Historically, camas harvests were an opportunity for indigenous peoples to trade and interact, both within and between different indigenous groups. Camas remains culturally significant with many groups still digging, harvesting, and baking bulbs and incorporating the plant in traditional diets and cultural practices. Camas requires specific habitat characteristics to ensure a suitably wet
growing season. In the 19th century, federal land policies removed many tribes and nations from their ancestral homelands and transferred ownership of those lands to settlers. Ultimately, agricultural land use proved destructive to wetland prairies. The decline of these camas prairies was not only a loss of valuable ecosystem function, but also reduced and degraded a culturally significant landscape. The focus of this work is the Weippe Prairie, an important traditional harvest site for the Nez Perce people. Prior to its designation as a site of Nez Perce National Historical Park, a unit of the National Park Service, agricultural conversion and associated land use practices significantly altered and degraded Weippe Prairie's wetland characteristics. I will present site specific strategies to increase success of camas-focused restoration projects, advance landscape restoration goals, and reassert cultural presence on the landscape. Research and management strategies are driven by the significance of this plant and its unique ability to connect people across backgrounds, cultures, research subjects, and disciplines.

Making carbon payments work for ecological restoration: Experiences from California

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Programs that pay landowners for greenhouse gas (GHG) emission reductions resulting from ecological restoration offer both promise and peril for biodiversity conservation. Conservationists have rightfully raised concerns about a narrow focus on carbon sequestration leading to "bio-perverse" outcomes, such as monoculture plantings, use of non-native species, and inappropriate site choices. This talk describes the development of carbon accounting protocols for ecological restoration under the State of California's Climate Investments Program (or Greenhouse Gas Reduction Fund). Policy features of the Climate Investments program permit the design and implementation of funding mechanisms that can better safeguard habitat quality and non-carbon ecosystem services than typical market-based carbon offsets programs. Relying on case studies from riparian/floodplain forests, wetlands, and oak woodlands, I describe the process of designing protocols for quantifying the carbon sequestration potential of ecological restoration in California ecosystems. I show how barriers such as lack of published data and feasibility concerns were overcome. These experiences can be instructive for others working in the California Climate Investments space, as well as for those designing other carbon payment mechanisms focused on land-use change.

The politics of landscape restoration: Lessons from Vietnam

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For many years, Vietnam was the posterchild for wartime devastation and the need for remediation in the aftermath of conflict. In the decades since the end of the war, Vietnam embarked on several ambitious restoration projects, including replanting of coastal mangroves and the expansion of inland forest cover through large-scale afforestation efforts. A Five Million Hectare Reforestation Project (5MHRP) that ran from 1998 to 2010 spent over US$1.5 billion total through state investment in seedling provision combined with land allocation to households to encourage them to plant trees. Such programs often focused on afforesting lands the state classified as “barren”, and recipient households transformed these lands into smallholder forestry plantations, ostensibly to reap both environmental and economic benefits. However, the social impacts of these restoration efforts, and the degree to which they were able to include equity and participation concerns, have not been well assessed. In our research with households involved in reforestation, there have been clear privileges afforded to richer households, and land stratification has been one result. Further, there have been negative impacts on women in particular (who often provided labor for tree planting but lost access to common lands they had used for non-timber forest product [NTFP] collection that were privatized as a
result). By examining the Vietnam restoration agenda in the post-war years, through several case studies covering different parts of the country and varying ecological landscapes, this paper will note particular challenges for restoration projects championed by national governments but carried out by local households.

**Restoration as a prominent solution to food-energy-water nexus challenges**

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The food-energy-water (FEW) nexus framework considers tradeoffs between food, energy, and water sectors in order to achieve effective, integrated solutions to natural resource challenges. Despite the capacity of restoration to address challenges at the intersection of human and ecological systems, and the acknowledgement of the central importance of ecosystem services to FEW systems, restoration has received little focus as a prominent solution within the FEW nexus framework. Additionally, the FEW nexus framework has not been leveraged in the field of restoration as a way to analyze cross-sector benefits of restoration to human systems. Restoration should be a prominent component of effective solutions to FEW nexus challenges because of its ability to increase and protect ecosystem services and mitigate impacts of FEW systems on ecosystems. Integrating across sectors, disciplines, and landscapes, restoration contributes to solutions that improve human livelihoods and protect ecosystems. Further, the FEW nexus provides an effective framework for analyzing and conveying the benefits of restoration to human communities, helping to promote restoration as a prominent solution to challenges at the nexus of human and natural systems. The objective of this presentation is to clarify the capacity of restoration to address FEW nexus challenges and to address the utility of the FEW nexus for promoting the benefits of restoration for human communities.

**Ajabu's Adventures in Wonderland: Theater as a powerful tool for student and community engagement, education, experience, and transformation in a restored indigenous forest in Africa**

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“Ajabu in Wonderland” is Brackenology's Kenyan-themed iteration of the story Alice in Wonderland with purpose—to wonder at restored African indigenous forest and to investigate through drama the ecological principles that will help sustain it. The re-imagined characters in the show are animals indigenous to the Afromontane forest, such as Thick-Tailed Bush Baby, Dung Beetle, Sykes' Monkey, Civet Cat, and Colobus Monkey. The Jabberwocky is a poacher, the Queen is an unscrupulous land developer, and the main character, Ajabu, is a Kenyan child searching for her rabbit, taking the audience on an interactive journey to meet the animals in the show, learn bits of ecological wisdom, experience African storytelling customs and culminate with cheering “Forests Forever!” This exciting, interactive show is a performance experience to engage and educate local students and communities on the critical importance and value of indigenous forests to the sustenance of human, animal, and plant life. Measurement of pre-show attitudes to forest conservation, along with post-show transformation of those same attitudes gauge the effect of interaction with the content of the presentation. According to Kenneth Kwok in the article, Drama-Based Teaching is on the Rise, drama “can deepen learning when the students make an emotional connection with what they’re studying.” With the show, “Ajabu's Adventures in Africa” Brackenology hopes to do just that—deepen people's understanding of and emotional connection with the indigenous forest and the critical need to protect it as something that sustains us all. Forests forever!
Connecting fire and ecosystem restoration in California shrublands and forests: New tools and strategies
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California wildlands are dominated by ecosystems adapted to two fundamentally different fire regimes. Before Euroamerican settlement (EAS), most widespread shrubland ecosystems were characterized by relatively infrequent but severe wildfires that removed much aboveground biomass. Uniquely among the Mediterranean Climate Regions, most forest in California is dominated by conifers ill-adapted to high severity fire, and the pre-EAS fire regime was characterized by frequent, mostly low-severity fire. In both ecosystems, recent wildfires have trended larger and more destructive to human life and property but causes and ecological effects of the megafire trend differ in the two systems.

In California conifer forests, fire suppression has greatly reduced fire occurrence, leading to increases in forest density and continuity and – in interaction with climate warming – increases in fire size and severity. In chaparral and related ecosystems, high numbers of human ignitions, invasion by annual grasses, and drought-induced mortality have interacted to increase fire frequency to the point that the sustainability of woody vegetation is threatened. In California, management of fire and “green” vegetation is inextricably linked to restoration and management of “black” vegetation after fire. We describe ecosystem management initiatives that seek to ensure the success and sustainability of fire and ecosystem restoration efforts in these two contrasting ecosystems. We focus on the importance of “ecological forestry”, ecologically-informed fire management, and flexible post-fire restoration strategies that center on long-term and broad-scale outcomes, and we describe a set of new tools that permit rapid identification of restoration priorities in both shrubland and forest ecosystems.

Soil properties and plant communities of mine dumps following technical reclamation, spontaneous revegetation, and near-natural restoration on the Loess Plateau, China
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Mining activities have caused severe damage to the ecosystem and left large amounts of mine dumps to be restored. Technical reclamation (TR), spontaneous revegetation (SR) and near-natural restoration (NNR) were the main approaches applied in the ecological restoration of mining dumps, however, the effectiveness of these methods on improving soil and promoting vegetation succession was not well understood. To address this, we compared the soil properties and plant communities of technically reclaimed, spontaneously revegetated and near-natural restored mine dumps located on the Loess Plateau, China. Soil backfilling and tillage were performed both in TR and NNR, while cultivation of various plants and management were only included in the technical approaches. Field investigation, soil sampling, and chemical analysis were undertaken, while plant species, diversity, biomass, soil moisture, bulk density, heavy metal content, as well as organic carbon etc. were determined to assess plant communities and soil properties. Results showed that the near-natural restored dump had the highest plant diversity, followed by spontaneously revegetated and technically reclaimed sites, although the biomass, average height, and coverage in the dump via TR ranked first. As for soil properties, the soil fertility in the near-natural restored dumps increased significantly and recorded the lowest heavy metal content compared to the other two sites. The various diversities, coverages, biomass, and differences in plant community composition among the three dumps were caused by the alteration in soil properties. Therefore, NNR could be an effective way to improve soil properties and rehabilitate plant communities without impairing plant diversity.
Typologies and outcomes of ecological infrastructure restoration investment models

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A sizable investment gap exists in South Africa for the sustainable and scaled funding of landscape-wide interventions to restore and/or rehabilitate functionally critical ecological infrastructure (EI). Such interventions have considerable potential to address water insecurity and contribute to the development of sustainable livelihoods. The analysis of existing EI restoration investment models can reveal the characteristics of the current investment landscape, provide a generalised understanding of effective implementation models amidst local complexities, establish the suitability for up- and outscaling, identify gaps, and interrogate barriers to investment. We used existing documentation and stakeholder interviews to compile an inventory of water-related EI interventions in the Berg-Breede and uMngeni catchments, South Africa. Analysis revealed eight typologies, which were refined and validated through a stakeholder process, and subjected to a post-hoc analysis to determine (dis)similarities of characteristics. Key distinguishing characteristics between contrasting typologies included the complexity and size of financial flows, the complexity of partnership arrangements, the changeability of mandates and goals at each funding step, the type of EI being restored/rehabilitated, and the model used (and constraints) for contracting workers. Four scalable typologies were identified that offer opportunities for greater investment across spatial scales with other typologies offering contextualised value in close collaboration with local communities. We conclude that a range of EI intervention typologies with differing biophysical and socioeconomic outcomes should be available to different types of investors. New models of investment from private sources are needed to augment the current, mostly public investment profile.

Interactions between fire and ecological restoration in southwest Australia

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Although an important natural process in SW Australia's terrestrial ecosystems, fire interacts with ecological restoration in diverse ways. Fire, per se, is rarely considered to cause degradation requiring restoration, however, 'changed fire regime' (often poorly defined) is a listed threat in many conservation-listed ecosystems. Restoration-focussed fire management and post-fire restoration activities occur but are limited. Reference ecosystems themselves are often managed to reduce fire risk, and restoration may create perceived and actual, fire risk – to restoration and/or its neighbours – and consideration for fuel management. Vegetation parameters have similar trajectories in recovery after fire and restoration establishment. Post-fire features (e.g. ephemeral species) provide functions and benefits, but restoration targets are often based on mature-phase ecosystems. Can awareness of post-fire establishment processes and trajectories enable smarter restoration objectives and more timely interventions? As many plants flower and/or recruit seedlings largely or solely after fire, vegetation structure and composition are limited by initial establishment until subsequent disturbance occurs. Can we assess long-term persistence and sustainability of restoration without fire? Should we implement fire to encourage it? Resilience, another critical restoration objective, cannot be directly assessed unless an impact occurs. Can we define and assess resilience in relation to fire? And at what age do restored ecosystems achieve resilience? Fire ecology can assist with restoration techniques.
Advances in fire-related seed biology have improved plant establishment rates, while treatment of topsoil donor sites with fire may also improve transfer effectiveness. Examples from research and practice are provided to illustrate each of these points.

A risk-based framework for completion criteria development

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This paper presents a framework for developing risk-based completion criteria. The framework defines a process to develop site-specific completion criteria for mining landscapes, incorporating risk-based assessments and associated monitoring. The framework builds on regulatory guidance and the recent release of the SER International Standards, in which closure or completion criteria are defined as “a detailed description of the measurable outcomes required at a restored site before restoration or rehabilitation works can be considered by a regulator as completed.” While the framework has been informed by evidence from the mining industry in Western Australia, it is relevant to other landscapes requiring rehabilitation or restoration. A review of relevant literature and research, stakeholder interviews and survey, three case studies, and a workshop informed the framework, resulting in identification of six steps in the development of completion criteria. These include post-mining land use, aspects and closure objectives, references, attributes and risk-based prioritisation, criteria development, and monitoring. The framework enables more effective identification of rehabilitation or restoration outcomes through systematic post-mining land use decision making and objective setting and the implementation of adaptive management processes that effectively link monitoring, trajectory assessment and activity implementation. This provides greater certainty and confidence for regulators and industry, assisting in a greater number of mines being successfully rehabilitated or restored and, ultimately, relinquished in a manner that delivers more effective outcomes for the environment and communities. This published framework, the first of its kind, is transferable, nationally and internationally, to other projects requiring land rehabilitation and restoration.

Drivers of community landscape service values across an East African landscape—a necessary understanding for bottom-up restoration

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Increasingly, land managers seek to restore forested landscapes for the value of the ecosystem services they provide. This is especially true in Kenya’s Mau Forest, a montane area that harbors some of Kenya’s most-important headwaters but has lost a quarter of its forest since 1999. While managing for the Mau Forest’s watershed services is a priority, without understanding why and how people value services, decision-makers will not be able to address underlying community-level interests in restoration. This research combines participatory mapping and interviews to analyze the factors that influence the distribution of value given to landscape services through a case study of two communities—Kedowa and Kuresoi—within the Mau Forest of Kenya. In total, 55 village residents were interviewed. The most commonly-listed landscape services were water, firewood, cultivation, grazing, timber, and medicine. These categories were generated by informants through open-ended questions and may be thought of as both indicators and direct benefits. Results indicate that four main factors determine the location from where these services were derived: historical and legal arrangements, interpersonal relations, market
access, and biophysical conditions. The way in which these factors affect where people value landscape services depends on the service and community. This study demonstrates that people in nearby communities can value the same services in different ways and that the spatial distributions of these services stem largely from a few underlying conditions. Understanding this heterogeneity can lead policymakers and managers to create restoration plans that adapt to local contexts and account for local dynamics of value.

Ecological impacts of the Eurasian Beaver Reintroduction Programme

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After an absence of 400 years the Eurasian Beaver, Castor fiber, was translocated back to Scotland in 2009 and granted protected species status in 2019, securing the future of this keystone species to Scotland. This is the first formal reintroduction of a mammal to the United Kingdom and follows decades of investigation, public debate, a rigorous five-year trial, and an unlicensed release. The decision to re-establish this species in Scotland was centred upon the beavers’, overall very positive influence on biodiversity, including species abundance and diversity, through creating new habitats, changing ecosystems, and provisioning ecosystem services. Nonetheless, such habitat changes in the semi-natural landscape had some adverse localised consequence for some species, and a wide range of interesting socio-economic impacts. The Scottish Beaver Trial also stimulated and informed wider debate on ecological restoration and reintroduction projects and heightened public awareness of these topics. This talk will explore the process, challenges and impact of the beaver translocation with specific reference to ecological restoration, including the conduct of monitoring and evaluation, population management solutions, and how the programme has influenced wider thinking on “re-wilding” and re-establishing ecosystem health.

Arid land rehabilitation in the Karoo, South Africa – Building skills, networks, and positive attitudes in globally-troubled times

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There is bad news everywhere about the state of the environment. People feel guilty, depressed, and disempowered. In arid Karoo areas of South Africa, European-style settled agriculture has in the past 250 years destroyed cultures, reduced productivity of natural vegetation, changed the fauna, and caused soil erosion. Doing nothing about these problems exacerbates both social and ecological health problems. With the challenges and opportunities for research, training, job creation, and business in mind, we established Renu-Karoo Veld restoration as a small business in the Karoo town of Prince Albert some 10 years ago. Although we have never engaged in any large scale, commercial rehabilitation work such as mine rehabilitation, we have carried out experiments at nursery and landscape scales, introduced hundreds of undergraduates to the challenges of ecological restoration under arid conditions, mentored honours and masters students, and trained 11 local people to collect and store seed and to grow local and translocated plants. Our activities have attracted the interest of other organisations such as garden clubs, schools, conservation agencies, farmers associations, and a psychologist specialising in the development of leadership skills. Our services are bought by farmers, landscapers, engineers, and home-owners. We contend that involvement in restoration actions improves self-esteem, is an opportunity for education, and brings diverse sectors of the community together. Our and initiatives and others like it have potential to create jobs and regenerate vegetation. Such initiatives deserve support.
The incentives for peatland restoration: From pilots to international conventions

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Peatland restoration when successful is beneficial for wide range of stakeholders. At the same time ecosystem restoration projects demand serious investments. Anyhow, there is problem to merge those who benefits with those who invest in the projects. The solution is in finding proper incentives related to specific stakeholder groups. Restoring peatlands is enhancing ecosystem services on local and global levels. Local beneficiaries as a rule cannot pay. The global beneficiaries such as Multilateral Environment Agreements (MEAs) can pay but demand clear accounting mechanisms to demonstrate benefit before the investment. This presentation covers case studies which demonstrate the benefits on the local, regional and global levels. The methods are demonstrated for how to upscale peatland restoration pilot outcomes and generate incentives for regional, national, and global players and investors. The approach for accounting for the input of peatland restoration to climate change mitigation and adaptation is suggested for pilots in Mongolia and Russia. The pilots are considered as demonstration projects for the integration of ecosystem-based solutions to the National Determined Contributions under the Paris Agreement.

Seed sourcing for plant restoration: Provenance effects alone do not categorically define seed sourcing methods under field conditions

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Decisions on the source of seeds can impact the success of plant community restoration. Local provenancing has been the preferred seed sourcing method. However, alternatives such as climate-adjusted seed sourcing have been suggested to provide plants that are adapted to changing environmental conditions. We tested these seed sourcing methods using Banksia menziesii, a restoration priority plant species on the Swan Coastal Plain of Western Australia. Seeds from fifteen sources along a climate gradient (annual rainfall range: 443 to 813 mm, annual mean minimum temperature range: 10.4 to 13.7 °C, annual mean maximum temperature range: 23.7 to 26.6 °C), were collected. These seeds were sown in field trials at four locations along a climate gradient in Western Australia, and seedling survival was recorded up to 9 months after sowing. Although there was not a significant provenance effect on survival based on pairwise comparisons, in three out of four trials seedling survival of the local provenance was above the overall average after six months. There was no evidence for advantage of climate-adjusted provenancing. This study shows that Banksia menziesii seedlings of warmer and drier provenances might not have higher survival when used for restoration in their non-local sites under field conditions. Further field trials are required to investigate if climate-adjusted seed sourcing can be beneficial over local provenancing in other plant species, under various climatic conditions and in the long term.

Restoring the forests of Mulanje Mountain: Securing a future for a Critically Endangered tree and providing jobs for more than 500 people

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Mulanje Cedar, Malawi’s national tree, naturally found only on Mount Mulanje, is now extinct in the wild as a result of uncontrolled logging. Mulanje Cedar has been a keystone species on the mountain and its cutting has resulted in devastating degradation of forests and a loss of habitat for other forest plants and animals. Destruction has also resulted in decreased resilience against heavy rains, which are now causing flash floods that have led to people’s farms and houses being washed away and, in the worst cases, people’s lives being lost. Over the past three years, ten community nurseries have been established around Mount Mulanje and a large-scale restoration programme for Mulanje Cedar has been initiated to try to pull this species back from the brink of extinction. The project has improved livelihoods of rural communities, with visible effect, by providing restoration-based employment to more than 500 people, with a focus on women for whom employment opportunities were restricted locally. The skills of botanic gardens are benefitting this project, for example by investigating optimal growing conditions and developing horticultural protocols for Mulanje Cedar, as well as designing trials to improve restoration results. This project is now expanding to identify additional opportunities for livelihood improvement based on restoration and sustainable utilisation of plant resources on Mount Mulanje. This presentation aims to encourage practitioners to adopt community involvement and botanical and horticultural knowledge as core ingredients in restoration project design.

**Socio-economic factors affecting adoption of soil and water conservation measures in Malawi**

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The Department of Land Resources Conservation and other stakeholders have been promoting Soil and Water Conservation (SWC) measures in Malawi for decades. Despite these efforts, it has been noted that the adoption of the technologies is still low. The 2016 soil loss study found that the average soil loss has increased from 20 tons/ha/year to 29 tons/ha/year since 1990. This study was conducted to understand the socio-economic factors that affect the adoption of SWC measures in Malawi. The study was conducted in Malingunde and Mngwangwa Extension Planning Areas (EPA) in Lilongwe District. The two EPAs are some of the sites where SWC measures are being promoted. Data was collected from a sample of selected farmers through the administration of a questionnaire. The questionnaire comprised closed- and open-ended questions. The study found significant positive correlation between age of the household head and adoption of SWC measures. The study also found that belonging to a farmer group, receiving training and farmer contact with the extension worker have significant positive correlation with the adoption of SWC measures. Based on these findings, it is recommended that farmers should be encouraged to belong to farmer groups as it enables mutual learnings and the exchange of ideas. Farmer trainings in the form of demonstrations should also be prioritized as it helps the farmers to have a practical approach to technology implementation. The study needs to be replicated in other areas as farmers operate under different socio-economic and ecological conditions.

**Defining ‘green’ for ecological infrastructure bonds**

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Increasing awareness among governments, companies, and financial institutions has spurred interest in ‘green’ labeled bonds and other investment vehicles as a mechanism to reduce risk and increase sustainability. Commonly used as long-term debt instruments, green bonds are issued by governments, companies, and other institutions to finance or re-finance assets or activities with environmental benefits. They may also be an efficient source of funding for ecological infrastructure (EI). EI encompasses a highly diverse set of
natural features that support socio-economic and environmental processes. EI assets can be maintained and enhanced through capital and operating expenditures by governments, businesses, communities, and individuals. Science-based criteria are essential to investor confidence in the sustainability dimensions of the green bonds they purchase. Such criteria should be designed to ensure that bond proceeds are used to enhance climate change mitigation, adaptation, and resilience of communities, infrastructure, and ecosystems. To maximize their potential contribution to global sustainability goals, green bond criteria should accommodate the full diversity of potential EI assets and enhancement activities (e.g., protection, restoration, sustainable use, warning systems), while also recognizing complicating factors such as transboundary issues. This discussion will explore principles and strategies for developing robust, broadly applicable, widely accepted green bond criteria. Specific examples from current practice will be shared.

Securing, restoring, and reintroducing: A case study from Ontario, Canada

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Nature Conservancy of Canada (NCC) has been conducting landscape scale securement, restoration, and succession management in Southwestern Ontario, Canada since 2005. NCC is working with species at risk biologists on potential reintroduction plans for locally extirpated species in these restored areas. NCC is Canada's leading not-for-profit, private land conservation organization. NCC focuses its work in areas of high conservation priority across Canada, one of which is the Southern Norfolk Sand Plain (SNSP) in Ontario. SNSP is part of the Carolinian Life Zone, which contains temperate forests, grasslands, and wetlands, and has 25% of Canada's human population as well as 25% of Canada's species at risk. SNSP has a history of intensive agricultural use and land clearing, however forest cover is 25%, the highest found in southwestern Ontario. NCC began strategically acquiring land in SNSP in 2005 and restoring agricultural land on these properties. NCC has acquired over 2,300 ha and restored over 650 ha in SNSP to date. Restoration includes altering topography to re-create sand dunes and wetlands and installing the seeds from over 100 native plants. As the restored areas mature, NCC is managing habitat succession at a landscape scale. This is being done to support species at risk with restrictive habitat requirements, while still benefiting species with more general habitat requirements. A recovery team for at risk butterflies has identified restoration sites as prime potential habitat for locally extirpated species. NCC is working with this team to inform management and create reintroduction plans for these butterflies.

Improved estimates of streamflow losses to Invasive Alien Plants in the Cape Floristic Region

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Invasive Alien Plants (IAPs) drastically reduce surface-water runoff in South Africa. In such a water-scarce country, the economic, social, and environmental costs of this lost runoff is vast. Despite control efforts, invasion densities continue to increase, exacerbating this problem. Given the need to augment water supply in preparation for population growth and climatic change, accurate estimates of runoff lost to IAPs are needed. These can then be used to weigh investment in ecosystem restoration through IAP clearing against engineering-based water-augmentation schemes such as groundwater abstraction or desalination. The current best-estimates of runoff reductions caused by IAPs are based on models combining data on climate, hydrology, the extent of IAPs, expert knowledge and
experimental data from countrywide multidecadal experiments monitoring streamflow in afforested catchments. These models produce point-estimates of runoff reductions with no indication of uncertainty or the range of possible values. Decision-makers thus have no idea how much they can trust these estimates, and scientists have no indication of how input data could be improved to produce more accurate results. We re-analyze the available data to produce updated estimates of streamflow losses to IAPs in the catchments of the Cape Floristic Region using a fully reproducible Bayesian model that propagates uncertainty from raw data to the final estimates. Our model quantifies the uncertainty associated with all parameters and the sources of uncertainty, serving as a guide for future data collection. These results provide improved estimates to decision-makers, acknowledging and quantifying inherent uncertainty, and enabling defensible decisions regarding water resource management.

Participative ecological restoration of mangrove ecosystem in the Monterrico Multiple Use Reserve: Capacity building to restore degraded mangrove areas in the Pacific Coast of Guatemala

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The Monterrico Multiple Use Natural Reserve is an important coastal marine protected area located in the Pacific Coast of Guatemala that provides goods and services for people's livelihoods. Mangroves represent one of the main ecosystems within the area that has been degraded by anthropogenic interventions such as fires and illegal logging. Restoring mangroves has become a priority for the management of the area; many efforts have been carried out in the past without positive outcomes. Through the implementation of a restoration pilot project in 2016, an academic exchange with Pronatura Veracruz, Mexico, was conducted in the reserve where governmental, academic and non-profit organizations related to mangrove conservation and communities were involved in training on innovative mangrove restoration methods, seeking to emulate natural patterns of recruitment that were applied in a degraded area as training practice. Also, as part of the restoration project, an assessment was carried out to identify degraded areas that could be included in the restoration incentive program of the National Institute of Forests in order to direct the collected incentives to community people involved in mangrove restoration. As a result of the project, two hectares were restored and have been monitored, showing good progress in natural mangrove recruitment after three years of implementation. Regarding the participative manner in which the mangrove restoration was implemented, the method applied has had acceptance amongst the organizations involved, and after promoting the positive results, it is being replicated in other mangrove ecosystem areas along the Pacific Coast.

Principles and key concepts for ecological restoration in the deep-sea

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The Society of Ecological Restoration updated the International Standards for the Practice of Ecological Restoration, including principles and six key concepts. The aim of this document was to “provide support for the technical application of ecological restoration across geographic and ecological areas to improve biodiversity conservation outcomes for all ecosystems, secure the delivery of ecosystem services, ensure projects are integrated
with socio-cultural needs and realities, and contribute to the 2030 Agenda for Sustainable Development”. In this talk we will present work carried out under the MERCES project; in particular how lessons learned from terrestrial and shallow water restoration along with previous deep-sea restoration work can be used to evaluate principles, concepts, and guidelines for ecological restoration of deep-sea ecosystems. We will discuss the challenges posed to describing local native reference ecosystem and identifying and measuring key attributes in the deep-sea using four case studies, requiring different degrees of intervention to assist their natural recovery processes. They include cold-water coral ecosystems in the Azores impacted by deep-water fishing (coral transplantation), soft bottom communities in the Mediterranean impacted by rock drilling activities (natural regeneration), abyssal plain communities in nodule-rich areas of the Pacific of interest to deep-sea mining (replacement with chemically-conditioned artificial nodules), and a hydrothermal vent field in the mid-Atlantic that may also be impacted by deep-sea mining (replacement of structures to speed up the development of hydrothermal vent chimneys). We will also discuss knowledge gaps, time scales, uncertainties, and challenges to deep sea restoration.

Trees, soils, and microbes: Restoration of degraded landscapes

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Landscape degradation continues to be a major challenge for the 21st century, and few activities are more destructive to a landscape than open-pit mining. Despite the destructive nature of open pit mines, one such mine in southwestern China provided an opportunity for us to learn about the effects that trees have on soils and soil microbial communities, and how these impacts change over time. Using a chronosequence ranging from freshly disturbed soils (time 0) through to about 30 years after restoration, we evaluated how different types of trees (N-fixing, pioneer, exotic, and indigenous) affected soil chemical properties and soil microbial communities in relation to adjacent undisturbed soils. As can be expected, time played an important role in the restoration process, however, we found that indigenous tree species were associated with a faster rate of recovery for soil microbial communities compared to exotic species. Both the biomass and diversity of soil fungi and bacteria recovered at faster rates in soils associated with indigenous tree species. Over time the differences observed between the tree types was diminished. The soil nutrient profiles did not vary greatly between tree types, although the N-fixing trees did accumulate significantly more soil N after 30 years when compared against other tree types. The soil systems, both microbial communities and nutrient profiles, reached a state comparable to the natural land used as a control after about 30 years. This work highlights the role of tree species selection in the restoration of highly degraded soil systems.

Invasive alien aquatic plant management: Ecosystem recovery and restoration

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Invasive alien aquatic plants (IAAPs) have severe ecological and socio-economic impacts on freshwater systems in southern Africa and beyond. The application of biological controls against floating IAAPs has significantly improved freshwater ecological and socio-economic returns, but the overall effects of successful biological control on ecosystem recovery remains poorly understood. This study quantifies ecosystem recovery and long-term ecological effects following mechanical and biological control of Salvinia molesta. A combination of mesocosm (Before/After, Control/Impact) and field (Before/After) experiments were employed to test: (i) changes in water quality, (ii) shifts in phytoplankton,
periphyton and aquatic macroinvertebrate assemblages, and (iii) shifts in trophic dynamics and aquatic food web structure before and after S. molesta management. Mechanical removal and biological control of S. molesta did bring about ecological recovery and ecosystem re-organisation, however, mechanical removal proved unsustainable by allowing a coinciding linear regime-shift from clear water to a submerged (Ceratophyllum demersum) and later, emergent (Nymphaea nouchali) IAAPs dominant state. This presentation will discuss ecological changes before and after S. molesta management using both mesocosm and field evidence and highlight possible restoration implications of the control methods for floating IAAPs. In conclusion, a biological control programme for IAAPs management, followed by active restoration practices (introduction of native macrophytes) is recommended. This study provides support for informed management recommendations for ecosystem recovery and restoration of invaded aquatic ecosystems in southern Africa and worldwide.

Engaging local citizens in scientific monitoring for catchment restoration: Benefits and recommendations for optimising their involvement

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The Tsitsa Project operates in the Mzimvubu catchment in the former Transkei homelands in South Africa, a poverty-stricken area with limited development opportunities and highly erodible soils. The project aims at rehabilitating degraded areas and limiting further degradation in a way that promotes local livelihoods. Environmental monitoring, a form of citizen science, delivers scientific data and also creates environmental awareness and custodianship. Local monitors have collected water samples for studying sediment transportation since 2015 and are paid per sample as the most feasible model. Until recently, limited research has been done on the potential and actual benefits for the scientific host organisation and none on the potential and actual costs and benefits for environmental monitors. The recent research reported here used document analysis, semi-structured interviews, and participant observations in a realist framing. A key finding was that the income earned plays a big role in the monitors' lives, but further than that they gained new knowledge, environmental awareness, and confidence. Mutual respect between the monitors and the coordinator was a significant enabling factor. A preliminary conclusion is that monitors want more involvement than just the data collection. Recommendations for how to achieve this will be shared in the presentation.

Strengthening the evidence for building resilience in ecosystem-based adaptation in Namaqualand: Ecological infrastructure, livelihoods, and benefits of natural resource management interventions

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Conservation South Africa (CSA) is an affiliate of Conservation International. CSA's key focus is restoration of South Africa's rangelands and sustainable land use management, working in South Africa's biodiversity hotspots and promoting regional economic development that values nature. The Namakwa District of the Northern Cape is likely to experience increasing temperatures, aridity, and water stress in the face of climate change. Adaptation strategies, including Ecosystem-based Adaptation (EbA), will be critical to sustain agriculture and maintain ecological infrastructure. It is cost-effective to build farming communities' resilience to climate change by restoring nature's capacity to retain soil, provide fodder, replenish aquifers, store water, and reduce impacts of floods. The Department of Environment, Forestry and Fisheries in South Africa has been successfully implementing a Natural Resource Management (NRM) programme that has been contributing to
restoration of rangelands for decades. The NRM programme, although contributing
towards adaptation, is not explicitly demonstrating and measuring the impact of its
intervention in terms of Ecosystem-based Adaptation. The programme as an EbA also has
significant potential to unlock further investment into ecological Infrastructure and to
support socioeconomic benefits for NRM workers and surrounding communities. A case
study conducted by CSA in the Namaqualand (Northern cape), shows how NRM
programmes implemented through partners within South Africa’s semi-arid rangelands
are through low cost interventions supporting Ecosystem-based Adaptation, both from a
biophysical and socioeconomic perspective. Recommendations are discussed as to how
the NRM programme can provide EbA to benefit effectiveness and unlock further
investment to build resilience in communities.

Duivenhoks River – from extinction to sustainability

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The Duivenhoks River required a radical intervention on many fronts. The priority was to
stop further erosion. The LandCare team, under the mentorship of Hans King, designed
innovative weirs and groyne structures to stabilise the river. Two weirs and 30 groyne
structures were built, creating jobs for 140 people at a cost of R40-million. Erosion control
and conservation cannot take place without alien clearing. LandCare teamed up with the
Grootvadersbosch Conservancy. Together they developed a clearing model where
LandCare provides 70% of the funding, while landowners commit to 30%. Eight contracting
teams employing 144 people now clear invasive plants. Where aliens have been cleared,
teams plant palmiet and other indigenous plants. None of this work could take place
without landowner buy-in. Over 10 years, the LandCare team worked to build close
relationships with landowners, to build trust, and so to change farming practices and
perceptions. The aim is to encourage farmers along the riverbanks to protect their natural
resources – to the benefit of nature, food-security, as well as the broader community.
Improvements took place both through LandCare’s direct contribution and through
indirect impacts. The 30 groyne structures and two weirs were strategically placed along
the river. One of the weirs was placed where an 11-m deep gulley had formed. This weir
lifted the gulley floor by 5-6 m. This has already had impressive results with the erosion
having stabilised and with palmiet returning to the region, as well as other indigenous
fauna and flora.

Where have all the flowers gone? Grassland diversity loss in South
Africa and implications for restoration

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Habitat transformation through land-use change threatens the persistence of many
grassland ecosystems worldwide. Restoration is often applied successfully to restore the
ecosystem functions after a major disturbance, but the plant diversity endpoint is difficult
to predict as we have a poor understanding of the factors that lead to species losses per
unit area of transformed grasslands. The aim of this study was to make use of
untransformed benchmark sites in the ancient biodiverse grasslands of South Africa to
determine how transformation influences the species richness of grassland ecosystems.
Floristic data were sampled at 18 sites representing land-use changes with varying
disturbance intensities (i.e. communal pastures, mine tailings, plantations, urban open
spaces, home gardens, crop fields, and eroded areas). Floristic diversity of four plots was
sampled within each of the 18 transformed grassland sites, paired with four plots in each
adjacent untransformed benchmark site. Our results highlight that grassland endemic and
threatened species are most affected, especially those growth forms are less tolerant to soil
disturbance, such as geophytes. Long-lived, shade intolerant grassland forb species have
evolved in open grassy habitats and contribute considerably to the phylogenetic and
functional diversity of these ecosystems but are most at risk of being displaced by alien invasives in disturbed habitat. An understanding of which land-use disturbances filter out which groups of species and identifying indigenous disturbance-tolerant species that may potentially facilitate other more sensitive species could inform restoration strategies in South African grasslands.

**Why the UN Decade on Ecosystem Restoration matters for the Food-Energy-Water Nexus**

**Musonda Mumba**
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The unprecedented levels of degradation of the Earth’s ecosystems can be seen from space. Anthropogenic and natural impacts have altered vital ecosystems and the services they provide for humans and nature. The recognition that self-sustaining and functional ecosystems are vital for our collective human wellbeing formed the premise behind the UN Decade on Ecosystem Restoration. Championed by the Government of El Salvador, the decade was passed as a United Nations General Assembly resolution on the 1st of March, ushering into motion probably the most immersive UN Decade. National Governments have called upon the world to help them explore the best way to work towards restoring our vital life-lines that provide our very sources of food, water, and energy. Based on many years of scientific and field-based evidence, there is a realization that degraded ecosystems create an imbalance in the Food, Energy, and Water Nexus. Through this paper, the aim will be to share the work that UN Environment and the Food and Agriculture Organization (FAO), the two UN Agencies mandated to lead the decade, will undertake. It will also explore what the wider world can also do as part of the restoration agenda in their respective communities.

**Indigenous soil microbes as bio-tools for enhancing plant diversity and soil function in dryland restoration**

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Despite the widely-accepted importance of drylands - which store 45% of global carbon and comprise a third of global biodiversity hotspots - and the large amounts of money invested in restoration, success rates are generally low. Given the large scale of restoration required, and severe deficits of locally-sourced soil materials that contain beneficial nutrients, microbes, and a residual soil seedbank, direct seeding is often needed for reinstating biodiverse vegetation communities. Cyanobacteria from soil biocrusts can act as bio fertilizers by promoting growth of certain plant species and contribute to multiple ecosystem services and functions, including soil stability, improved surface hydrology, C sequestration, and N fixation. These organisms can survive extreme conditions such as low precipitation, high solar radiation, and extreme temperatures. However, despite their global importance, the potential of cyanobacteria for dryland ecosystem restoration is yet to be harnessed. Here, we investigated: i) the effects of bio-priming seeds with indigenous cyanobacteria on germination and plant growth of native plants used in dryland restoration, ii) the potential of cyanobacteria complexes for restoring soil function on reconstructed soils used in restoration; and iii) the development of novel methodologies for targeted delivery of cyanobacteria (i.e. via bio-encapsulation in extruded pellets). Our results showed that cyanobacteria can promote seed germination and seedling growth of native arid species. We also found that cyanobacteria inoculation can rapidly modify properties of degraded soil substrates such as increased soil carbon. These biotechnological approaches for cyanobacteria application in degraded drylands are now being tested in large-scale restoration programs.
Monitoring dryland restoration outcomes to improve future treatments

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Restoration treatments are widely practiced but their outcomes are infrequently monitored to increase the effectiveness of subsequent treatments. Monitoring outcomes can be especially informative in drylands, where low water availability and high top edaphic variability create large challenges for promoting ecosystem recovery. We synthesized treatment and associated ecosystem recovery information from multiple databases, site revisits, and networked experiments across the western United States to gain insight on successful practices. We found that in the last 70 years, the cost and size of treatments has steadily risen, with a higher number of species and more native species used in seed mixes and a growing number of herbicide and prescribed burn treatments implemented across the region. High precipitation and low evaporative demand had a positive effect on total vegetation recovery, but their influence varied across time and space. Native perennial cover increased after disturbance but was not always affected by seeding and was negatively affected by non-native perennial cover. Seed germination was positively affected by treatments that encouraged water retention, and plant survival was higher if their traits (e.g., specific leaf area, seed mass) matched the environmental conditions of the restoration site. Spending more resources on treatments led to greater vegetation recovery, but only for specific treatments, indicating opportunities to refine cost-effective strategies. Our results are motivation to track and link monitoring outcomes across global drylands that have been historically difficult to restore.

Assessing the structural integrity and functionality of wetland restoration interventions: A case from Working for Wetlands, South Africa

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Globally, restoration outcomes are seldom assessed. In South Africa, wetland restoration is a relatively new field of practice and requires monitoring and evaluation to: (1) detect intervention maintenance requirements before loss of intervention integrity is too far advanced; (2) identify further interventions and/or modifications that may be required to enhance the functionality of interventions; and (3) learn from the outcomes of restoration interventions in order to improve overall practice. A checksheet tool for assessing integrity and functionality of a variety of restoration intervention types was developed in collaboration with the Working for Wetlands Programme and is now actively applied as part of routine monitoring and evaluation. In order to demonstrate the application of the tool and how the results are being interpreted and used by the programme, two wetlands in contrasting land-use contexts are presented. The assessment showed that in certain portions of the wetlands the integrity of the interventions, mainly weirs in the channel and furrows, was good and functioning effectively to re-wet adjacent wetland areas. However, in the first wetland, in a conservation area, structures were compromised due to hydraulic pressures as a result of high sediment loads upstream of structures and undercutting downstream. In certain areas of the second wetland, located in communal grazing land, the functionality of the interventions was poor, notably where flows were bypassing the interventions amongst other reasons, due to tampering. These evaluations highlighted key locations in the two wetlands where maintenance needs were high.
Restoring wetlands on a limited budget: The evolution of engineered interventions

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South Africa’s Working for Wetlands programme was established in 2000 through Expanded Public Works funding with the aim of restoring wetlands in a manner that maximizes employment creation, develops small enterprises, and transfers relevant and marketable skills to local communities. Balancing between the ecological and social outcomes of wetland restoration presented challenges in terms of the performance triangle of cost, time, and quality of constructed engineered interventions. The use of small, inexperienced contractors and labour drawn from local communities to work in often difficult wetland conditions and at isolated locations compounded the problem. The scale of degradation and the nature of the wetland systems requires a range of “soft” and “hard” interventions to be designed and constructed, and these range from the re-vegetation of mildly eroded soils to complex concrete weir structures that protect bed profiles of large wetland systems. Over time, the engineering budget has been declining, yet the pressure to improve efficiency and deliver more with less has been mounting. This has pushed the boundaries of innovation for the engineering team in terms of more cost-effective materials and cost-efficient designs. New design and construction principles, and more tolerant risk assessment criteria, sometimes going beyond the conventional approaches to engineering design have been developed. This paper presents the history, with examples, of how the engineering component of wetland restoration in South Africa has evolved. These engineering experiences have shaped the way wetland restoration planning and implementation are conducted in the country and may be applicable outside South Africa.

A pathway to integrated objective based monitoring at mines to ensure net positive biodiversity outcomes

Chrizette Neethling
Endemicvision, Kathu, South Africa

Land management on mines cannot be effective without useful, reliable information on changes in their environment. Biodiversity inventory is a point-in-time effort to quantify species resources in space. Ecological monitoring is the sequential measurement of ecological systems over time, detecting trends in the components, processes, or functions. Mining companies are required to monitor biodiversity. South African legislation does not prescribe monitoring and provides no guidance from on submitted monitoring. The result is contrasting monitoring of limited value, functioning as repeat inventories with limited decision support capabilities. Confidence in biodiversity monitoring is poor, reducing budgets over time, interrupting long-term data, and reducing data integrity to obsolescence. If an objective based monitoring framework is in place, land management will be informed practically and increase net biodiversity value. Specialist studies and intern programs on mines can compare data across different areas. Legal obligations in terms of environmental, water, biodiversity and closure are integrated. Biodiversity risk assessment results provide further focus. From this point, the site level drivers and specific monitoring objectives are determined. Long-term and short-term key questions are formulated to provide precise results. The monitoring parameters and criteria are determined with supporting monitoring methods and schedules. Finally, the monitoring site determination and plot layout are designed, to obtain the most monitoring and data use efficiency. We present a monitoring framework based on reverse planning principles with objectives addressing key questions to improve biodiversity management through setting up parameters, criteria, and benchmarks in an integrated way. Results are presented using two case studies.
Challenges in determining the best rehabilitation parameters and criteria for arid areas with specific reference to the Southern Kalahari region of South Africa

Chrizette Deona Neethling
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Transformation of arid areas is extensive due to inter-generational accumulation of mining impacts. Transformation is further escalated as water supply infrastructure allows for higher population development than naturally possible. Arid ecosystems offer limited land use opportunities and respond at a slower, non-successional rate than other ecosystems. The high cost of rehabilitating arid areas is difficult to justify, especially with success uncertain. This study investigates how to select the best parameters and criteria to determine rehabilitation success in arid areas. The changing, more demanding legislation and increasing rehabilitation costs to meet mine closure obligations requires a greater understanding of arid area rehabilitation. Rehabilitation aimed to restore mined areas to its “predetermined natural state” as legally required is a challenge. Normally, the original natural state has not been quantified. Many times, a broad understanding of the natural state is used. In best practice, analogue benchmarks are validated chrono-sequentially. The specific issue we address is which parameters and criteria should be used to determine rehabilitation success. We systematically evaluate 40 records in the field of arid area rehabilitation in Australia, South Africa, and Namibia. Publications from 2005 to 2015 are compared and fifteen case studies are showcased. Over 114 parameters are used in arid areas. Through an analytical hierarchy process we determined the best parameter combination for mines in the Southern Kalahari region in South Africa. Forty-six percent of the cases use analogue models successfully. A sample of parameters are generally used to derive limited conclusions. Sometimes this can be defended as efficient.

Defining the decision space for ecological restoration at the landscape scale

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Given the immediate need to meet global restoration targets (e.g., UN Aichi Targets and Sustainable Development Goals), the restoration community is ramping up efforts to develop national and regional restoration plans and to develop monitoring and assessment frameworks. Central to these efforts is the need to ensure that activities that are planned and implemented under restoration initiatives are restorative and have the potential for both strong biodiversity conservation and human wellbeing outcomes. For example, ecological restoration by definition aims to repair degraded ecosystems and, therefore, restoration planning at the landscape scale should focus on identifying degraded landscapes. In addition, restoration plans must consider biodiversity conservation and ecological complexity and sustainability, in addition to the ecosystem’s goods and services of interest to stakeholders. Despite widespread agreement on these principles, the international community lacks comprehensive and widely endorsed guidelines for landscape-scale restoration. In this presentation, case studies of assessments of priority areas for landscape restoration will be used to explore the need for landscape-level guidelines. In addition, a framework for defining the decision space for ecological restoration planning will be proposed. The framework and guidelines will provide a tool for decision-makers, stakeholders and scientists to use in both restoration planning and assessment and will assist with separating ecological restoration and restorative activities from other areas of ecosystem management.
eDNA Metabarcoding - A new approach to monitoring of restoration

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Recent decades have seen a marked increase in both the scope and complexity of ecological restoration projects, partly in response to the increasing scale and severity of degradation to natural ecosystems. Individual restoration projects now operate over scales from hectares to hundreds of square kilometres and are increasingly underpinned by diverse and multidisciplinary science. These projects must be supported by measurable and realistic outcomes and standardised, accurate, and reliable approaches to their monitoring. However, studies indicate that monitoring is conducted ineffectually, or not at all, resulting in a poor return from restoration investments. This talk first outlines limitations of current approaches to monitoring biodiversity throughout ecological restoration, including their limited focus on the return of vegetation. I will then discuss how eDNA metabarcoding has potential to revolutionize the practical contribution of genetics to monitoring in a restoration context. I also discuss current limitations (e.g. assay design and taxonomic reference databases) to a DNA based approach to biodiversity assessment in restoration.

Species-diverse forest restoration in East Africa for biodiversity conservation

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Brackenhurst Botanic Garden, Kenya

In the year 2000, an indigenous forest restoration project was initiated in the highlands of Kenya by Plants for Life international at Brackenhurst, Tigoni. The site was registered as a botanic garden in 2006. Indigenous trees were propagated and planted on land previously used exclusively for exotic species, including cypress, eucalyptus, and wattle. Twenty hectares (50 acres) have now been restored. After an initial focus on planting trees, vigorous planting of an understorey layer of herbs, ferns, orchids, and shrubs (particularly Rubiaceae and Euphorbiaceae) followed in order to increase biodiversity and enhance restoration. The restored forest incorporates more than 600 East African woody species. Several threatened species are growing well and producing viable seed. Restoration efforts are generating information about propagation techniques and growth rates of indigenous species. The site is used for training and demonstrates that a highly diverse forest can be restored in the East African highlands in a short time. In addition to actively planted species, additional plant species are coming back naturally. Bird numbers on the site have doubled since restoration efforts began, and a wide diversity of mammals, invertebrates, and reptiles have reoccupied the site. The multitude of benefits and ecosystem services generated from planting a highly diverse forest in a highland area surrounded by tea plantations will be shared in this presentation, providing a valuable model for scaling up restoration efforts across East Africa, achieving AFR100 pledges whilst delivering biodiversity conservation.

Secondary invasion after clearing invasive Acacia saligna in the South African fynbos

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It is often assumed that clearing invasive alien species will lead to the dissipation of their negative impacts and recovery of native biodiversity. However, this is often not the case because clearing of primary invasive alien species can lead to secondary invasion by non-target species. We investigated the effects of vegetation type and application of fire during management of biomass after clearing invasive acacias on secondary invasion in the South African fynbos. Furthermore, we determined how these effects change with years after clearing. We sampled vegetation in lowland and mountain fynbos cleared of Acacia saligna using the “fell, stack and burn” method. During burning of the stacked slash, the area at the centre of the stack experiences a high severity fire while the area at the edge experiences a low severity fire. After fire, burn scars remain in place of the stacked slash. We sampled in and outside of 80 burn scars over three years after clearing. We identified 32 secondary invader species. Secondary invader cover was lower where there were no fires compared to where there were high severity fires (27%) and low severity fires (30%). Three years after clearing, secondary invader richness and cover remained similar to or higher than in the first year, while secondary invader richness was similar between lowland and mountain fynbos. We conclude that practicing restoration ecologists have to manage these species to ensure successful restoration of native biodiversity.

Re-establishment of Protea repens after clearing invasive Acacia saligna: Consequences of soil legacy effects and a native nitrophilic weedy species

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Invasive Australian acacias can alter soil chemistry and microbial communities in areas they invade. After clearing invasive acacias, these changes can persist, and previously invaded areas can become dominated by nitrophilic weedy species. Restoration of viable native plant communities through seed often fails due to a lack of native species re-establishment. Therefore, to improve restoration outcomes, it is important to understand the effects of soil legacies and nitrophilic weedy species on native species re-establishment. To investigate the effect of soil chemical legacies, we germinated and grew Protea repens (native proteoid shrub) seedlings in soil taken from areas cleared of Acacia saligna in lowland South African fynbos, and from non-invaded areas under controlled conditions. To investigate the effect of soil biotic legacies, we sterilized half the soil from each cleared or non-invaded area. We grew Ehrharta calycina (a native nitrophilic weedy grass) in half of each treatment and measured the effect of treatments on P. repens germination and growth. Germination percentage and root and shoot dry mass of P. repens did not significantly differ between altered and native soil chemistry. Germination percentage of P. repens was significantly greater (93%) in the presence of soil microbial communities than in their absence. Root-to-shoot ratio of P. repens was significantly greater (29%) in the presence of E. calycina than in its absence. We conclude that restoration efforts do not always have to manage altered soil chemistry after clearing A. saligna because it does not have direct negative effects on P. repens germination and growth.

Naming invasive Alien Plants (IAPs) into indigenous languages: KwaZulu-Natal case study, South Africa

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The spread of Invasive Alien Plants (IAPs) across countries does not only reduce indigenous biodiversity richness and degrade environmental integrity of local environments, it also threatens ecosystem services. IAPs pose negative impacts on cultural application of indigenous plants. Indigenous plants have an intrinsic value and are also used for various reasons including traditional medicine, food, shelter, and cultural rituals. Traditionally, indigenous plants are well known by their isiZulu common names. With the influx of IAPs, confusion between indigenous and alien plants has crept in. In some instances, an indigenous plant and an alien plant which resemble each other share the same isiZulu common name. This is a concern when people specifically intended to use indigenous plants for medicinal use. This further impacts on the management of IAPs. Additional problems arise when the intention is to propagate an indigenous species and yet an IAP ends up being propagated instead. Furthermore, where indigenous plants have been over-utilized, switching to an IAP that resembles the scarce indigenous plant occurs. Finally, when it comes to naming IAPs (since the process is unregulated), IAPs are given attractive, positive names that further create a misconception that “these plants are good”. A model for naming IAPs into Indigenous Languages is presented. This work advocates for the engagement of indigenous communities in the naming of IAPs into indigenous languages and that the naming process should be regulated. Existing Common Names, including English Common Names, should be reviewed and IAPs should be given negative names.

Restoring functional diversity in tropical grasslands

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Grasslands cover a substantial area in the tropics and contribute to the provisioning of key ecosystem services. Restoration of biodiverse tropical grasslands is complex, and the current success of these projects is low. The reasons why biodiverse grassland restorations fail remains unknown, although it is likely that plant species being targeted lack suitable functional properties to survive and compete in the degraded environments that are being restored. The species composition of surrounding undisturbed grasslands is being used to guide current restorations, however these species may not be successful on degraded land, which tends to have compressed drier soils and altered nutrient composition. Neotropical Grasslands are slow to mature and successful restoration relies on future-proofing suitable ecosystem function against future changes in climate, which is determined by functional trait composition. The latest research from rainforests suggests a focus on plant resource-use strategies, and particularly, hydraulic functional traits are key to determining ecosystem-scale stability and climate resilience in drought-prone areas. In this talk, I will present how we are applying these research techniques (developed by our team in rainforests) to test the importance of functional trait composition to the success of grassland restoration and the provisioning of key ecosystem services in grasslands in central Brazil.

Breaking dormancy of selected Asteraceae annuals in the winter-rainfall region of South Africa

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Arctotis hirsuta (Harv.) Beauvard, Cotula duckittiae (L. Bolus) K. Bremer & Humphries, and Oncosiphon suffruticosum (L.) Källersjö are three South African winter-rainfall annuals of the Asteraceae family. This family shows remarkable variation in growth form and general morphology because it occurs in so many different localities and habitats. This ability
allows humans to benefit from the genetic diversity, as seeds offer the potential to introduce an exciting range of plants with new floral or habit form. Despite the economic value it may offer, the full potential of South African daisies as ornaments and as part of seeding mixes for lowland Fynbos restoration, has not been fully optimized yet. In South Africa, growers encounter poor germination of several Asteraceae-species. The selected annuals are species that horticulturists at the Kirstenbosch National Botanical Garden have been struggling to introduce as bedding plants from fresh seed collected in the wild. Moreover, C. duckittiae is an annual with a Vulnerable (VU) status that is threatened by invasive aliens, farming, and urbanisation. There is limited research available on the temperature, light requirements, germination, or the pre-germination treatment of seeds and the effects of after-ripening at different regimes on seed dormancy of the three species. This is a gap in the existing body of knowledge on the germination ecology of Asteraceae winter annuals that can potentially be utilized as garden ornamentals or for inclusion in large-scale restoration-projects in South Africa.

**Seeds and stewards of the future: A U.S. collaboration**

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As the foundation of healthy functioning ecosystems, native plant communities buffer the impacts of extreme events such as wildfires, invasives, and prolonged drought. Under the Bureau of Land Management’s (BLM) “multiple-use” mandate, there is a significant need for locally adapted, native plant materials to restore and support resilient ecosystems. BLM leads Seeds of Success (SOS), a U.S. native seed collection program, in partnership with numerous other federal agencies and non-federal organizations. SOS was established in 2001 as the first step in the Native Plant Materials Development Process, with the mission to collect wildland native seed for research, development, germplasm conservation, and ultimately ecosystem restoration. Portions of each collection are held in long-term storage facilities for conservation. SOS has a national protocol to coordinate seed collecting and species targeting efforts. To date, SOS has more than 24,400 native seed collections through its diverse network. SOS includes many partners, such as arboreta, zoos, municipalities, and botanic gardens, including Chicago Botanic Garden, which developed the Conservation and Land Management (CLM) internship program. The CLM program places 75-100 early-career scientists in five-month paid internships to assist professionals with projects, including SOS. Since 2001, the CLM program has successfully placed over 1500 interns, providing them with a rich experience from which to launch their professional careers. The success of both CLM and SOS are contingent upon each other and the highly qualified interns who have made the majority of SOS collections.

**How livelihood vulnerability influences participation in forest governance at the community level: A case study from Liberia**

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Differences in product choices, risk behavior, knowledge, and skill in tending to different forest resources makes the participation of women and men in forest governance essential for sustainable management practices in sub-Saharan Africa. However, there are gaps in our understanding of how social processes that lead to inequalities in power, representation, and inclusion unfold at the community level. This paper assesses how livelihood vulnerability among women in two Liberian communities intersects with pressures to meet roles and responsibilities attached to their social identity and normative definitions of forest governance. We examine how the unfolding of these intersections creates differences in the ability of women vis-a-vis other women and men to engage in forest governance mechanisms. Data collection was carried out among two communities in River Cess County, Liberia, using individual and key informant interviews with
community members, community-based organizations, and community institutions over a period of seven months. Given that community forest user groups reflect the norms and attitudes of the community, meaningfully engaging women in these groups is not as straightforward as inviting women into meetings. Actors trying to increase the engagement of women need to increase the legitimacy of women’s roles vis-à-vis the forest, employ different engagement strategies for different socio-economic groupings, and progressively build women’s participation in decision making. We make the case that restoration policies and practices that do not account for entrenched social norms may perpetuate the marginalization of women, particularly those from the most resource-poor households.

Agroforestry for conservation: Building resilient landscapes in the Columbian Amazon

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The Caqueta is a department located in southwest Colombia. Spanning close to 88,965 km², Caqueta is a strategic gateway from the Andes mountain ranges to the Amazon plains. This vast, beautiful and biodiverse area has been one of the most affected areas by the internal armed conflict over the last 50 years. Though the peace agreement signed in 2017 stopped the armed conflict in Caqueta, it also brought a multiplicity of competing claims on natural forest, which have led to an unprecedented increase in deforestation rates. Despite government efforts aimed at conserving forested areas, Caqueta is the highest deforestation hotspot, representing 28% of national deforestation. In addition to causing loss of biodiversity and affecting ecosystem services, conversion of forested areas to other land uses is one of the main causes of CO2 emissions in the country. In this context, it is a priority but also a great challenge for the country to base a peace building process on promoting economic development without environmental degradation. Aiming at contributing to sustainable forest management and development of the Amazon Region, The Nature Conservancy (TNC) is implementing the “Agroforestry for Conservation” project. Promoting strategic multi-stakeholder arrangements that bring together local communities, governments and other influential stakeholders, TNC supports the alignment of forest conservation and restoration with sustainable production and social agendas. It contributes to consolidate resilient landscapes with increased forest and biodiversity protection and connectivity, increased carbon storage contributing to climate change mitigation, and higher productivity and profitability for local communities depending on forests.

Ecological restoration's impact on public health: Results of a literature review, some reflections and predictions

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Different kinds of ecological restoration activities are being investigated and tried across the globe, many to great success. To strengthen and broaden the impact of these efforts, and to rapidly increase the amount of ecological restoration throughout the world, the EcoHealth Network (EHN) is creating an interactive network of long-term sites that will address key deficits in science, education, and outreach. EHN will discuss this work and also its efforts to combine social, economic, and ecological perspectives to address two related knowledge gaps: 1) soil responses to restoration, and 2) the relationships between ecosystem health and human health. We will also explore existing and new research opportunities on soil biodiversity in relationship to human health and as a foundation to ecosystem health. Human health and ecosystem health are seldom linked by the disciplines that study them, with the exception of traditional ecological knowledge (TEK), with its dynamic, holistic approaches. Research linkages could show, for example, how
health outcomes might inform ecological restoration and, for instance, the public health benefits of the cumulative impacts of restored ecosystems. To address knowledge gaps about relationships between soil biodiversity, human health, and ecological restoration, we have undertaken an interdisciplinary literature review on the inclusion of public health and other health outcomes in ecological restoration. Based on the synthesis of the literature, we will present TEK case studies, research possibilities, collaborative opportunities, and policy initiatives that can accelerate public understanding and awareness of the enormous benefits of ecological restoration for human health.

Scaling up landscape restoration through education on sustainable business models

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For the past centuries, economic growth has come largely at the expense of nature, resulting in degraded landscapes, climate change, and extensive species extinctions. Developing landscape-scale resilience to address the combined and accelerating crises of climate change, biodiversity loss, and soil and water degradation is a major societal challenge. We need to find ways to restore and sustainably manage landscapes while simultaneously returning economic and societal benefits. This requires transdisciplinary cooperation among different specialists and stakeholders. Currently there are wide gaps between economy and ecology and business and environment, which hinder large-scale landscape restoration built on sustainable business models. Bridging these gaps requires students and professionals to be equipped with new knowledge and skills related to restoring and managing landscapes with social, cultural, and financial returns. Educational materials to take on the global challenges defined in the SDGs are lacking. To develop such high-quality education, the ENABLE¹ consortium, an Erasmus+ co-funded programme, was established. We have developed a diverse portfolio of case-teaching materials and two massive open online courses (MOOCs)² on how restoration of degraded land can provide a return of inspiration and of financial, natural, and social capital. We have also established an e-platform for innovation and learning, where practitioners, experts, and learners can access and contribute to case studies, and exchange knowledge and tools. Our goal is to reach business students and practitioners to energize and accelerate large-scale landscape restoration based on sustainable business models.

¹https://www.rsm.nl/enable

Identifying priority species for grassland restoration – a conceptual framework illustrated for south Brazilian subtropical grasslands

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Seed limitation has been recognized as a general restriction for restoration of tropical and subtropical grasslands, making seed introduction necessary for recovery of these systems. This contrasts with reality: at current, seeds of native grassland species are practically unavailable in most regions, which impedes the upscaling of restoration efforts. A first step towards the establishment of seed production and distribution infrastructure is the definition of priority species for restoration. Using species-rich subtropical grasslands in southern Brazil as a case study, we here present a framework for the definition of priority species. Starting with regional species pools of different grassland regions, we apply several filters based on biological characteristics of the species and relevance for specific restoration objectives in distinct settings, for example in privately owned grazed grassland and in ungrazed grassland in protected areas. Data bases for this are published studies on
vegetation in well-conserved and degraded areas, species distribution data, trait data, and information on forage value of grassland species. This allows us to identify from a species pool of more than 900, a manageable number of species that are of particular relevance for restoration in the different grassland regions and for which research on propagation and establishment is now a second step. The explicit inclusion of criteria related to grassland productivity helps to increase stakeholder participation into restoration projects. Systematic approaches such as ours are fundamental to create a sound scientific basis for the challenging restoration aims in tropical and subtropical regions.

Maximizing seedling outplanting success with organic soil amendments

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Soil organic matter (SOM) is critical for ensuring both forest soil and tree health. Although soil organic matter represents only 5% of the soil, it is critical for cation exchange capacity, water and nutrient retention, and overall site productivity. However, increased populations and a changing climate have contributed to the loss or degradation of SOM. It is critical to understand how soil texture and the type of organic amendment may interact to alter soil processes before planting for site restoration. Restoring organic carbon can help reverse soil productivity declines and improve plant establishment and growth. Application of organic matter to soils can supply needed plant nutrients and can improve water holding capacity to make soils more resilient to drought or flooding. Biosolids or manure additions rapidly release nutrients and can enhance plant growth in the short-term. Biochar additions, while low in nutrients, offer a stable source of soil carbon and can increase water and nutrient holding capacity. Sawdust or wood chips is another option for amending forest sites, but it is often surface applied and can decompose quickly. Organic amendments are more effective at increasing understory plant production rather than tree seedling or older tree growth, but the alteration of water holding capacity may reduce the risk of insect or disease attack.

Public resistance against ecological restoration: Possible reasons and feasible solutions

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Committed stakeholders in ecological restoration are just as, if not more, important than appropriate restoration techniques. Stakeholders will assure the long-term success of most restoration projects; therefore it is crucial to engage them from the planning process until the completion. Our case study takes place in Butte, Montana, where historic mining and smelting caused extensive environmental damage and public health issues. Today the area is part of the largest Superfund complex of the United States. Unlike other mining impacted landscapes, mining operations were in amongst Butte’s urban environment. Mine waste is located within the residential areas in addition to sites surrounding the community. To preserve human health, a relatively quick remedial action was taken, where waste was capped in place and was “stabilized” by agronomic grasses. However, the ultimate goal is to restore these sites. For that reason, numerous entities perform restoration projects in the area. Surprisingly a number of the local residents expressed anger over a restoration project in their neighborhood. Their complaint especially addressed the plant species used in the project, which were all locally adapted native grasses and forbs. In the end, the site needed to be turned over to an irrigated lawn. This example shows that if stakeholders are not vested in a restoration project, they can sabotage progress. What caused the failure of that project? Could we change people's attitude with education or proper planning? In our presentation, we attempt to find answers to these questions and demonstrate feasible solutions.
Can translational research be used to engage and hear stakeholders, rather than another mechanism to get others to agree with us?

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Examples of restoration efforts highlight the importance of stakeholder input early in the process to insure restoration success. When studying the adaptive management experiences related to Mercury in the South River, Virginia, USA; Selenium in Stuart Lake, Utah, USA; and Urban Stream flow into Little Stringybark Creek, Melbourne, Australia and a restoration demonstration project on a Superfund site in Butte, Montana, USA we realized that the value of stakeholder input was instrumental and could change the goals of the restoration. As we look for ways to identify and communicate with stakeholders respectfully, ethically, and effectively the implementation of Translational Research could benefit all participating parties. Translational Research is adapted from the medical field and uses defined plans to communicate basic research. This process can be adapted to restoration ecology with planned and methodical engagement of stakeholders. Because of the importance of stakeholder input it becomes necessary to institute procedural plans for that participation in much the same way we plan technical aspects (e.g. move dirt) of a restoration. Proper planning for stake holder input would elevate its necessity as an element equal with others in the restoration process. Rather than simply using the stakeholder input as a vehicle to persuade stakeholders to adopt a predetermined protocol, it can allow for meaningful dialogue and inclusiveness.

Engaging society and building polycentric governance for integrated land and water management: Insights from a science-led restoration programme

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Interventions for development, such as catchment-scale landscape restoration, have a history of ambiguous outcomes and outright failures. How can interventions, and especially those that involve government, research, and stakeholders, including local residents, result in sustainable outcomes that persist beyond the intervention? We suggest that participatory governance, within an evolving polycentric governance system, offers a promising mechanism. We used transdisciplinarity (TD) as the underpinning research methodology, within a recognition of the Tsitsa River catchment as a complex social-ecological system (CSES). Much of the Tsitsa is an eroding grassland landscape that is over-grazed and invaded with alien trees. Restoration was, from the start, embedded in a theory of change leading towards social well-being and sustainable natural resource-based livelihoods. Bio-physical research was dominant, seeking insights into sediment process, key-resource ecology (such as hill-slope seep wetlands), and spatial resource-use by livestock. However, we recognized that a science-based understanding of the catchment, linked to active restoration, would not secure a sustainable future. Consequently, we began to build a process of linking formal natural resource governance systems with an emerging catchment resident participatory governance system in a process of purposeful co-learning. Local residents and a wide range of stakeholders with a range of natural resource governance roles, are working together towards people living well in the landscape: i) engaging confidently and knowledgeably with responsive government, and ii) crafting their future landscape, to their benefit. In this process, investment in active restoration is the key driver of change.
Stakeholder perceptions of marine restoration: Beliefs, preferences, and supporting actions

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Aiming to reverse loss and limit further habitat degradation, International and European policies have put restoration at the top of their agenda, incorporating high-level policy objectives such as the protection of 10% of marine habitats and the restoration of 15% of damaged ecosystems. While there are many widely publicly supported terrestrial (e.g. forest restoration) and land-coast interface (e.g. sand dunes) restoration projects, ecosystem restoration as a concept and practice is lagging behind for many strictly marine ecosystems of many European countries. There is also limited understanding of what the stakeholders involved with the use, management and protection of marine ecosystems know about marine restoration. How committed to protection and restoration of degraded ecosystems are they? Within the MERCES project, the first European H2020 project to focus exclusively on marine restoration concerning a number of key ecosystems, we investigated stakeholder perceptions about restoration of degraded marine ecosystems, most of which we do not usually get to see. We are looking at preferences and reasons behind social acceptance of conservation and restoration. A European survey was conducted based on an anonymous on-line questionnaire targeting government, NGOs, researchers, and marine users. Survey results indicate that while stakeholders in general agree that marine restoration can reverse negative human impacts there is some heterogeneity in their degree of agreement. There are clear favourites (e.g. many favouring higher targets or preferably supporting local projects) and scepticism over some restorative approaches (e.g. recreation elsewhere is not considered a solution by many stakeholders).

Secondary invasion: The bane of weed management – identifying and overcoming the gap

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Exotic plant invasions present a global threat to natural ecosystems, yet successfully mitigating this threat remains a challenge. An implicit assumption in weed management has been that killing target invasive weeds addresses this problem. However, studies increasingly demonstrate that a common response to killing a dominant target weed is secondary invasion – an increase in abundance of non-target exotics following target invader suppression. We present results from a global literature review and meta-analysis quantifying the magnitude of the secondary invasion problem and identifying possible causes. Of 168 studies examining the efficacy of exotic plant management in terrestrial habitats, only 29% quantified community responses sufficiently to evaluate secondary invasion. Meta-analysis of 60 cases from 38 studies showed that control efforts strongly reduced target invader abundance overall, but the system responses tended toward increases in secondary invaders more than native plants. Importantly, 89% of the secondary invaders identified were classified as noxious or invasive plants. Available information suggests that control method may sometimes favor secondary invasion due to side effects of management tools, such as when the use of broadleaf herbicides to target invasive forbs facilitates invasive grasses. However, secondary invasion is most strongly linked to reductions in the target invader's abundance, suggesting that other invaders simply outcompete native plants in recolonizing following target weed suppression. These results demonstrate that we are becoming more effective at controlling target invaders.
However, suppressing a dominant invader does not necessarily restore plant communities. We discuss current strategies for mitigating secondary invasion and future research needs.

**Making the most of seeds in mine site restoration**

**Simone Pedrini**  
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Seeds are a key component for the successful restoration of landscapes degraded by mining operations. The collection and production of seeds of the appropriate origin, in the quantity and diversity needed to achieve a satisfactory degree of recovery, are onerous tasks that require careful planning and a significant budget. However, once seeds are obtained, at an average cost of 750 $/kg, sub-standard storing and processing practices can drastically reduce the viability (and value) of the collections. The adoption of practices, standards, and technologies used in the agriculture seed industry and conservation seed banks can help obtain high quality seeds and maintain viability through the seed supply chain. This would improve chances of seed germinating; however, numerous impediments of post-mining restoration scenarios, such as unsuitable substrates and abiotic stresses, still limit seedling emergence and successful plant establishment. Seed coating could help overcome some of these logistical and ecological barriers. Seed coating is a technology developed in the agricultural sector that is used to modify the shape and size of the seed and deliver active ingredients that provide protection from predators and pathogens, stress resistance, enhance growth, and improve survival. A recent study showed that seed coating with salicylic acid improved the survival of three Australian grass species, during the dry summer months. Ongoing research is testing the effect of germination promoters and beneficial microbes, delivered via seed coating, in order to promote plant establishment and, ultimately, improve mine site restoration outcomes.

**Seed encrusting with salicylic acid: A novel approach to improve native grass survival**

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Grasslands across the globe are undergoing degradation due to climate change and human impacts. If restoration of degraded native grassland is to be achieved at the scale required, cost-effective means for seed-based establishment of grass species is crucial. However, grass seeds present numerous challenges associated with handling and germination performance that must be overcome to improve seeding efficiency. Seed coating technology, allowing for increase of seed size and weight and providing active ingredients for seed protection and enhancement, could improve grassland restoration efficacy. Salicylic acid (SA) is a compound known to improve plant resistance to biotic and abiotic stress, but it has rarely been tested through seed coating and never on native species. The coating technique of encrusting was tested on three Australian grass species (Austrostipa scabra, Chloris truncata, Microlaena stipoides var. Griffin and Rytidosperma genicula var. Oxley). Salicylic acid (SA) was delivered to the seed by imbibition and through the coating. Treatment effects were tested on germination in laboratory conditions, and seedling emergence, survival, and growth in field trials. The encrusting and imbibing processes were not detrimental for seed germination and seedling emergence. SA did not significantly improve germination and seedling emergence, but plants established from SA treated seeds exhibited improved growth and survival compared to the untreated control. When SA delivery mechanisms of imbibing and encrusting were compared in terms of delivering plant survival and growth, a significant difference was rarely detected, suggesting that seed encrusting could be used to deliver SA and its stress resistance inducing properties.
A standardized UAV coastal inventory protocol for consistent restoration project planning

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Rising water levels and increased frequency of extreme weather events are rapidly eroding coastlines around the world. Despite the challenges posed by ongoing climate change, restoration projects have the potential to mitigate the negative consequences of climate change in coastal communities. Using unmanned aerial vehicles (UAVs) as the method for documenting coastal restoration projects and natural disasters is becoming more popular as UAV technology is becoming cheaper and more user friendly. Global efforts are underway to restore coastal ecosystem services that lessen the impact of natural disasters and promote native biodiversity, but the integration of UAV acquired coastal inventory data is lacking consistency. I examined case studies from a diverse group of restoration projects using UAV derived data for best practices to create a standardized UAV coastal inventory protocol. I tested the proposed UAV coastal inventory protocol on a green infrastructure project on the southern coast of Lake Superior in Marquette, Michigan, United States. Lake Superior is experiencing record wave heights and water levels, intensifying coastal erosion and the need for restoration project monitoring. I propose standardizing coastal inventory data collection to allow for consistency in the comparison of future coastal restoration project results. The implications of comparative photographic analysis derived from the standardized UAV coastal inventory protocol will allow project funders to compare past project results with increased transparency. This standardized protocol will also help coastal restoration planners compare strategies during the planning process of projects to inform decision making and local policy change.

Standards for certification of forest restoration projects in Spain

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Since 2010 WWF has been analyzing the forest restoration situation in Spain and some important deficiencies in public policies were detected. Forest Restoration Projects only address degradation symptoms, and are not effective in integrating social, economic, and ecological aspects. Projects do not include maintenance and monitoring or public participation processes, and they invest excessively in reforestation, forgetting about other actions needed to recover a degraded, damaged, or destroyed ecosystem. In order to improve this situation WWF began developing a certification system for forest restoration projects. The main objective of the standards is to establish when a forest restoration project can be verified with a common and standardized methodology that takes good restoration practices under consideration. The WWF Standards have been developed to be applied to forests in any of Spain's biogeographic regions (Atlantic, Mediterranean and Macaronesian). In 2011 a first draft was agreed upon by an expert group. In early 2012 an independent audit was developed to validate the standards (8 principles, 33 criteria and indicators defined) in a field test at two places affected by wildfires in different regions in Spain. The working group debated the suggestions made by the auditors and agreed on the final document. Now it will be applied in a large-scale restoration project in Valencia to
set an example. WWF Standards have not been certified by any Accreditation Entity yet. We are aware that SER is developing a standard and we want to share our regional experience and seek collaboration to complete this process.

**Use of nitrogen fixers in the restoration of legume shrubs in Mediterranean ecosystems**

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Soil losses in arid and semi-arid Europe is increasing and rehabilitation of heavily damaged soils is a challenge due to the inhospitality of the environment and the limits for the re-establishment of native vegetation. In particular, recovery of anthropogenic soils cannot rely on spontaneous processes, and low-cost/low-impact strategies are needed to prevent greater soil degradation. Mediterranean wild legume shrubs have great potential for soil recovery and conservation thanks to their biological nitrogen fixation ability. In addition, there are a high number of species this group that are drought resistant, which represents an additional advantage for withstanding the harsh environment in the Mediterranean. In this study we report results on how inoculated autochthonous wild legume shrubs were used in a long-term trial to recover an anthropogenic soil in semi-arid sites of the Iberian Peninsula. Microbial inoculants strongly enhanced plant establishment and growth on the anthropogenic soil in the greenhouse and in the field for up to two years. In addition, soil microbial activities were enhanced and the accompanying plant communities around the inoculated plants were richer that those in the neighborhood of the non-inoculated shrubby legumes. These results demonstrate that inoculation of wild legume shrubs with nitrogen-fixing bacteria is a promising strategy to rehabilitate anthropogenic soils in Mediterranean semi-arid regions.

**Paludiculture – A way to restore ecosystem services of peatlands with continued productive use for economic benefits**

**Jan Peters1, Andreas Haberl1, Wendelin Wichtmann2**

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Climate-smart land use with close-to-surface groundwater levels (paludiculture) could restore ecosystem functioning and reduce GHG emissions, and thus contribute considerably to reaching restoration and climate mitigation targets. However, adapting peatland agriculture to higher water levels is a challenging task for society. This talk will highlight examples in Europe including which plant cultures are used and how paludiculture delivers synergies between land use with economic benefit and restoration targets with environmental benefit. It needs to be incorporated into national and regional strategies to steer spatial and rural development planning, including delineation of target areas of organic soils to create common understanding for all affected stakeholders (farmers, but also water management, conservation, tourism and others) and authorities. As a basis, updated peatland distribution data is used, which can be merged in GIS and other planning data. Biomass is either used to substitute fossil materials (construction, insulation, horticultural substrates, etc.) or for generating renewable energy for heating and electricity. Environmental benefits are GHG emission reduction, nutrient and water retention, local cooling, and biodiversity, which depends on habitat management. Review of research for the benefits is presented and how it can be implemented into national and international policy frameworks.

**Using long-term ecological data to establish benchmarks for restoration in South African drylands**

**Hana Petersen1,2, Timm Hoffman1, Joh Henschel2**

159
The Succulent Karoo biome forms part of one of the most arid regions of South Africa and is recognised by the IUCN as a biodiversity hotspot. Historical landscape photographs from this biome illustrate the condition of the landscape a century ago and are an under-utilised source of ecological data in an otherwise data-deficient geographic region. Taking contemporary repeats of historical photographs provides a valuable means of comparison between the past and present condition of the landscape. The observed changes in various land cover classes from several sites in the Tanqua Karoo (Northern Cape) are attributed to major changes in land-use, notably a decrease in livestock as a consequence of de-agrarisation and a shift to a more conservation-oriented function of privately-owned farms. Long-term ecological research emanating from Tierberg-LTER in Prince Albert (Western Cape) with over 30 years of climatic and ecological data demonstrates the utility of routine monitoring and resampling of fixed plots over successive years in providing insight into the influence of different livestock stocking rates, changing climatic conditions, and extreme weather events such as drought. These examples highlight the usefulness of various sources of long-term ecological data in establishing benchmarks for restoration and rehabilitation in the economically and ecologically important Karoo region of South Africa.

Performance and biomass: Carbon sequestration of rehabilitated mangroves in Myanmar and Vietnam

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Mangroves provide vital ecosystem services for livelihoods and sustainable development in tropical coastal communities, but they have been deforested in many nations. A common approach for restoring mangrove ecosystems in severely degraded areas or areas requiring rapid re-establishment is planting seedlings. Thousands of hectares of mangrove plantations have been established over the last several decades in Vietnam and Myanmar. Examination of mangrove plantation performance and factors influencing growth is important for developing management options for successful mangrove restoration. We surveyed 220 mangrove plantations in Vietnam and 216 in Myanmar. Growth data, environmental parameters, and management practice information were collected. We used boosted regression tree models to evaluate the most influential variables on plantation performance. Our results reveal that management and environmental factors play similar roles (35% vs 40%) in the success of Vietnam’s restoration plantations, while unplanned disturbances, e.g. illegal cutting, were the major threat (70%) to Myanmar’s plantation establishment. The results imply that silvicultural practices are less influential than mangrove protection on plantation success. Biomass growth of different mangrove species were modelled for forecasting carbon sequestration in both countries. Without major disturbances, most plantations had lower aboveground biomass growth rate than naturally regenerating stands (e.g. biomass of 8-year-old plantations was 39 Mg ha⁻¹ while biomass of 9-year-old regenerating stands was 70 Mg ha⁻¹ in Myanmar). At later successional stages (e.g. plantations older than 35 years), undisturbed plantations had similar biomass and species composition to adjacent mangroves that naturally regenerated (120 Mg ha⁻¹ vs 135 Mg ha⁻¹).

Pollinator responses to restoring shrub steppe habitat for the Greater Sage-Grouse

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The sagebrush steppe habitats of North America are experiencing rapid conversion to non-native annual grasslands because of an increased frequency of wildfires. The Greater Sage-grouse is a flagship species for sagebrush ecosystems that provide habitat for many other species. Declines in sage-grouse populations have led to habitat restoration efforts across millions of hectares of shrub steppe. Here we investigate how these restoration efforts are influencing forb communities and their pollinators. We sampled post-fire restoration areas at 7 wildfires in the first 5 years after treatment and quantified the diversity and abundance of bee genera in seeded and control plots, as well as nearby unburned reference plots. Preliminary results suggest that the most common bees in burned areas were from the family Halictidae, primarily from the genera Lasioglossum and Halictus. These genera are tolerant of disturbances and are generalist foragers that can take advantage of resources provided by non-native forbs that tend to dominate post-fire environments. We observed differences in bee community composition among treatments suggesting that some genera are more sensitive to disturbance than others or that floral resources varied by treatment. Our data also suggest that surrounding unburned areas may provide source populations of bees. Overall, our study demonstrates the complexities of post-fire habitat use by bees in restoration areas aimed at restoring shrub steppe habitat for a flagship bird species. Improvements in establishing native forbs in post-fire restoration areas might allow bees to be used as a faunal indicator of restoration success in the future.

Forest seed potential for direct seeding in tropical regions

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Direct seeding is a low-cost technique applied at different scales and easily mechanizable. However, it requires many seeds, presents high mortality, and requires further dissemination of techniques and legal acceptance. The search for potential species requires identification of functional traits that favors establishment and represent the species' potential for direct sowing. We carried out a systematic review of the literature and analyzed direct seeded plantations from several regions of the Seasonal Forest in Brazil. The species' functional traits were determined at the population level, including mortality, dormancy, natural longevity, seed size, germination speed and community approach (pollination syndrome, dispersion, deciduous nature, successional group, natural distribution, and occurrence). We evaluated the establishment and survival success (the chance that a seed germinates and produce a seedling and the survival of the seedlings until the end of the experiment). On average, 108 potential species were identified, with 18.5% (n = 20) being established and surviving in all studied areas, 40% from eight genera of the Fabaceae family and 15% from the genus Byrsonima (Malpighiaceae). Dormancy was the most determining trait for establishment, followed by rapid germination and natural longevity (>6 months) at the population level. The potential of a species for direct sowing was not related to the successional group and wide natural occurrence was the most frequent trait associated with the 108 potential species. The strategy of recruitment from seed and seedling banks may be related to the potential of some species for direct seeding.

Overcoming limiting factors to seedling establishment:
Physiological, morphological, spatial, and temporal tactics

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Using nursery-produced seedlings for restoration helps achieve on-site objectives by increasing the trajectory of ecosystem services compared with natural regeneration. This function, however, is only possible with quality seedlings that are matched to the
objectives with the appropriate morphology, physiology, and genetics. Within the nursery culture environment, it can be possible to express seedling traits that favor establishment on outplanting sites that have a myriad of limiting factors such as depleted soil moisture and competing vegetation. Simple morphological traits that include longer root systems or greater height are logical targets in such instances. One critical aspect to quality seedling attributes that is less understood, however, is how a seedling functions—its physiology. In a sense, morphological attributes are just proxies for physiological functioning. But how do you, or how can you, condition a seedling to “function” for a specific purpose? Nursery culture has the opportunity to lay the foundational building blocks—i.e. quality—on which seedlings rely on for establishment and growth. It stands to reason, that seedling physiological conditioning can offer gains in potentially limiting outplanting conditions. Unfortunately, the direct links from nursery culture to physiology on the outplanting site are not fully realized. Our research explores the intersection of building target seedlings by varying nursery culture to match outplanting conditions with a better understanding of morpho-physiological functioning.

The 10-year journey of the Atlantic Forest Restoration Pact (PACT)
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The Atlantic Forest Restoration Pact is recognized as one of the largest global coalitions in favor of the restoration of Tropical Forests. This presentation will present the main results achieved in these 10 years of existence.

Restoration of Mediterranean temporary ponds in Portugal:
Challenges and opportunities
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Mediterranean Temporary Ponds (MTP) are habitats of major conservation importance in Europe due to their extensive decline in area and quality. Our work was part of the LIFE Charcos project*, directed to implement restoration actions to preserve this habitat on the Southwest Coast of Portugal. These ecosystems are strongly dependent on rainfall and annually experience a flood / dissection cycle. The exclusive fauna and flora that colonize MTP are specialized to exist with this alternation of ecological conditions. Restoration of typical MTP ecology presents major challenges and opportunities. The recovery of the basin's topographic profile is challenging and has to be carried out considering specifically the special characteristics of the MTP hydroperiod. The annual species and those with dormancy mechanisms are more resilient and exhibit higher recovery rates. The annual dynamics of the ecosystem present a great opportunity to monitor restoration success and consequently adjust recovery actions on an annual basis. We carried out physical replacement of pond basin topography, invasive vegetation control, and plant community enhancement. The restoration results are positive with reinforcement of the spatial differentiation of the floristic communities and increase of characteristic and indicator plant species. Regarding the control of invasive species (Acacia spp. and Carpobrotus edulis), the results are encouraging, since the removal of the vegetal mass allowed the germination of the small annual species characteristic of the MTP.

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Biodiversity responses to restoration of linear features associated with oil and gas exploration in boreal peatlands of western Canada

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Exploration of Alberta's oilsands has fragmented much of the boreal forest in the Province, with thousands of kilometers of linear features (mainly seismic lines) constructed. Seismic line restoration has become important for the oil and gas industry, with treatments mostly focused on reducing line use and access. Mounding and tree planting is a commonly used treatment in peatlands, as mounds provide higher ground, improving seedling establishment/survival, increasing topography, and reducing wildlife and human traffic. Mounding/planting has broader implications on local recovery and ecological properties than those related to functional restoration, which can be useful to assess restoration success. We evaluated habitat conditions and biodiversity (ground invertebrates and plants) three years post-treatment application in relation to untreated lines and the adjacent forest. Results show higher ground water content on the line compared to the adjacent forest, with no differences between treated and untreated lines. However, higher natural regeneration was observed on mounds compared to untreated lines and the adjacent forest. Plant richness was similar among habitats; however, invertebrate richness was lowest on mounded sites. Invertebrate abundance and plant percent cover was lowest in mounded sites. Species composition of plants and invertebrates was different among habitats (forest, mounded vs. untreated), with mounded sites the most different. Although restoration has influenced habitat conditions relative to those of untreated lines, it is still too soon in the recovery trajectory to evaluate whether mounding improves habitat conditions compared to those in the reference forest. Thus, longer term monitoring is required to better assess restoration success.

Application of Canadian Forestry knowledge and tools to impact assessment, mitigation, and restoration of oil and gas disturbances in Alberta, Canada

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Over many decades, the forestry sector in Canada has generated a wealth of knowledge about forest management that can assist the relatively new Oil and Gas (O&G) sector in addressing ecosystem management concerns. First, we present a summary of how ecological and silvicultural knowledge can be applied to environmental impact assessments, as well as to mitigation and restoration of disturbances associated with the O&G industry operations that take place in boreal forests of the western Canadian Province, Alberta. More specifically, we use examples of ecological and silvicultural knowledge, which resulted from research performed under a highly successful, long-term forestry project in Alberta - the Ecosystem Management Emulating Natural Disturbance (EMEND) project. Second, we discuss examples from initiatives led by the federal government's Canadian Forest Service (CFS), which use ecological and silvicultural knowledge for addressing O&G environmental concerns and improving restoration success of disturbed sites. The examples of the products from these initiatives include fact sheets and field guides as well as the development of demonstration field sites that help in the assessment of environmental impacts of O&G development on biodiversity and exemplify restoration measures based on silviculture practices that proved to be successful in forestry for restoration after harvest operations. Transfer of knowledge from Canadian forestry to the O&G industry will help to innovate and speed up current restoration practices in the energy sector and maximize the resilience of forest sites considered for the future industry development.
Native oyster restoration in Europe: Background, progress, and best practice

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Oysters provide a multitude of ecosystem services: they are primary reef-builders and increase biodiversity. Today, temperate biogenic reefs are among the most threatened habitats globally, as much of the continental shelf and coastal waters have been homogenized by bottom trawling and dredging. In Europe the native oyster, Ostrea edulis, is an endangered species and functionally extinct in several ecoregions. Reintroduction and restoration of this ecological key-player in European seas contributes to nature conservation objectives such as the OSPAR Convention on Protection of the Seas, the EU Flora–Fauna–Habitat Directive and the Marine Strategy Framework Directive. In general, several constraints to restoration have to be considered, e.g., lack of broodstock; degraded habitats, which are probably less suitable for recruitment; diseases and biosecurity; as well as the potential lack of suitable, protected restoration sites. The presentation will provide an update on the background and progress of oyster restoration in Europe, focusing on:

▪ best practice as formulated by the Native Oyster Restoration Alliance (NORA) in the Berlin Oyster Recommendation
▪ restoration in sublittoral offshore waters by presenting a case study in the German Bight: Applied methods, experimental set-up and key findings
▪ site selection with regard to ecological history, environmental conditions and feasibility of restoration

The presentation will point out major developments, challenges, limitations, and perspectives.

Systems thinking within restoration for resilience: Collectively understanding and managing relationships between land- and water-restoration and human livelihoods

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Despite the progressive and enabling legislative framework for Integrated Water Resources Management (IWRM), the integrity of many southern African river systems is declining. Many basins are challenged by balancing social development imperatives with resource sustainability. Such challenges resonate with global concerns of water security given an increasingly complex and dynamic context within which water governance has to act. This paper describes the uptake of IWRM in the Olifants Catchment, shared between South Africa and Mozambique, and the Tsitsa Catchment in the Eastern Cape. A systemic catchment management approach is described - not as an end in itself but rather as a process for managing and restoring water and land resources as shaped by the socio-economic and political context. This context is important because many of the issues apparent today are systemic in nature and hence require systemic approaches. We focus on restoring and maintaining environmental water requirements as a lens through which to examine the need for systemic, integrated, and adaptive responses. Regular non-compliance in South African rivers reflects the complexities of governing in dynamic, socio-ecological environments where operationalizing policy depends on the collective contribution of a number of strategies, plans, and practices. We highlight the importance of governance, a practice-based understanding of policy, the role of leadership and communication, collective action and regulation, and self-organisation. These issues are explored through the evolving experiences of working first in the rivers of the Kruger National Park, the uptake of these ideas into the Olifants, and subsequently the Tsitsa Catchment.
Designing back from practice: Keeping the Olifants River and benefits flowing through systemic, collective action approaches during the worst drought on record

Sharon Pollard¹, Hugo Retief¹, Eddie Riddell²
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This paper describes the use of systemic, collective approaches to keeping the Olifants River flowing during the worst three-year drought on record. Without this, flows in the lower catchment would have failed, impacting livelihoods and ecosystems both locally and downstream into the Kruger National Park and Mozambique. This success is described through the evolution of a resilience-building programme known as RESILIM-Olifants. For a number of years AWARD and partners have sought to support systemic, tenable governance arrangements reinforced by appropriate tools for Integrated Water Resources Management. The approach was initiated through a focus on ‘real-world’, practice-based needs of water resources managers and designing back from these to develop appropriate institutional and technological arrangements. Importantly the work is catalyzed by the implementation needs, rather than a research focus. The entry point was one of supporting the policy requirements for water resources protection whilst at the same time recognizing the practical needs of managers to allocate water in a stressed catchment and to monitor both status and water use against legislated benchmarks. This recognises that within South Africa, as in many countries, there is a commitment to environmental water requirements. Whilst methods for their determination are well-developed, implementation measures are still weak. Constraints to this such as institutional uncertainty, weak capacity, and inappropriate tools are discussed. We describe testing such an approach to sustain flows in the Olifants River and explore the benefits of doing so. We conclude by exploring both strengths and risks for such a system in the longer-term.

Effective strategies for the restoration of drastically disturbed sites

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The lack of effective methods for the restoration of mining and other drastically disturbed sites can constrain the treatment of sites humans disturb. Natural processes have been restoring natural disturbances (glaciation, natural landslides, volcanic eruptions, riverbank erosion, etc.) for millions of years. By following the methods that these natural processes use to restore the disturbance, strategies for the restoration of human disturbances can be developed. The first step in defining recovery strategies is to identify the filters or constraints that are preventing the natural recovery of the site. In many mining and industrial situations elements such as steep slopes (angle of repose waste rock dumps) or compacted surfaces such as the tops of waste rock dumps and haul roads create constraints that only weeds can address. By identifying and then dealing with the constraints, the natural recovery processes can be allowed to operate. In most cases, local pioneering species will move into prepared sites for free and quickly and there is no need for extensive planting programs. If the site is very large or there are not pioneering species nearby, then seeding with the seeds of suitable pioneering species is an appropriate option. Making disturbed sites rough and loose creates a condition that fosters the natural establishment of pioneering species and is inexpensive compared to traditional treatments.

Social-ecological catchments for prioritizing restoration efforts

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Ecological restoration efforts occur within coupled social-ecological systems, and therefore these efforts must consider human behavior to be effective. The allocation and distribution of limited resources to restore social-ecological systems involves trade-offs among potential actions and associated outcomes. What habitats should be prioritized to optimize our efforts and how will these actions influence human behavior? Recreation-based systems, like inland fisheries in the USA, offer a unique opportunity to explore how anglers respond to habitat restoration efforts on aging and degraded reservoirs. Anglers and the waterbodies they use are patchily distributed across the landscape; tracking and understanding how these non-uniform spatial distributions concomitantly respond to restoration efforts is difficult. To address this challenge, we constructed waterbody-specific, social-ecological catchments that represent the spatio-temporal draw of anglers to a waterbody. Social-ecological catchments were developed from U.S. Postal Service Zone Improvement Plan (ZIP) information collected from anglers who were fishing at a waterbody; these angler distributions were mapped using kernel density estimation techniques. We highlight how ecological restoration efforts could benefit by considering landscape context (i.e., waterbody rich vs. waterbody poor, urban vs. rural), heterogeneity of angler types, and reservoir age or degradation status. We discuss how social-ecological catchments could provide a powerful and practical tool for managers to visualize and quantify changes in social-ecological dynamics on the landscape.

Is the restoration of thicket in the Albany Thicket Biome with woody species really not feasible?

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It has been reported that the restoration of semi-arid thicket with woody species is not ecologically feasible in South Africa. Transformed and degraded semi-arid thicket exhibits exceedingly poor resilience with normal succession precipitating low species diversity dominated by grasses and ephemerals. The transformed and degraded mesic-thicket types have only slightly improved resilience but also limited species richness with many guilds missing – despite many decades without the drivers of degradation being present. The restoration of thicket has largely been focused on the en masse planting of one species (Portulacaria afra) with the assumption that, once established, it will facilitate the natural return of the other species, specifically the missing woody plant guild. A lack of understanding regarding the ecophysiology of key woody species, as well as the nuances of the microclimate needed for succession has limited restoration success in the thicket. This research seeks to take a systems approach to understanding the multi-scale dynamics for the restoration of mesic-thickets, then apply the wisdom gained from this process to tackling the major challenge of effective restoration of degraded thicket areas with woody species. The results from fifteen common woody species found in mesic thickets indicates that drought-sensitivity, germination success, seedling growth rate, herbivory, nurse-planting, tree-shelters, ponding, and other treatments have significant species-specific effects. The intimate understanding of these relationships correlated spatially and temporally with the major thresholds that limit the germination, establishment, survival, growth rate, and canopy recruitment – will enable the successful restoration of thicket with woody species.

Worldwide patterns of spontaneous succession and implications for ecological restoration

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There is a lack of studies comparing a high number of successional series at broad spatial scales such as continental or global ones. We asked what are successional patterns among world biomes and types of disturbances regarding: (a) the probability that spontaneous succession (= passive restoration) reaches its target, (b) what are prevailing successional trajectories, and (c) how do the species number and participation of alien species change in the course of succession? We found the probability that spontaneous succession reaches its target increases with latitude; divergent trajectories prevail, especially at lower latitudes; species richness mostly increases during succession but without a relationship to latitude; and the importance of invasive alien species in late successional stages decreases with latitude. Using spontaneous succession in restoration is especially recommended at higher latitudes in less human-altered landscapes.

Remarks: At the end of the talk, summarized results of the special symposium will be presented.

The worldwide analyses were done in collaboration with Lawrence R. Walker, Petra Janečková, and Lubomír Tichý.

Using a landscape approach to overcome barriers to restoration: Lessons from Tanzania

Mampiti Matete, Pelle Bågesund, Maria-Ana Borges, Nadine McCormick

IUCN ESARO - South Africa Water Programme, Pretoria, South Africa, IUCN Global Water Programme, IUCN Global Business and Biodiversity Programme

Africa is the next frontier for transformation through rapid economic growth. New investment targets infrastructure and activities in the agricultural, mining, and energy sector - natural resource-based industries that provide anchors for new trade opportunities, job creation, and ultimately, poverty reduction. However, with poor planning and biodiversity management, such developments risk causing an overall negative impact on communities as well as biodiversity and ecosystem services. Governments and businesses, with increasing participation from civil society, are working together to proactively shape investments in geographically defined development initiatives called 'growth corridors'. These frameworks also offer the means to be able to collectively identify strategic opportunities for landscape restoration. IUCN will present its lessons learned from its work in Tanzania through the SUSTAIN initiative. Partners from the public and private sectors and rural communities have been supported to demonstrate how climate-resilient solutions for land, water, and ecosystem management can be coupled with economic growth initiatives to build and sustain water and food security. Lessons include: the importance of governance as a critical entry point for ensuring social inclusion and requiring interventions that proactively build local community participation in economic decision making, including resource use and allocation; having an integrated approach to water, land and ecosystem management backed by up-to-date and scientifically robust knowledge; and the role of businesses as key actors for bringing forward solutions and innovation but also to influence with other actors in the landscape.

How to get more inclusive restoration programs? Governance process, social engagement, and gender perspective

Ludmila Pugliese

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Landscape restoration programs should be designed not only considering theoretical and ecological aspects, but also in the social dimension, since it just makes sense through human lens and intervention. This view change implies a broad perspective of the concepts and assumptions related to restoration initiatives with consequences on how to think and conduct restoration projects. The challenge now is how to integrate this aspect in our project, especially with regard to social engagement. The Atlantic Forest restoration PACT - a multi-stakeholder coalition that brings together more than 280 members to
restore 15 million hectares on the Atlantic Forest Biome by 2050 - thereby enlightening some major issues related to scale-up process. Looking through PACT's study case, we could analyze the main mechanisms associated with governance models, tools for analysis and monitoring protocols, and influence on public policy discourse, in terms of social engagement perspectives. The foremost achievements of the working groups, beside the total amount of the projects registered in the geodatabase, and public policy advocacy, suggest that the transdisciplinary approach, with the participatory methods, during all the stages of the process, can broaden the reach of the projects and also allow advances in knowledge in the field of landscape restoration.

Does facilitation promote establishment of native plants in a salt marsh recovering from invasive plant eradication?

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Harnessing positive species interactions (facilitation) has recently been shown to be promising for enhancing recovery of degraded coastal ecosystems in a few studies from the United States. Its generality, however, still needs to be tested more broadly in other countries and regions where obstacles to species recovery in degraded coastal ecosystems can be unique. Here, we used field transplant experiments to test if clumping increases the survival of salt marsh outplants and promotes native vegetation recovery in the Yangtze River Estuary, an estuary that has been cleared of invasive Spartina alterniflora, although native vegetation has yet to fully recover. There were three experimental treatments: i) dispersed planting, ii) clumped planting, and iii) unmanipulated control (n = 8 per treatment). Each plot within the former two treatments had nine transplanted soil blocks containing Scirpus maritimus, and survival of each transplant was estimated periodically. Results showed that the average survival rate of transplants was higher in clumped plots than in dispersed plots initially, but differences waned with time. In both dispersed and clumped treatments, planted S. mariqueter were competed eliminated by grazing by herbivorous salt marsh crabs. This indicates that crab grazing overrode any beneficial effects of clumping on plant survival and salt marsh recovery. We conclude that while clumping might increase the survival of salt marsh outplants and promote salt marsh recovery in some places, its efficacy must be tested in comparison to the impacts of major biotic and abiotic stressors hindering salt marsh recovery.

Promoting sustainable permanent grassland systems in Switzerland: Lessons learnt from 20 years of policy-driven restoration efforts

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Promoting ecological restoration at a scale commensurate with international sustainability commitments requires coherent policies and multi-stakeholder approaches. Since the recognition of agricultural multi-functionality in 1996, several policies have been introduced in Switzerland to balance rural development, food security, and environmental objectives. The lessons learnt after 20-odd years of implementation can guide future land management decisions. This paper, which originates from the Europe-wide research undertaken for the EU-supported SUPER-G project (SUstainable PERmanent Grassland: https://www.super-g.eu/), focuses on the effects of Swiss agro-environmental policies on sustainable permanent grasslands in the country. We use a socio-ecological systems approach and stakeholder analysis to assess the outcomes of policy instruments on grassland biodiversity, ecosystem services and farmers' income. The data comprise a qualitative analysis of official policy documents and grey literature as well as semi-structured interviews with key Swiss stakeholders. Preliminary results show that better ecological outcomes could have been achieved and trade-offs mitigated with more integrated and inclusive solutions. These findings can improve the calibration of policy
instruments to enable land managers to restore and maintain permanent grasslands in good condition. Questions of applicability and upscaling to other bio-geographical regions and socio-economic contexts further reveal the need for integrated monitoring and assurance systems for investors, land managers, and consumers.

**Lessons learnt from 13 years of restoration in a moist tropical forest: The Fandriana – Marolambo Landscape in Madagascar**

**Simon Rafanomezantsoa, Appolinaire Razafimahatratra**
*WWF Madagascar, Antsakaviro, Madagascar*

In 2005, WWF initiated a Forest Landscape Restoration (FLR) programme in the Fandriana-Marolambo landscape situated in Madagascar’s iconic moist forest (Center-East). The landscape, harbouring fragmented forest interspersed with savannah, exotic plantations, and fields stretches over 203,080 ha and is home to 150,000 people. It is rich in biodiversity but under pressure of deforestation. The objective of the programme was to restore ecological integrity and improve human well-being. The main lessons learnt:

- Establish multi-level partnerships and start with capacity building so stakeholders and partners understand all concepts. It is necessary for sustainability and includes technical aspects as well as organizational ones.
- Strengthening local governance structures and working with a strong social dimension: the sites that were established through a local decision-making process, which was based on social conventions, present the best rate of success and are currently still developing. While those established following unilateral decisions from the forest administration and those decided in a mixed way have varying success. Also, restoration methodologies matter as areas with active and mixed restoration actions are more successful compared to sites with passive restoration.
- Ground implementation in scientific knowledge: the recommended species have statistically higher growth rates. Linked to the household strategies, restoration areas with households that are less dependent on forest and with other additional activities have good results.
- Commit to the long term and design an exit strategy.

**A thorough and accessible method for restoration site selection: A coastal case study using seagrass**

**Anuradha Rao1,2, Dianne Sanford2, Nikki Wright2, Sarah Verstegen2, Jamie Smith2, Justin Bland2, Jeff Skinner2**
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Communities and non-profit organizations are playing a greater role in ecosystem restoration, particularly in nearshore habitats such as seagrass. Seagrass restoration success rates are variable, partly due to challenges with site selection. These challenges are greater for small organizations with limited resources. We summarize a seagrass restoration site selection method used by a Canadian non-profit organization, and a case study in Sechelt Inlet in southern British Columbia to analyze its utility. The site selection method includes assessments of socio-political, economic, ecological and physical criteria, with required and optional considerations. Socio-political factors relate to local support and absence of incompatible activities. Economic factors include time and budget. Ecological factors include local seagrass presence, lack of stressors, and a need for active restoration. Physical factors include suitable substrate, slope, depth and exposure. This selection method was applied to eight sites, of which three were rejected due to continued stressors, lack of local seagrass, or lack of support. Seagrass was transplanted at the remaining five sites and monitored for up to 4 years. Of these transplants, three were considered successful based on areal extent and density relative to reference beds. The remaining two were unsuccessful due to insufficient understanding of particular required criteria. This site selection method enables a clear understanding of biological, physical, and social contexts.
to enable site prioritization and selection. It also enables a thorough assessment of the reasons for restoration success or failure. This method can be adapted for restoration site selection in other marine and terrestrial ecosystems.

**UNESCO Man and the Biosphere (MAB) approach to ecological restoration in the Lake Chad Basin area**

Noëline Raondry-Rakotoarisoa
UNESCO HQ, Paris, France

The UNESCO Man and the Biosphere programme (MAB) put ecological restoration at the top of its agenda in the framework of its 2016-2025 Action plan framework. It is a technical partner of the Lake Chad Basin Commission (LCBC) in the implementation of the Programme of Rehabilitation and Strengthening the Resilience of Socio-ecological Systems in the Lake Chad Basin (PRESIBALT), UNESCO through BIOSphere and Heritage of Lake Chad Basin (BIOPALT) Project. The project's final objective is to support countries to establish World Heritage and biosphere reserves transboundary sites in the cultural landscape of Lake Chad. In doing so, the project aims at reconciling conservation and development in the area. In particular, the project is engaged in pilot actions of ecological restoration and ecosystem rehabilitation as well as promotion of green economies to contribute to increasing livelihoods and conservation of ecosystem services. These actions could ensure sustainable use of natural resources and reverse the trend observed in land degradation and ecosystem depletion in the Lake Chad Basin as well as reduce resources access conflict and promote peace among millions of peoples whose livelihoods depend on it. This presentation will present the multisectoral approach of the BIOPALT project and its added value to address multifaceted issues for achieving sustainable development in the Lake Chad area.

**Using a political ecology lens to examine forest restoration, water insecurity, and climate change in rural Bolivia**

Meagan Rathjen, Zhao Ma
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Approximately 20% of Bolivia’s population are water insecure, with most living in rural areas. Climate change is expected to exacerbate this condition. Since the 1990s, Bolivia has lost around 20% of its forest cover, mainly to agricultural production, reducing water retention. Bolivia recently committed to restore 4.5 million hectares of degraded forests by 2030, as part of their Nationally Determined Contributions stemming from the Paris Agreement and aligning with the United Nations’ Decade on Ecosystem Restoration. As such, it is critical to assess restoration interests, potential, and challenges from rural communities' perspectives and evaluate restoration priorities at multiple scales. Our study focuses on five rural municipalities in Vallegrande, Bolivia, a semi-arid agro-ecological zone. By conducting and analyzing 30 rapid ethnographies and semi-structured interviews with community members, natural resource professionals, and other governmental and non-governmental actors, we find some level of local ecological knowledge regarding ecological conditions and the associated needs for restoration, suitable species, traditional land use patterns, and current changes. We find that some actors connect forest restoration with improved water security, although such knowledge has not been sufficiently incorporated into local restoration programs. We find that community members desire certain species for livelihood reasons, some of which are actually ill-fitted to the local water reality. These results reveal dynamic power relations within and among groups of actors regarding whose knowledge, needs, and desires are being acknowledged, considered, and acted upon. Insights from this research can be used to inform the development of equitable, inclusive, and sustainable forest restoration.
To restore or not to restore: Examining the socioeconomic impacts of Prosopis juliflora in the Banni grassland, India

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Invasive alien species are among the leading causes of ecosystem modification. They can cause loss of native species, alter key ecosystem functions, and impact traditional livelihoods. For such modified systems, ecological restoration has become a crucial management goal. The Banni—a ~2500 km² arid grassland adjoining the Rann of Kutch, a large salt-marsh desert—is such a system. Banni has historically been home to the Maldharis (Mal~livestock, dhari~owners), traditional pastoralists, well known for their animal husbandry practices and milk economy. An invasive tree, Prosopis juliflora, was introduced to Banni in the 1960s to prevent desertification. Prosopis now dominates 60% of Banni. Prosopis invasion impacted the Maldharis by replacing large tracts of pasture area. This modified state of Banni led to calls for restoring the system to its historical state. However, we found, through a combination of quantitative and qualitative research, that Banni is now in a state of novel dependence on Prosopis for economic and cultural uses. Almost 70% of Banni’s people are dependent on income from Prosopis charcoal for their sustenance. Paradoxically, charcoal income has led to poverty alleviation through herd expansion, and an upsurge in the local milk economy. Our work suggests that Banni has become a novel social-ecological system, rendered irreversible due to people’s newfound socioeconomic dependence on this invasive species. Banni demonstrates the importance of taking a holistic view to restoration—that restoration must take into account the socioeconomic and cultural dimensions of species invasions along with the ecological.

Long-term change in the forest-grassland mosaic of Central Highlands, Madagascar, and its conservation implications

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Ecosystem degradation has been reported worldwide but particularly in the tropics where it was accentuated by deforestation. For Madagascar, the Central Highlands, thought to have been covered by forest, are currently dominated by grassland. As a result, restoration projects were conducted in these areas, but so far, very few results have been recorded. However, the success of such an approach can only be guaranteed with full understanding of ecological processes which occur on a scale of centuries to millennia. This research aims to reconstruct the vegetation and fire history of two sites in the region during the Holocene using fossil pollen, carbon isotopes, and microscopic charcoal in sediment samples. Results show that the first site, Ambohitantely, was dominated by C3 plants before 1300 yr BP, confirmed by the abundance of Podocarpus (Podocarpaceae), Syzygium (Myrtaceae), Proteaceae, and Ericaceae pollen, but shifted to C4 plants (Poaceae dominated) from 1300 yr BP to the present period. Current abundance of grassland in the area correlated positively with increased fire events as identified through charcoals. However, Dangolahy, the second site, displayed an abundance of C3 plants over time from the late Holocene even with the slight increase in grass at the near present period, which coincides with increase of charcoals. These results indicate that within the Central Highlands, there were internal differences in vegetation histories which suggest different management strategies. If Ambohitantely would benefit from restoration projects by reintroducing its tree component, Dangolahy would require monitoring of fire frequency to maintain its local biodiversity.

Climate change experiment suggests assisted migration may be necessary to save range-restricted plant species

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Climate change poses an existential threat to plant species with restricted geographic ranges. However, climatically favorable habitat may exist at higher latitudes if species can reach such locales. Thus, successful restoration projects should consider how climate change impacts species ranges in the future. In a climate manipulation experiment conducted between 2016-2018, we monitored populations of 14 range-restricted native species in three prairies across a 520 km latitudinal Mediterranean climate gradient in the Pacific Northwest, USA. At each site, 20 plots were divided evenly into controls and three climate treatments: drought, warming, and warming+precipitation. Each year, we measured rates of survival, growth, and reproduction to calculate population growth rates ($\lambda$). We found that for many species $\lambda$ was greatest at the northern site and $\geq 1$ (growing or stable), with climate treatments being neutral or beneficial relative to control. At the central site, warming often negatively impacted $\lambda$ relative to the control, with several species exhibiting $\lambda < 1$ (decline) under warming but $\lambda > 1$ in the control. Lastly, $\lambda$ was $<< 1$ for most species at the southern site under all treatments. These results suggest that conditions are already detrimental towards the southern end of this gradient, and that climate change may make matters worse within some parts of these species' ranges but be neutral/favorable towards the northern edge of/beyond their ranges. Thus, these species may need to migrate northward to cope with climate change. If they are unable to do so alone, assisted migration may be the only option for their persistence.

Landscape and abiotic factors driving spontaneous succession: A meta-analysis at a country scale

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Many studies have investigated the effect of environmental factors on the course of succession. However, there is no study testing their influence across various successional series at a broader geographical scale. We established a database of successional series consisting of 21 different succession types occurring in various disturbed sites in the Czech Republic, central Europe that were comprised of 2,846 phytosociological relevés. The stages ranged from 1 to $>150$ years old and included 1,012 higher plant species. Altogether 13 succession types were classified as primary (mostly mining sites), six as secondary (abandoned fields, emerged bottom lands, forest clearings, burned forests, urban ruderals, and former iron curtain corridors) and two that could not be unambiguously classified (road verges, artificial fishpond islands) and were excluded from successional status analyses. The abiotic factors included macroclimate characteristics and substratum pH, biotic factors comprised different land use categories within a 1 km radius of the sampled site. All abiotic and landscape factors considered had significant effects on the course of succession in disturbed sites at the country scale. However, the effects of abiotic factors appeared to be more important than land use. Species richness appeared to be higher on basic substrates. The number of target species increased with the proportion of forests in the surrounding landscape and decreased with urbanisation of the landscape. The differences between primary and secondary seres were negligible. Quantification of the role of particular factors may help to determine when spontaneous restoration is a viable option for restoration of disturbed sites.

Long-term success of different intervention measures in grassland restoration: The concept of ecosystem multifunctionality

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Evaluation of long-term ecological restoration projects is indispensable to effectively assess recovery after intervention and validate successful re-establishment of the targeted species or ecosystems. Main goals of restoration are to restore biodiversity and ecosystem processes. Higher biodiversity generally provides higher functional diversity, and both are crucial to reach similar levels of ecosystem processes as the targeted ecosystem. Recently, the concept of ecosystem multifunctionality, integrating biodiversity and multiple ecosystem processes, gained importance. However, ecosystem multifunctionality has so far rarely been used to evaluate long-term restoration success. We assessed how ecosystem multifunctionality, calculated from above- and belowground, biotic and abiotic functions, differs between three restoration measures of increasing intervention intensity (harvest only ≤ topsoil removal ≤ topsoil removal + propagules). We compared restored grasslands with intensively managed grasslands (initial state) and semi-natural grasslands (target state) 22 years after initial restoration interventions. Our results show the potential of the three restoration measures for restoring grassland multifunctionality. Not only microbial, faunal, and plant diversity successfully developed towards the targeted species-rich grassland ecosystems, but also high levels of ecosystem processes (e.g. nitrogen mineralization) were re-established in the long run. All three restoration measures significantly improved belowground biodiversity and ecosystem processes similar to the one of the target grassland ecosystems. However, aboveground biodiversity and ecosystem functions clearly differed among restoration treatments, with low intervention intensity failing to reach high levels of the targeted grassland ecosystem. Consequently, our study demonstrates that higher intensities of intervention are needed to re-establish grassland multifunctionality. The negative effects of topsoil removal are outweighed in the long run.

Assisting natural regeneration in agricultural landscapes

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Landscape transformation due to agriculture affects ca. 40% of the planet's land area and is the most important driver of losses of biodiversity and its services (ES) worldwide. Strategic revegetation including living fences, road sides, riparian systems, and woodland islets are an alternative to designing ecological restoration in extensive agricultural landscapes. Some benefits of such green infrastructure are well documented in the scientific literature. However, the benefit of triggering natural regeneration is poorly quantified and guidance for large-scale restoration to provide multi-functional landscapes is often lacking. I provide evidence of natural regeneration in Mediterranean cropland 25 years after abandonment and introduction of small woodland islets. Over that time period, an average of 3.8 individuals per ha per year were established. Initial oak regeneration triggered by the planted islets is slowed down by high acorn predation, seedling herbivory, and stressful microclimatic conditions. In addition, I present seven guidelines for buffer strip and hedgerow restoration that stem from ecological principles, the scientific evidence, and experience as practitioner. I tailor these guidelines to a case study in a Chilean biodiversity hot spot as a step towards cost-effective restoration. The target landscapes require restoring 0.89 ha km⁻² of woody buffer strips to meet Chilean law; 1.4 ha km⁻² of new hedgerows are also proposed. The cost of restoration in this landscape is estimated in ca. USD 6,900 planted ha⁻¹ of buffer strips and hedgerows. Financial incentives, education, and professional training of farmers are identified as key issues to implement the suggested restoration actions.
Mapping vocation for forest restoration and multifunctional landscapes in Rio Doce Basin, Brazil: Vocation for Restoration Index (VRI)

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Considerable efforts have been devoted to exploring pathways for moving toward resilient landscapes. A particular challenge is to reconcile the needs for economic growth, provision of ecosystem services, and social development across the landscape. This paper has three objectives: The first is to draw upon conceptual models for addressing production vs. conservation challenges. We adapted the land-vocation concept into the context of forest restoration in Brazil, based in three modalities: i) vocation for natural regeneration, ii) forestation for conservation purposes and iii) vocation for agroforestry systems, as an opportunity for landscape planning, after one of the worst man-made disasters in Brazil, caused by the Fundão Dam break in the Rio Doce Basin. The second objective is to apply the conceptual framework to a spatially-explicit index for mapping vocation for forest restoration (VRI), aiming to map the most favorable areas for receiving approximately USD 300 million of restoration investment over the next 10 years. Finally, we address implementation issues and the way IVR is taken up in the Brazilian decision-making context. Our results show that IVR is innovative and suited to dealing with the whole-landscape-approach conceptual framework. The methodological approach, as well as results of VRI received constructive feedback from both governmental institutions and local/regional stakeholders. We expect this work to inspire and gauge the implementation of forest restoration at the landscape scale in Brazil as a way to go beyond land sparing, instead of reconciling land vocation for production (agroforestry) and conservation (natural regeneration nd plantations) at the landscape scale.

Increasing operational resilience for sagebrush ecosystems by integrating indicator species metrics at multiple spatial scales into decision support tools

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Unprecedented conservation planning efforts for imperiled sagebrush (Artemisia spp.) ecosystems of western North America increasingly focus on enhancing operational resilience though tractable decision-support tools that link spatially explicit variation in soil and plant processes to outcomes of biotic and abiotic disturbances spanning large spatial extents. However, failure to consider higher trophic-level fauna in these tools can hinder efforts to operationalize resilience owing to spatiotemporal lags between slower reorganization of plant and soil processes following disturbance and faster behavioral and demographic responses of fauna to disturbance. Here, we provide multi-scale examples of decision-support tools for management and restoration actions that evaluate ecological resilience mapped to variation in soil moisture and temperature regimes through new lenses of habitat suitability and population performance responses for an at-risk obligate species to sagebrush ecosystems, the greater sage-grouse (Centrocercus urophasianus). We then describe pathways for more explicit integration of sage-grouse fitness with factors influencing variation in sagebrush resilience to disturbance and resistance to invasive species (e.g., annual grasses). The intended product of these efforts is a more targeted operational definition of ecological resilience for managers with quantifiable metrics that limit spatiotemporal mismatches among restoration responses owing to differences in engineering resilience between sagebrush ecosystem processes and sage-grouse population dynamics. We primarily describe tools that address threats to sagebrush ecosystems in the Great Basin in the western portion of sage-grouse range (i.e., grass-fire
cycles and conifer expansion), but underlying concepts have broader application to a range of ecosystems. Some preliminary information is provided for timely best science.

**Giving seeds a fighting chance: The use of seed enhancement technologies to overcome barriers to restoration success**

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New restoration seeding technologies are needed to overcome the diverse array of barriers to native plant establishment. Large parts of Australia have already passed beyond “safe limits” of environmental degradation. For instance, in southwest Western Australia (SWWA) 10-15kg/ha of seeds is required to achieve a low-moderate reinstatement of species diversity. However, with an average commercial seed price of $2,800/kg, procurement of seeds at scale is costly. It is imperative that seed resources are used efficiently. Water repellent soils are a major barrier to plant establishment (e.g. >10M ha of arable sandy soils affected in southern Australia). Soil water repellency decreases water infiltration and moisture retention in the soil resulting in poor germination and seedling survival. Recent ‘extruded’ seed pellet development (seeds embedded in a soil matrix) that contain soil wetting agents (surfactants) have shown promise in restoring proteaceous species in SWWA. For example, Lambertia inermis seedling emergence was 20% greater from pellets in comparison to bare seeds. For Banksia menziesii, pellets significantly improved the average survival of seedlings after a severe drought by 2.6 days. The benefits of surfactant-based pellet formulations on increased infiltration rates, loss of water repellency, and seedling recruitment have now been investigated using distributed temperature sensing (DTS). DTS has shown improved niche-level processes (e.g. increased water infiltration) and demonstrate the possibility of creating favourable microsite conditions for seedling establishment and improving the deployment of seeds. Through time these new technologies aim to provide the necessary seeding advancements for restoration programs across Australia.

**A review of African Quarry Life Award projects for biodiversity and community resilience, highlighting the key collaboration between academia, communities, and the industry**

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In more than 1,000 quarries and pits worldwide HeidelbergCement is committed to managing biodiversity during and after extraction by promoting and supporting a high diversity of native flora and fauna. The Quarry Life Award (QLA) is a scientific and awareness-raising contest which is organised by HeidelbergCement and proposed to a range of academic researchers, students, or other conservation practitioners. It aims to both raise awareness on the biodiversity value at extraction sites and find new ways to further enhance it during or after operations. For quarries with a high biodiversity potential (i.e. near important biodiversity areas such as Protected Areas), or for the ones with an after-use plan focused on Nature/Conservation, it is expected that findings and recommendations derived from QLA projects can guide and provide best practices for setting up or updating Biodiversity Management Plans and optimising rehabilitation plans. In several African countries, the last four QLA competitions show that projects aiming at promoting biodiversity in quarries were often combined with targeting positive impacts on communities’ livelihoods. For such projects, the concept of nature-based solutions was therefore prominent, whereby biodiversity could and should provide local communities with provisioning ecosystem services such as fuel (timber, biochar), food (agroforestry,
vegetable plots, aquaculture, bee-keeping) or medicinal plants. These QLA projects were, therefore, specifically designed to reach out to a range of local communities who could benefit from rehabilitation processes by combining both biodiversity and socio-economic aspects. This presentation will review case studies of such QLA projects in Africa.

**Existing and emerging use of drones in restoration ecology**

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The commercial, recreation, and research sectors have witnessed a rapid progression in the development and use of unmanned aerial vehicles (UAVs)—commonly known as drones. A diversity of modules and sensors are now available for fully integrated and customisable drone systems that harness the power of artificial intelligence (AI) to provide greater autonomy and efficiency in practice. The versatility of the drone system encourages innovation across different disciplines, and drones are now emerging as a valuable and cutting-edge tool in restoration ecology. Here, I will showcase the existing and emerging use of drone-based tools in restoration ecology. For example, several ambitious reforestation projects have recently used drones with sophisticated algorithms to disperse seedpods and fertiliser across vast areas of land. There are now also drone-based light detection and ranging (LiDAR) modules that can provide a high degree of spatial accuracy, enabling the scanning and modelling of structurally-diverse and dynamic habitats to help monitor changes over time. The ability of drones to operate in previously inaccessible sites, covering vast areas of habitat with a high level of efficiency, can bring significant benefits to projects that are time, labour and economically intensive. A wide range of drone-based opportunities now exists for restoration ecologists - from seed dispersal and sample collection to modelling and monitoring, but there are also several legislative, social, and spatial constraints. To maximise the potential benefits of drones in restoration ecology, it will be increasingly required that practitioners and researchers are aware of their strengths and weaknesses, uses and misuses.

**Knowledge for restoration ecology: Floristic and functional diversity along successional trajectories of abandoned tropical pastures**

Caqueta, Columbia

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The plant community assemblages and their space and time variation are important for understanding the fate of biodiversity under anthropogenic alterations. Understanding this pattern can help us plan ecological restoration for highly diverse ecosystems such as the Amazonian forest. It has been considered that plant attributes and their proportional changes should follow a complicated pattern of direct and indirect relationships among them across environmental gradients. We used models of trait-based community assembly to predict the probability for any species to pass through environmental filters. We suggest that such an approach is useful to refine (or to predict) the best community composition to carry out plantations for restoration. Our study was carried out in in the Amazonian Piedmont in the Caquetá-Colombia, in a disturbed and fragmented landscape. The vegetation cover is composed of a relict of humid tropical forest in different successional states. We selected a pool of plant functional traits to predict species abundance across the chronosequence. We asked if the strength of filtering changes along an age gradient and quantified the trait importance to predict species relative abundances. Preliminary results show that species abundance in the Amazonian forest was explained by leaf dry matter content and wood density. In addition, the landscape measures also explained the abundance. We are moving to use these results to select the plant composition to be used in higher level interventions to restore the humid forest in the Amazonian Piedmont in Caquetá-Colombia.
Seeding dates and seeding rates for grassland restoration in the semi-arid steppe of northern China

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Inner Mongolia contains the largest intact steppe in China, but rapid population growth has increased demands for food production from northern China’s farmlands and grasslands. This results in grasslands being overgrazed or converted to cropland. Revegetation of perennial grassland by seeding is an important tool in restoration. Successful seeding, however, depends on many factors, such as appropriate seeding date, seeding rate, and competition from native vegetation. The objective of this study was to develop an effective seeding protocol by determining an optimal seeding date and seeding rates for two reseeding species commonly used for restoration in these semiarid grasslands. We examined restoration success associated with mixed seeding rates of 200 to 1,100 pure live seeds (PLS)/m² for Medicago falcata and Leymus chinensis using strip-seeding at different seeding seasons (spring, summer, and late autumn) in northeastern Inner Mongolia. Restoration success was evaluated based on optimizing desirability across three individual responses: biomass and diversity of seeded and native species and the density of seeded and native species. Greatest restoration success after one growing season occurred with summer seeding and a seeding rate of 820 PLS/m² for Medicago falcata and 200 PLS/m² for Leymus chinensis.

Mapbiomas: Methodology to produce 30 years of annual maps for forest dynamics

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The MapBiomas project began in July 2015 with the purpose of generating annual land use and land cover maps for all Brazilian territory, using digital image processing of Landsat imagery from 1985 to the current day (Souza & Azevedo, 2017). Automatic classification was performed using the Random Forest machine learning algorithm implemented in Google Earth Engine. Large-scale tropical forest dynamic analysis in Brazil Atlantic Forest Biome with 131.000 Mha was performed using the GEE platform, comparing pairs of land use maps in consecutive years (transition maps) from 1986 to 2016. Forest Restoration was divided in two different classes: Persistent Restoration includes areas of Pasture or “Mosaic of Agriculture or Pasture” mapped three consecutive years as forest and then persisted as Forest until 2016 and Non Persistent Restoration includes areas that were mapped as Forest and were deforested afterwards. Forest dynamics show a reduction of deforestation in old growth forests while restored forest increased forest cover over the last decade.

Restoration of ecological infrastructure through collaboration and LandCare partnerships

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Climate change, failing ecological infrastructure, mining threats, unsustainable land use practices, uncoordinated conservation and restoration initiatives, overlapping mandates, and poor buy-in from private landowners are some of the challenges constantly in competition with sustainable natural resource management (NRM). The challenge remains - how to improve the coordination of joint conservation and restoration goals and ensure individual landowner and community buy-in on a landscape scale. LandCare Area Wide Planning was the catalyst to start an innovative platform that resulted in an improved collaboration amongst various role-players. The benefit of such an innovative platform was the creation of a common vision by the various stakeholders who had a collective interest
in the restoration of ecological infrastructure on a landscape level. Once common ground was found, challenges were analysed, and potential solutions were identified and put into effect. This network platform resulted in an improved coordination of restoration activities, commitment from the local communities, and innovative ways to create opportunities for the development of SMME's through river restoration. The most powerful benefit of such an innovative platform is that it provides a vehicle to improve communication between government bodies and local communities. Farmers and other stakeholders could now voice their opinions and press for changes in policies, strategy, and implementation as an equal partner on a landscape scale. To scale up and out the different innovation platforms can generate, test, and implement local solutions to local problems, share ideas, learn from one another, and influence policies to have a nationwide impact.

**Restore & Renew: Providing large-scale evolutionary, environmental, and ecological information in support of restoration practices**

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Restore & Renew is project aimed at creating a comprehensive and easy to use webtool supporting sustainable land restoration that is readily accessible to restoration stakeholders (www.restore-and-renew.org.au). Utilising genomic analyses and environmental modelling techniques, the project is uncovering an unparalleled level of information to understand how genetic diversity is partitioned across the landscape, and if genetic provenances are associated with climatic and environmental variables. The project is collecting, analysing, and sharing genetic, adaptive, environmental, and ecological data for over 200 plant species commonly used in restoration projects across Australia's eastern seaboard and representing the region's floristic, ecological, and phylogenetic diversity. This community resource aims to improve the success and long-term viability of land restoration projects, as well as providing the opportunity to ‘climate-proof’ restored areas. The genetic data is used to identify local neighbourhood boundaries, reduce relatedness, and maximise diversity within specific climate-based scenarios. Interpretations are backed by an increasing number of collaborative experimental trials testing, for example, relative genetic fitness and climate adaptation profiles. I will illustrate how, beside supporting restoration practices, the data produced by this project can be used to discover regions of high genetic diversity, identify commonalities among taxonomic and functional groups (improving our ability to generalise beyond the 200 species), and enable us to explore how species and assemblages are likely to respond to change through time.

**Ongoing restoration on phosphate open-pit mining fields: What can we learn from the arthropod community?**

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Large natural habitats and open lands in arid and hyper-arid regions are negatively affected by human activity around the world. Mining is one of the most significant factors that leads to this damage. Phosphate open-pit mining fields cover over 200 km² of the Negev desert in Israel. However, the ecological effect of the ongoing restoration efforts of the mines has not been studied. Our research group developed a conceptual model of ecological restoration, which helped us study the effects of said ongoing restoration efforts on: microbial soil crusts, plants, and arthropod communities. With respect to arthropods, we focused our research on two separately restored mining sites along the Zin river valley, comparing the ground-dwelling community of restored plots within these areas to those in adjacent natural plots. At each plot we used 24 one-liter dray pitfall traps to sample the arthropods. The traps were left open for 72 hours, after which we collected the trapped animals and classified them to order or family levels in the lab. We found the animals in the restored plots to be of significantly higher abundance and species richness than those found in the natural plots. In addition, we found a high degree of similarity between the
different restored arthropod communities, but a low degree of similarity between those from the restored communities and those from the natural ones. The significance of our findings is that the arthropod community that exists in the restored plots is different from the arthropod community in the natural plots.

The role of restoration plantings in the landscape structure and functionality of a tropical forest

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Much is discussed regarding the urgent need to scale-up ecological restoration to recover biodiversity loss and achieve international agreements. However, how restoration plantings are integrated and can effectively help connect fragmented landscapes is poorly understood. We combined landscape ecology and a metanetwork approach to understand whether restored areas enhance landscape structure and functionality at the local- and regional-scale, respectively. We further asked which plant species show higher potential to connect the regional landscape and which traits are associated to that. The study was conducted in the Atlantic Forest, an extremely threatened tropical forest in southern Brazil, characterized by its high beta-diversity of plant and animal species throughout the fragmented landscape. We mapped 14 local-landscapes to compare their forest cover and connectivity before and after restoration plantings. For the metanetwork analyses, we sampled adults and seedlings of woody plant species in both restored and secondary forests within the local-landscapes, totalling 28 areas. We found that restoration plantings significantly increased forest cover and reduced patch isolation at the local-scale. At the regional-scale, metanetworks were poorly connected and significantly modular with sub-groups formed by a combination of naturally-regenerating species different than the planted ones, suggesting propagules-movement among studied areas. Plants potentially connecting the metanetworks were mostly fast-growing, animal-dispersed species. We demonstrated the positive effects of restoration on landscape structure while the species pool used in restoration initiatives seems to be maintaining the characteristics of a tropical fragmented metanetwork in which forest patches share, and are potentially connected by, a small-subset of generalist species.

Supporting ‘green-preneurs’ for landscape restoration

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Sustainable restoration of degraded ecological infrastructure requires that local land users appreciate the benefit of the restoration activities. This might be directly as a result of improved productivity or indirectly through linked economic activity. A recent research project in the Tsitsa River Catchment of South Africa applied action research and social learning to an investigation of how green entrepreneurship could be integrated into a catchment scale restoration project initiated by the Department of Environment, Forestry and Fisheries (DEFF). Two main enterprises emerged. The first was to support home-based garden nurseries growing vetiver grass for sale to the restoration programme. The second was to link improved grazing practice and better ground cover to increased income through livestock sales via village-based auctions. At the end of the two-year project, in November 2018, interest had been expressed by community members for both types of enterprise. Sixteen month later, fifteen vetiver nurseries have been established whereas interest in improved grazing and livestock sales has waned. In this presentation we reflect on the reasons for success and failure of the two initiatives and provide recommendations for future entrepreneurship activities related to restoration. Barriers to progress can be
linked to community dynamics that result in a lack of trust required for community initiatives; household-based enterprises have a better chance of success. Time is also needed for the funders (the DEFF) to be confident that an initiative will give the required returns and to adapt their management methods to facilitate its development.

Examining the cost effectiveness of stream and coastal restoration in the Chesapeake Bay, U.S.A.

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Legislative and regulatory changes since 2013 have significantly increased compliance challenges for many localities within the Chesapeake Bay watershed located in the eastern United States of America. These localities are responsible for sediment and nutrient load reductions from existing sources, or retrofits, for the first time. Stormwater retention ponds and engineered wetland facilities are commonly considered one of the more costly interventions on a dollar per pound of removal basis. Stream restoration, on the other hand, has recently proven to be one of the more cost-effective practices that are approved for water quality (WQ) treatment purposes. The US EPA Chesapeake Bay Program Office (CBPO) estimates that 670 kilometers of urban stream restoration will be implemented by 2025 in Virginia and Maryland because of these new water quality requirements. To quantify nutrient reductions, the CBPO developed a practical guidance document outlining acceptable methodologies for both river and coastal restoration projects. Within these documents are protocols that assist the locality in quantifying nutrient reductions for proposed WQ improvement projects. Over the past 6 years, Stantec has tested the relevant protocols, evaluated case studies, and consulted our clients on the most cost-efficient practices for sediment and nutrient crediting towards these requirements. This presentation discusses where numerous case studies on stream and coastal restoration practices fall regarding cost effectiveness versus more traditional engineering approaches. Understanding these data and conclusions has assisted many municipalities with making the best financial decisions regarding both their environmental responsibilities and their tax paying constituents.

Ridge to reef ecosystem restoration and sustainable management of the Jacotet River in Mauritius

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Amid increasing demands for freshwater as a basic human need, anthropogenic impacts, and global climate change, there is a growing global need for innovative and integrated catchment approaches to water resource management. This is especially important in Sub-Saharan African countries where water is generally a scarce resource, engineered infrastructure is lacking, and environmental considerations are often superseded by human needs/service delivery. The Jacotet River in Mauritius provides the ideal template for implementing an integrated and phased “Ridge to Reef” restoration project and catchment management approach. Supported by landowners and a diverse group of stakeholders, restoration will focus on water retention, storm-water regulation, improved water quality, conservation and protection of native marine/freshwater species, and riparian biodiversity. Upper reaches of the river drain a protected area, while lower reaches are utilized by rural fishing villages and the tourism sector and thus face impacts from agriculture, human settlements, and mixed land use. Villages in the region comprise inhabitants dependent on daily subsistence fishing with limited access to education and new livelihood opportunities. Therefore, there is an inherent link of people living within the region and the overall health of the catchment. This project, a first for Mauritius, will provide opportunities for local communities through training and job creation linked to restoration, maintenance, and ongoing monitoring, while tourism initiatives will support
restoration and contribute to citizen science. Combining quantitative sampling with citizen science, training, and capacity building will contribute to the sustainability of the project and further restoration of the river corridor.

**Secondary invasion: The need for a proper river restoration management plan**

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Effective ecological restoration following alien plant removal requires detailed monitoring to determine the success achieved through different interventions. However, unintended secondary invasion by alien plants may occur, thus affecting the native species recovery trajectory. Between 2011 and 2017, vegetation recovery was monitored on riparian sites along the Berg River in the Western Cape, South Africa, that were cleared of Eucalyptus camaldulensis in 2010 using two clearing methods (fell-and-stackburn and fell-and-remove) and two restoration approaches: passive and active. In 2011, significant increase in vegetation cover (P < 0.001) and diversity (P < 0.05) of secondary invaders, mostly alien grasses and herbs was recorded in both passive and active restoration sites. Although native vegetation cover and diversity increased six years later, the increase in the cover of woody invasive alien plants was observed. Only four of the nine native species that were planted to fast-track restoration were still present, but the abundance of these native species was significantly (P < 0.001) lower in 2017 than in 2011. The study concludes that although native vegetation recovery following E. camaldulensis removal is following a positive recovery trajectory, the reinvansion by secondary invaders has the potential to slow down and halt the recovery process. Management interventions that prioritizes removal of secondary invaders are required. Such interventions may include removal of reinvading invasive alien plants during follow-up monitoring, seeding fast growing native species that can out compete secondary invaders, and soil nutrient manipulation soon after clearing to reduce growth of secondary invaders.

**Establishing seed collecting networks and community nurseries to ensure Uganda’s Bonn Challenge pledge brings benefits to people and biodiversity**

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The Uganda Forest Landscape Restoration Opportunity Assessment, published by the Ugandan government and IUCN, states that 17% of Uganda’s land is severely degraded, 30% highly degraded, and 31% moderately degraded. This has serious implications for Uganda’s long-term development and causes the loss of 4-12% of Uganda’s GDP annually. Under The Bonn Challenge, Uganda has pledged to restore 2.5 million hectares by 2020 and aims to plant 200 million trees in priority areas to improve human well-being and ecological productivity. This represents an opportunity for biodiversity conservation and job creation. Uganda has more than 800 native tree species, 30 of which are globally threatened. However, government and commercial nurseries in Uganda focus on a small number of species, most of which are exotic. Tooro Botanical Gardens runs the largest indigenous tree nursery in Uganda and has worked in collaboration with local communities for over a decade to carry out successful forest restoration projects that bring benefits to nearby communities. Based on lessons learnt, Tooro Botanical Gardens and partners have established seed collecting networks and high diversity nurseries across Uganda that employ people in rural areas to grow a supply of high-quality indigenous seedlings for forest landscape restoration. This intervention is demonstrating that large-scale restoration targets can be met in a way that benefits people and biodiversity.

**Engaging vulnerable groups in peatland restoration projects**
For a long time, peatlands were considered a “storehouse of resources” for humans; their ecosystem services provided a steady income to local residents. Due to peat development cessation and closure of enterprises, local residents have lost their jobs and interest in peatlands. As a result, abundant peat cut fields became fire-hazards. A sociological study was undertaken in order to identify which groups of local residents could benefit from peatland restoration. The study was conducted in four pilot regions of Russia as part of the project “Restoring peatlands in Russia” (PeatRus), funded by the International Climate Initiative with German-Russian cooperation. The vulnerable groups of the population (the older generation, women, people with disabilities, and people with low financial income) were addressed first. For the considered pilot regions, ecological restoration projects had become drivers of socio-economic development and gave a start not only for restoration of peatland ecosystem functions, but also for developing the economic potential of the territory and the local community. In the course of the PeatRus implementation we developed a unique method for interaction with different stakeholders, including especially vulnerable ones. The presentation describes an example of a completed project in the Kameshkovsky district, Vladimir region. The applied method of stakeholder involvement will be replicated in other areas. Therefore, the ecological restoration projects allow reduction of the fire hazard, launches ecosystem restoration processes, as well as to identifying new opportunities for the use of peatlands' ecosystem services for the sake of the local community's sustainable development.

Assessing large-scale restoration interventions in Africa’s Great Green Wall programme

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Africa's Great Green Wall (GGW) is a transformative initiative to combat desertification, land degradation, and the effects of climate change in drylands around the Sahara. Large-scale restoration interventions are the priority actions that are implemented to increase biomass production, vegetation cover, and land productivity for small-scale farming and pastoral systems. We hypothesised that standardised assessment can be carried out within the first years of restoration interventions. Using innovative high-resolution satellite imagery and spatial assessment tools, we investigated participatory field operations over five years in 120 plots of 50 to 200 hectares under restoration involving 100 village communities in Burkina Faso and Niger. Comparative assessment results showed an 80% match between collected field data and computerised data just after mechanised ploughing, using Radar detection techniques of soil disturbance. After restoration planting, the vegetation index data (NDVI) showed a significant increased biomass in years 3 and 5 in all the plots. Plots planted 5 years ago, showed land cover improved 10% to 40% on average. Qualitative data of species enrichment also showed an increase in biodiversity, as a methodical combination of woody and herbaceous native species were planted. However, there was very little cumulative increase in NDVI values of natural regeneration in control plots for this Sahel region. The combination of field data with remote sensing data to provide a standardised, affordable and objective assessment of the biophysical impact of restoration interventions is now used by FAO to support the whole GGW restoration programme and is proposed for other large-scale restoration initiatives.

Tracking multiple ecosystem components to establish benchmarks for restoration in an arid rangeland in South Africa

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Due to the long history of overgrazing in the arid Tanqua region in South Africa, large parts of the area became degraded. Subsequently, the Tankwa Karoo National Park was established to contain ongoing degradation and conserve a wealth of endemic biodiversity. This study was implemented to acquire baseline information on various ecosystem components and functions in order to inform the restoration of the park. The study assessed above and below ground ecosystem components and functions for the various vegetation types at multiple temporal and spatial scales using field surveys, laboratory and greenhouse experiments, and remote sensing. Results indicate that over the last 30 years, vegetation productivity has remained stable, signifying a halt in further degradation of the park. At a landscape scale, the park was characterised with low vegetated patchiness with fertile islands being less prominent in areas with low vegetation cover, which reduces landscape functionality in retaining and utilizing resources. The similarity between the soil seedbanks and the vegetation was about 25% mainly due to the absence of many perennial species in the soil seedbank. Using an ecosystem services approach, these and other ecosystem components and functional processes investigated during this study highlight the entry points for restoration interventions. However, each vegetation type retains its own state and provisioning of ecosystem services, and therefore, the restoration intervention should not be the same across all the vegetation types.

**Restoration in freshwater ecosystems - taking climate change into account**

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Humans are dominant bioengineers that dictate the form, function, goods, and services of freshwater resources across the globe. Freshwater systems are also among the most highly impacted ecosystems globally. Humanity uses over 50% of all accessible freshwater runoff and species diversity losses in freshwaters are greater than for terrestrial or marine systems. This is a resource that is globally rare (i.e. <1% of earth's surface). Climate change will interact with current stressors, further disrupting freshwater ecosystems and the goods and services they provide. However, climate change means more variability, which will occur unpredictably. Its interaction with current stressors is locally unpredictable, and the ecosystems and species themselves show large variation in capacity to cope with or adapt to this stress. Providing ecosystems the best chance to adapt should be the best strategy to ensure freshwater goods and services. This means conservation and connectivity in pristine areas but focusing management on current and past stressors (i.e. eutrophication, acidification, connectivity, flow regime) in impacted areas. At a national level, we categorized and mapped water types according to their sensitivity and likely exposure to climate change, degree of present impact, current protection, and location. The results systematize water types and their threats in order to focus management actions and restoration at local and regional scales. Part of this management is accepting that change will occur and forming realistic restoration goals under a changing climate.

**Restoration in Canada’s oil sands**

Jack O’Neill, Neil Sandstrom
1COSIA, Calgary, Canada, 2Canada’s Oil Sands Innovation Alliance,

The Canadian oil sands are one of the largest oil reserves in the world and sit underneath the boreal forest. Efforts to ensure coordination and cooperation for restoring the boreal forest in the oil sands region is done in part through a unique collaborative, Canada’s Oil Sands Innovation Alliance (COSIA). Development of the oil sands resource is contingent on approvals, including the restoration of land disturbed by development. Development approvals require significant investments to ensure that upon completion and closure, the disturbed boreal forest establishes equivalent land capability and ecological function. There are two unique restoration approaches for oil sands as the resource is surface
minable (roughly 5% of the oil sands area) in the northern portions and recovered from within a reservoir (in situ) in the southern areas. The in situ area is where most of the oil sands resource is recovered from. To assist with the scope of reclamation efforts in the minable area, various tools and mechanisms such as the Oil Sands Vegetation Cooperative are employed. Surface clearing for the in situ area is comparatively small compared to the mined area, but the landscape has become dominated by linear clearings for seismic exploration, roads and pipelines. These linear disturbances have fragmented the landscape and have been proven to be access corridors for predators such as wolves, contributing to the decline of the threatened and iconic Woodland Caribou. Linear restoration programs have been underway for several years in efforts to restore functional contiguous habitat.

Fire drives abandoned pastures to a savanna-like state in the Brazilian Atlantic Forest: Implications for ecological restoration

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Most tropical forests are threatened by a myriad of human-induced disturbances associated with land use changes, altered fire regimes, and direct deforestation. The combined effect of multiple disturbances can shift forests towards a new, resilient state that is qualitatively distinct in structure, species composition, and function. We found that abandoned pastures affected by fires showed similarity in terms of vegetation structure, species composition, and plant functional traits to a savanna-like ecosystem. The study was carried out at Poço das Antas Biological Reserve, located in the Rio de Janeiro state, Brazil (22° 32`17``S, 42° 16`50``W). Burned communities exhibited more C4 grass cover, a higher proportion of resprouts, and lower canopy cover as compared to the old-growth forest. Moreover, 81% of species at the burned sites have a widespread distribution and are also found in the Cerrado biome. Species composition was strikingly different from old-growth forests since burned sites were dominated by Moquiniastrum polymorphum (Less.) G. Sancho (Asteraceae), which was absent in the old-growth forests. The results observed in this study provide biological evidence of arrested succession with the establishment of a savanna-like ecosystem as an alternative stable state. These results have important practical implications because differences between tropical savannas and forests imply important changes in the provision of ecosystem services, restoration and conservation strategies, as well as in the way these communities will respond to climate change.

Age and persistence of secondary Atlantic Forests in Brazil

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During the last three decades the Brazilian Atlantic Forest has reversed centuries of deforestation into a net gain of forest cover. Forest restoration occurred mainly due to natural regeneration of abandoned areas and, to a lesser extent, by planned restoration. Restored forests may not persist due to intentional deforestation to avoid legal restrictions regarding mature forests. Considering this scenario, we evaluated the current situation of the Atlantic Forest regarding forest fragment ages and also the persistence of restored forests. During the last three decades, more than 11 million hectares of forests were restored in the Atlantic Forest. However, only 43% of the restored forests persisted until 2016. These restored forests represent approximately 20% of the current forest cover. Moreover, 10% of the current forest cover was restored less than 15 years ago. The
persistence of restored forests is critical, especially during the first years as more than 37% of restored forests are cut before 4 years. Also, more than 30% of those restored areas that reach 9 years old will be cut before reaching 10 years. Although we identified a reduction of overall deforestation trends, there is a constant deforestation rate of restored forests, which is leading to a process of rejuvenation of the Atlantic Forest. The adoption of natural regeneration for large scale restoration as a strategy to mitigate climate change and to conserve biodiversity must be associated to policies focusing on protecting restored forests to ensure their persistence.

**Getting to know the river: Experiences of a citizen technician from the Tsitsa River Catchment, Eastern Cape, South Africa**

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The Tsitsa River catchment is located in the northern Eastern Cape, South Africa. The catchment is characterised by degraded grasslands, materially poor rural communities with uncertain livelihoods, extreme climatic conditions, and high sediment yields. The Tsitsa Project was initiated by the Department of Environment, Forestry and Fisheries (DEFF) to reduce soil erosion, improve equitable access to natural resources, and sustain land-based livelihoods. Grace Saunders is a prominent community member who lives near the Tsitsa River. She has partnered with the Tsitsa project since December 2015, capturing sub-daily river level and water clarity information and collecting water samples to provide suspended sediment concentration data (as an indication of catchment erosion). Grace’s work contributes directly to catchment research that aims to guide catchment restoration and sustainable land management. Grace has become a community champion for the environment, both through her active role in the restoration project and through her engagement with policy makers for sustainable land management based on personal experience. Grace describes her daily routine, including the main observations related to rainfall, land degradation, and river dynamics, and shares the ways in which this has influenced the way she views land degradation and restoration. Grace also shares the challenges and benefits that she has experienced as a result of engaging with the river monitoring work.

**Socioeconomic and environmental suitability of rural properties: A strategic engagement for community and forest recovery**

Lucas de Oliveira Scarascia, Vitor Hermeto Coutinho, Gabriel Correa Kruschewsky, Bruna Aparecida Marcatti, Leonardo Ferreira da Silva

Renova Fundation, Belo Horizonte, Brazil

The failure of the Fundão dam on November 5th, 2015, represents the most substantial socio-environmental impact of a mining dam in history. The tailings deposits in the floodplains and river beds caused severe effects on rural and agricultural activities for approximately 2000 landowners, mainly due to production restrictions and water availability. The need a full reparation of rural properties conducted by the Renova Foundation considers the engagement of several actors. It should be considered that the current profile of land use and occupation usually diverges with agricultural vocation, causing production inefficiency and deforestation. The Socioeconomic and Environmental Adequacy of Rural Properties assessment (SEARP) is part of the development of a methodology for the evaluation of the Indicators of Sustainability in Agroecosystems (ISA), developed by relevant governmental institutes and universities in Brazil. This integrated approach to rural properties enables intelligent management of agricultural areas, increasing productivity and reducing pressure on areas to be reforested, reconciling increased income and environmental suitability. Current results demonstrate a high percentage of adherence to this proposal, mainly by small and medium farmers. Around
150 hectares of native forests were planted together with the recovery and management of agricultural production. Demonstration units related to commercial use of forests and ecological management of pastures, along with quality technical assistance and rural extension, strategically integrate the possibility of a large-scale land-use alternative, strengthening public policies and sustaining the proposal in the medium and long term.

**Making money grow on trees - How water funds pay for long-term ecological restoration (across five continents!)**

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Ecological restoration often struggles to find revolving funding that will provide a long-term sustainable base for needed activities. Restoration is rarely a one-off ‘event’ so being able to secure this funding can be paramount in ensuring that ecological benefits accrue and are sustained over time. Water funds, a tried and tested approach, originally from Latin America, but now globalising fast, offer interesting insights into how this can be achieved. By providing a robust governance and financing framework that sees downstream ‘beneficiaries’ pay for upstream ‘restoration’, water funds can provide a platform that delivers not only restoration at an impressive scale, but which ensures its longevity in the face of increasing economic and societal pressures. This short IGNITE talk, using the business case behind the Greater Cape Town Water Fund as an example, will highlight how a water fund comes about and how it delivers on a range of aspects surrounding the ‘Economics of Restoration’, including job creation, long-term investment, payment for ecosystem services, and a route to public sector funding. Other examples, ranging from Brazil and Peru to Botswana, will show how a range of ecological restoration can thus be funded. For those interested in knowing more, TNC will be happy to share findings from ongoing scientific research that looks at how to standardise both “business cases” and develop a flexible financial model that can support others’ efforts to replicate these successes.

**An unconventional PES program leveraging ecological restoration and food security**

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Three important policy goals in Africa are economic growth, poverty alleviation, and environmental protection. Policies that promote agriculture can contribute to economic growth, and those supporting small family farms can alleviate poverty, but both pose a major threat to ecosystem conservation. Restoration of ecosystems is urgent, but the conversion of farmland to natural ecosystems can reduce economic growth and drive farmers into more poverty. This conflict has ignited a debate, which places the agriculture sector against environmentalists. Adversarial approaches cannot solve the problem since both food production and restored ecosystems are essential to human well-being. Additionally, a growing body of scientific research has shown that agriculture impairs but also depends on critical ecosystem functions generated by healthy natural ecosystems, such as climate regulation, water regulation, erosion control, nutrient cycling, pest control and pollination. We fell into this predicament because we designed agricultural systems that failed to account for resilience, and the path forward requires redesigning. In Southern Brazil, we have been working with small family farmers, local and state government, and NGOs to develop Multifunction Riparian Forests and High Biodiversity Silvopastoral Systems to address this challenge, as well as the policies required for the adoption and dissemination by the stakeholders. Appropriate policies must recognize that rural
landscape can be managed for agri-environmental stewardship and multifunctionality. This paper describes a pilot project for payments for ecosystem services for agroecology schemes in Santa Rosa de Lima Southern Brazil, designed as Participatory Action Research to accomplish these three important policy goals.

### Biodiversity loss, disease spread, public health, and ecological restoration

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It seems that our relationship with the environment has not been the best, lately. We have this seemingly unnatural tendency to destroy biomes and decrease their biodiversity as we invade them. From depleting natural resources to the eradication of key species to ecological webs that used to sustain us, biodiversity has proven to be more ingrained in our daily lives than previously thought. The transmission of zoonotic diseases and its correlation to biodiversity is a topic that has been vastly expanded and must be faced. This study aims to understand how biodiversity influences pandemic disease emergence, and how invasion and ecological disruption affect the likelihood of epidemiologic outbreaks. It will also map the likelihood of an epidemiologic outbreak in relation to risk areas that have been disrupted by human populations. Finally, this research will predict possible epidemiologic outbreaks in high-risk areas, their effect on human populations based on previous pandemic outbreaks and suggest ecological restoration actions to avoid future problems. Biodiversity data will be collected on sites of zoonotic disease outbreaks that happened recently in Africa. Biodiversity will be measured in 4 categories: plant diversity, animal diversity, soil microbiome, and aquatic organisms. This research will then tie together three subject areas that are not often linked and provide researchers with insight on disease management thru ecological restoration as the main mitigating process. The model will help governments and communities prepare for the likelihood of these breakouts and their prevention prevent with concrete data to back up their claims.

### Mitigating bush encroachment via habitat manipulation: Ecological cascade effects

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African savannas are characterized by a mosaic of trees and grass. The ratio of trees and grasses exists along a continuous gradient in savannas, resulting in savannas that range from open, grassy savannas to denser, closed-canopy savannas. However, climate change is leading to woody thickening in African savannas, and predictions suggest that by 2100 savannas will become forests, thereby threatening the ecosystem services provided by savannas. To combat this woody thickening, many land managers across South Africa have implemented large-scale (>100 ha), decades-long tree clearing in an effort to maintain areas of low tree densities. However, the implications of these habitat manipulations for herbivore communities are unknown. Thus, we aimed to identify how tree clearing influenced herbivore community composition. We used herbivore counts from survey data collected in a South African savanna from both the wet and dry seasons that link with savanna vegetation structure (i.e. tree-grass ratio). We used model-based clustering to identify unique herbivore-vegetation structure states. The model-based clustering revealed that both bush encroached areas and large-scale tree cleared areas result in states that have depauperate wildlife communities compared to intermediate woody states. This suggests that both the effects of bush encroachment and the implemented management practices have similar, negative effects for herbivores. Thus, to restore savanna ecosystem
functioning, our results suggest that degraded, cleared areas should be restored and that savanna management should strive to maintain an intermediate woody density.

Modelling the interlinkages between food-energy-water and agricultural production in northern Ghana

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The increasing complexity between individual land management, farming area scarcity, and water availability is of emergent concern in Sub-Saharan Africa. Agricultural production requires huge natural resources, which is why decision-makers have to consider the demand and supply of food, energy and water. Applying the three elements in an action concept allows to identification of synergetic benefits, exploring holistic relations and trade-offs in agro-ecosystems. Taking the Bolgatanga region in Ghana as a study site, we will present a systemic decision-making framework to investigate the interconnectivity between a social network analysis as an appropriate tool to highlight stakeholder complexities within the food-energy-water concept. The approach combines data analytics, participatory methods, and modelling aspects toward a better coordination between key stakeholders, land management, and ecosystem restoration. The study scope will show how understanding relationships between institutions and the private and public sector can be a prerequisite for harmonizing policy-making in restoring degraded land. We found that collaborative advances in social-ecological sciences provide an approach to analyse agronomic and biological techniques. Consequently, we will discuss land management strategies to protect the soil from erosion in order to strengthen agricultural production.

A typology of worldwide Forest and Landscape Restoration (FLR) projects

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Recent worldwide commitments, such as the Bonn Challenge and the New York Declaration on Forests, have placed Forest and Landscape Restoration on the agenda of countries worldwide as a means to attain sustainable development goals and mitigate climate change. Given these social and ecological goals, FLR programs should incorporate ecological, social, historical, and economic dimensions in their goals and implementation strategies. However, FLR programs within the Bonn Challenge are mostly in planning or early implementation stages and therefore little is known about their governance arrangements, the incorporation of multidimensionality in their objectives, and the strategies for implementation. Fears exist that unless FLR is more clearly defined and principles and standards drafted, FLR interventions run the risk of falling on a “business as usual scenario” geared toward achieving only a limited number of objectives. We compare projects in the global south led by different actors, multilateral agencies, transnational NGOs and impact investors mostly, regarding their governance arrangements, objectives, and strategies. Our research is not yet finished, but we already find projects are working closely with national governments to better integrate diverse land use policies; they are prioritizing implementation of productive restorative actions, and thus do not emphasize the implementation of various types of interventions for the restoration of multifunctional landscapes.

Land rehabilitation for sustainable development in northern Ethiopia

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Land restoration, mainly soil and water conservation (SWC), has been undertaken in the last 30 years in the Tigray region in Northern Ethiopia. The aim of the SWC activities has
been to minimize the deterioration of agricultural land productivity and livelihood of the society. Findings show that intensive SWC activities reduce erosion and degradation due to their high sediment trapping capacity, improved soil physico-chemical properties, and carbon sequestration. Similarly, rehabilitation of deforested lands through area exclosures provides economic benefits by supplying raw material to meet the local demand for wood, reducing the pressure on the remaining forests, and supplying various non-timber products. The physical SWC measures, exclosures, and community-based watershed management and restoration activities have contributed considerably to enhance soil fertility and productivity, groundwater recharge, solving the shortage of biomass for fuel, and generating income through beekeeping and animal fattening. The ultimate goal of policy-based SWC practices in the region was to improve community livelihood besides the physical restorations. Results indicate that, SWC activities enhance ecosystem services of the treated areas and have contributed to the betterment of household income. The government policy and strategies of implementing natural resources rehabilitation and conservation is through a bottom-up approach of planning and implementing community-based SWC practices. Establishing and strengthening institutions at the grass root level have also proved to be effective ways of sustaining rural livelihoods. Therefore, community based SWC activities have multiple benefits to the farmers: preventing erosion of productive assets; improving food availability and recovering the environment at large.

Towards ethical water management: Piloting an ethics methodology on the Cape Flats Aquifer in the Philippi Horticultural Area

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Water policy and legislation in South Africa was welcomed as ground-breaking by the international community shortly after the advent of democracy. However, despite the progressive nature of the National Water Act and the principles of Integrated Water Resource Management it adopted, it has failed to bring about sustained transformation in water management. This paper argues that it has failed because policymakers assumed the existence of social cohesion and shared values in divided communities, and that communities were ready to engage in multi-stakeholder platforms on water management where diverse values were prioritised and negotiated. Using the contested Philippi Horticultural Area located on the Cape Flats Aquifer in Cape Town as a case study, this paper introduces an ethics methodology involving individual interviews, multi-stakeholder feedback workshops, and a proposed set of joint interventions. The methodology requires community members to identify their core values around development and water, jointly prioritise what this means to them in terms of community development, and then move towards a preliminary action plan to build social cohesion and improved water management in their particular context. It is proposed that if communities move towards future solutions, after deep reflection on jointly shared core values, they are better able to live with past conflict and opposing points of view. The paper documents the ethics methodology process undertaken and evaluates its potential for developing a supplementary bottom-up approach to water management that would improve community engagement in government-led water policy and legislation processes in South Africa.

Partnerships in peatland restoration projects

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Ecological restoration projects demand an integrative approach that includes the ecological and socio-economic aspects. Usually these projects involve nongovernmental, volunteer and governmental organisations, dealing with science or environment, and to a lesser extent – business. At the same time, the social and environmental policy is becoming a distinctive feature of leading industrial companies. The presentation aims to demonstrate
the case studies within the project “Restoring peatlands in Russia” and several projects in the Russian Arctic when both local communities and business had been involved. The involvement of the local communities gives opportunity to meet the regional concerns. The involvement of the companies brings additional funding to restoration projects as well as gives a pathway for sustainable development of the area and creates a positive image of the entire company. The involvement of both actors demands clear incentives which should be communicated to the stakeholders. The presentation includes a description of the method for identification of specific stakeholder benefits gained from the ecosystem restoration. The identified benefits for a wide range of stakeholders are presented for three restoration pilots, including one where one of the beneficiaries was the key investor.

Livelihoods and ecological infrastructure interventions: What are the benefits for workers involved?

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Ecologists, hydrologist, and restoration scientists in South Africa have contributed substantially to the knowledge on how interventions in ecological infrastructure, such as alien clearing and wetland restoration, can increase surface water flows, groundwater infiltration, and water quality with additional benefits for disaster risk reduction (floods, droughts and fires). Much less research exists on the socio-economic benefits of these interventions. Although scholarly efforts have hypothesized that the interventions can support livelihoods (the capabilities, assets, and activities required for a means of living) in multiple ways, empirical evidence on the linkages remains limited. In short, the literature mentions that interventions might provide livelihood benefits both directly (e.g. job creation) and indirectly (e.g. reliable access downstream to sufficient and clean water). Interventions might also enhance livelihood diversification, strengthening and providing development opportunities for economic sectors such as sustainable agriculture, agri-tourism and eco-tourism, the development of new value chains based on cleared biomass, restoration-related activities such as plant nurseries, and enhanced agricultural production. This paper reports on the empirically examined livelihood outcomes of ecological infrastructure interventions (primarily clearing of alien species) for those people employed by a variety of projects. Drawing on household surveys (n=150) conducted with workers across two districts and 4 municipalities in the Western Cape, we examined people's motivations for getting involved in the projects, the more direct benefits (such as new income and consumption opportunities provided by the projects), and other less obvious outcomes, such as increasing social networks, new skills, and decreasing crime rates.

Soil seed banks in the alpine grassland ecosystem: Structure and function during vegetation degradation and restoration

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Although soil seed banks have long existed in alpine ecosystems, current studies indicate that soil seed banks are not very effective in maintaining function in stable alpine vegetation, especially those of alpine vegetation system that rely heavily on asexual reproduction. Based on analyses of the soil seed bank and vegetation changes in the alpine ecosystem globally and analysis of changes in the soil seed bank in alpine grassland on the Tibetan Plateau, we found the following: 1) With severe environmental changes, the impact of soil seed banks on vegetation in alpine ecosystems immediately had a strong driving effect, 2) In the process of vegetation degradation, some species with enormous seed numbers in the soil became the dominant populations in the process of dynamic vegetation change (e.g. Artemisia spp., Potentilla spp., Koenigia spp.), 3) The soil seed bank
density of some species is continuously enhanced, making the toxic weed community formed more stable after the disturbance, and making difficult colonization by some native plants, 4) Relying on native vegetation’s soil seed banks (e.g. Kobresia spp., Poa spp.) to recover degraded grasslands is difficult, and 5) Artificial soil seed bank donations can help the reconstruction of vegetation and accelerate the near-natural recovery process of vegetation. Therefore, we should pay attention to the preservation and adoption of donation technology for native plant seed banks in alpine grassland. These can help to obtain faster natural recovery processes in the restoration engineering of degraded alpine ecosystems.

**Influence of herbivores on ecological restoration after invasive shrub clearing in the Kafue Flats Wetlands, Zambia.**

**Griffin Shanungu**$^{1,2}$, Nils Hereman$^2$, Floyd Steven$^1$, Judith Sitters$^2$, Harry Olde Venterink$^2$

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The Kafue Flats Wetlands in central Zambia has experienced significant spread of the alien invasive shrub, Mimosa pigra (mimosa). Efforts are ongoing to remove up to 95% of the current 3,000 hectares of mimosa cover in Lochinvar National Park (LNP) with the aim of restoring this area to increase biodiversity. The restoration area hosts large populations of Kafue Lechwe antelope which feed on fresh grass regrowth in the cleared areas. Hence, it is likely that they will affect vegetation recovery, but it is unknown which species, native or alien, they will particularly support during this process. Our study therefore focused on answering the question: how does herbivore grazing impact vegetation restoration after large scale invasive plant removal? Five months after mimosa removal, we commenced a two- year field experiment in LNP with eight paired plots. At each paired plot, one plot is fenced to prevent grazing and the other unfenced to allow grazing. We have measured the initial vegetation parameters in these experimental plots: i.e., seedling density of mimosa and diversity and composition of the native plant community. Initial results after five months of experimental treatments show that the lechwe herbivores do indeed influence vegetation recovery. Grazed plots had a higher mimosa seedling density, and a lower cover, biomass, and species richness of the native community than the fenced plots. These early results suggest that large-scale restoration projects should factor in the influence of grazing – and its management – to optimise restoration efforts and their subsequent biodiversity benefits.

**Securing a future for the world’s threatened trees through species recovery and ecological restoration programmes**

**Kirsty Shaw**

Botanic Gardens Conservation International, Nairobi, Kenya

At least 16% of the world’s 60,000 tree species are globally threatened with extinction. Ecological restoration programmes present an opportunity to conserve these species in the landscape, but many practitioners are lacking the skills and knowledge to do so. The Global Trees Campaign (GTC) is a joint initiative between Botanic Gardens Conservation International and Fauna & Flora International to secure a future for the world’s threatened tree species in situ for the benefit of people and wildlife. GTC delivers targeted conservation action for the tree species most at risk of extinction. Through the Global Tree Assessment, which will provide conservation assessments for all of the world’s tree species by the end of 2020, we are producing peer-reviewed maps for all assessed species and a conservation tracking tool for single-country endemics. These tools will be presented, enabling practitioners to identify and prioritise threatened tree species to include in restoration programmes. Case studies of restoration programmes that incorporate threatened trees will be shared as models of best practice. A portfolio of GTC projects that are restoring populations of tree species on the edge of extinction will be shared, providing guidance on delivering targeted species recovery actions. GTC cannot single-handedly
secure a future for the world's >10,000 threatened trees but mobilising the restoration community to take action will have a big impact on species conservation.

**Selecting species and delivering forest restoration that benefits people and biodiversity: Tools and resources**

*Kirsty Shaw*
Botanic Gardens Conservation International, Nairobi, Kenya

African commitments to the Bonn Challenge (AFR100) represent a huge opportunity for delivering species conservation, increasing biodiversity on farms, and delivering genetically and taxonomically diverse ecological restoration that benefits people and wildlife. However, currently there is: i) little understanding of the benefits of delivering genetically biodiverse forest landscape restoration (and the risks of not doing so), ii) high demand for, and availability of, exotic species across the continent, iii) limited availability of native seeds and seedlings due to a lack of knowledge about how to propagate native species among community nurseries, farmers, and government, and iv) no up-to-date forest policy in many African countries, and hence, no mandate for planting indigenous species. As a result, there is a risk that exotic species will be used instead, delivering species-poor forest landscape restoration that misses climate mitigation, biodiversity conservation, and employment opportunities for rural people. This presentation will use our newly published GlobalTreeSearch database to highlight the diversity of native tree species present across the African continent. Results will be presented from a comparative study of material available in government and commercial tree seed centres versus botanic garden nurseries. Tools developed by the botanic garden community to support delivery of species-diverse forest restoration will be shared, including training resources and training opportunities. Alongside case studies that will be covered in more detail in this symposium, we will demonstrate methodologies and experiences that can be applied across Africa and worldwide to enhance forest restoration, ensuring Bonn Challenge pledges benefit people and biodiversity.

**An information system for monitoring changes in South Africa's freshwater biodiversity and ecosystem condition**

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South Africa's unique freshwater biodiversity is under enormous pressure from human activities, climate change, and invasive species. River health is deteriorating faster than it can be measured, and the data that do exist suggest that human impacts have and continue to severely compromise biodiversity and aquatic ecosystem function. This can have serious adverse consequences for ecosystem services, such as the provision of food and safe, clean drinking water. Until now, there has been no informative and accessible database for hosting river biodiversity data in South Africa, impeding assessments of historic and current river conditions. Such information is critical for establishing baselines and measuring patterns of change in response to human-linked impacts and restoration efforts. The Freshwater Biodiversity Information System (FBIS) is a response to this knowledge gap, and through consultations with data users and contributors, and collaborations with key partners and stakeholders, aims to provide South Africa's first platform for rapid and reliable assessments of change in freshwater biodiversity and ecosystem condition. The project seeks to mobilize and import to the system baseline biodiversity data, identify strategic long-term monitoring sites (including sites associated with key restoration projects), and train key organizations on how to use the information system. Through the use of map-based visualisations, user-friendly data dashboards and rapid data extraction capabilities, the system will improve knowledge of freshwater biodiversity and long-term river health, and thereby support better-informed river management decisions and ecological restoration projects.
An evaluation of methods for alien fish removals in headwater streams: Lessons from South Africa
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Headwater streams are critical habitats for conserving freshwater biodiversity, but invasions by non‐native predatory fish can compromise the value of otherwise-pristine headwater habitats as sanctuaries for native species within largely transformed riverscapes. In certain situations, the removal of alien fishes can be an effective means for rehabilitating invaded rivers through increasing habitat area and connectivity for threatened and fragmented native species populations. While both developed and developing countries recognize the threat posed by non-native fish, few of the latter have implemented control programmes to manage it. In South Africa, introduced predatory fish have depleted, or eliminated, native fish populations, modified community structure in otherwise pristine headwater streams, and pose a serious future threat to several endemic freshwater species. In response to this situation, recent interventions, including both chemical and mechanical approaches, have been applied to rivers in South Africa with varying success. Here, we review the different options available for removing non-native fish from headwater streams and draw on case studies from South Africa to identify strengths, weaknesses, and criteria for maximising the success of future-such interventions.

Effects of simulated N deposition on photosynthesis and productivity of key plants from different functional groups of alpine meadows on the Qinghai-Tibetan plateau
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Little is known about the response mechanisms of individual plants in alpine regions to N deposition. We conducted a field experiment with three treatments, including 0 kg N ha\textsuperscript{-1} year\textsuperscript{-1} (CK), 8 kg N ha\textsuperscript{-1} year\textsuperscript{-1} (Low N), and 72 kg N ha\textsuperscript{-1} year\textsuperscript{-1} (High N) established to simulate N deposition in alpine meadows of the Qinghai-Tibetan plateau. The results showed that responses of alpine plants were species-specific under N deposition. Compared with grass species (Agropyron cristatum) and forb species (Thalictrum aquilegifolium), the sedge species (Carex melanantha) was much more sensitive to N deposition; a lower N load (8 kg N ha\textsuperscript{-1}year\textsuperscript{-1}) can cause a negative effect on its photosynthesis and productivity. Additionally, N deposition can promote plant N uptake and significantly decreased the C/N ratio. High N deposition inhibited the photosynthesis and growth of the forb species Thalictrum aquilegifolium and sedge species Carex melanantha. In all three functional types of herbage species, the grass species A. cristatum tended to show a much higher photosynthetic capacity and better growth potential; thus, suggesting that grass species A. cristatum will be a more adaptive alpine plants under N deposition. Our findings suggested that plant photosynthetic responses to N deposition were species-specific, low N deposition was not beneficial for all herbage species, and N deposition may change plant composition by the differential photosynthetic responses among species in alpine grassland. Plant composition shifts to grass-dominance in alpine regions might be attributed to a much higher photosynthetic potential and N use efficiency of grass species.
The importance of root hydraulic function for the survival of planted seedlings in dry conditions

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Root function and growth is critically important to the survival and performance of planted seedlings, especially in ecosystems with seasonal dry periods. In many restoration sites, limited access to soil moisture has the potential to reduce outplanting success. Root hydraulic conductance, Kr, measures the capacity of a plant's root system to supply the shoot with water. Kr can be impacted by planting practices, environmental conditions, and subsequent seedling growth. Using techniques from plant hydraulic physiology, we conducted a greenhouse experiment to measure changes in root hydraulic conductance in Douglas-fir seedlings (Pseudotsuga menziesii) after transplanting. Douglas-fir is a key forest species in the western United States and planted Douglas-fir seedlings must survive summers with very little rainfall. We found that Kr increased linearly with seedling leaf area in well-watered conditions. However, in water-limited conditions, Kr did not increase as seedlings grew new needles, which in turn reduced photosynthesis and lowered total seedling biomass. These results indicate that water limitation changes root function even before the seedlings experience xylem cavitation and in ways that impact the water supply to the shoot. From these conclusions, we emphasize the importance of restoration practices that can mitigate water stress after planting, such as the timing of planting, site preparation methods that reduce competition for soil water, and nursery growing and handling protocols that promote high capacity for root growth. Careful attention to root quality, understanding root function, and taking actions to ensure root growth will be important for the success of restoration with planted seedlings.

How ecosystem networks reveal resilience

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Ecosystem resilience is vital for an ecosystem to function, especially in the current Anthropocene. Measuring an ecosystem's resilience will allow understanding of how well an ecosystem is able to persist despite the plethora of natural and anthropogenic perturbations. How to accurately measure ecosystem resilience, however, is clouded by uncertainty due to its complex foundations, many definitions, and few reference points. This review aims to constrain the uncertainty by using a systems approach that Analysis (ENA) is proposed as such a systems approach, which makes use of flow networks that illustrate the diverse connections within an ecosystem. We propose a suite of existing ENA metrics that are able to characterize components of an ecosystem's resilience. One component being the adaptive cycle, where the changes in flow diversity and magnitude as well as the extent of order or disorder in the flow organisation along this trajectory, and their relative metric changes delineate the distinctions between the different stages. For example, the metric Total Systems Throughput is valuable to delineate the stages characterized by the accumulation or conservation of energy. Metrics to characterize other components of resilient ecosystems such as persistence and adaptability are also described. This allows for an assessment of the status quo, and how the resilience of an ecosystem could be increased or decreased. Providing a comprehensive yet digestible view of ecosystem resilience to conservation authorities could contribute to improved and targeted management and restoration strategies.

Drought-tolerant savanna forbs: Comparing diversity and function between livestock and wild herbivore sites

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Tropical grassy biomes are resilient to disturbances with which they evolved. Changing the nature of disturbances, e.g. replacing diverse herbivore communities with single domestic grazers, should change plant community structure and ecosystem functioning. Furthermore, projected future climate will increase the frequency and severity of drought events, which will intensify disturbances such as overgrazing. Understanding the combined effects of drought and herbivory on species diversity and function is important to inform restoration strategies. Forbs contribute most to herbaceous diversity in grassy biomes, although their contribution to resilience is poorly understood. In a drought-affected semi-arid savanna, we linked forb species and functional diversity across land-use types representing opposite herbivore diversity and intensity. Herbivore intensity significantly affected forb species, but not functional trait composition. Several forb species tolerated drought conditions at both sites, although only a few could maintain their dominance after drought release. Others were not recorded during the drought but responded significantly to drought release. Certain plant functional traits dominated during the drought but failed to persist after the drought. Drought-tolerant forb species and traits were limited and dissimilar across herbivore diversity and intensity sites. Our results suggest that species and functional traits are equally important for drought-tolerant forb communities, although the identification of species and traits suitable to understand the combined effects of herbivory and drought remains poorly understood, even in systems that evolved with such disturbances. Narrowing down the species and traits adapted to herbivory under increasing drought events, is believed to inform restoration attempts in dynamic semi-arid ecosystems.

Functional traits predict herbaceous responses to land-use intensities in the grassy biomes of South Africa

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Disturbance alters the taxonomic and functional composition of vegetation. In disturbed ecosystems, plant fitness (i.e. survival, growth and reproduction) is dependent on local environmental conditions such as climate, fire, and herbivory. Interconnected effects of land-use intensity and local environmental stressors on herbaceous vegetation resistance and resilience are poorly understood in the grassy biomes of South Africa. A functional-trait approach was used to define traits related to vegetation resistance and resilience across three disturbance gradients in grasslands and savannas. At each grassland and savanna site, areas of cultivation, urban open space and mining sites were sampled, all of which covered three land-use intensities (i.e. old growth, hybrid, and novel ecosystems). Measures of functional trait loss were used to evaluate vegetation resistance and resilience to land-use intensity combined with local environmental stressors. Compared to the more resilient grassy savanna ecosystem, the grassland sites showed considerable losses in the functional trait pool, especially from the hybrid to the novel ecosystem state. Both biomes are seasonal, fire-driven grassy ecosystems and yet they respond invariably to land-use intensification. Functional traits in the grasslands are mostly related to below-ground storage organs to survive natural disturbances, including frost. This trait pool may persist in hybrid states but disappears with land-use intensification related to soil disturbance. Savannas host a much larger trait pool, which buffers the system against both anthropogenic and natural disturbances. Delineating the functional traits related to plant fitness should allow for meaningful contributions to restoration efforts, provided that local environmental adaptations are considered.

Challenges in applying seed ecology knowledge to restoration of grasslands on extremely impoverished soils

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Restoring the Colorado River Delta - A framework for binational cooperation in restoration science, finance, and resource management.

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The Colorado River delta once consisted of 800,000 hectares of riverine, wetland, and estuarine habitat. This ecosystem has contracted to a fraction of its historic extent due to flow regulation and water consumption upstream. In 2012 a novel agreement between Mexico and the US provided for sharing of water under drought conditions and committed water and funding for ecological restoration. A coalition of environmental groups that facilitated negotiations partnered with the two governments to fund and implement restoration. Successful implementation has led to a successor agreement that provides additional commitments of water and funding to support expanded restoration. Remnant wetlands in the delta are part of a UNESCO Biosphere Reserve and Ramsar wetland. The Colorado River is one of the most intensively managed of 263 international rivers; it provides water for 40 million people and supports critical year-round agriculture through an extensive network of dams, reservoirs, and canals in an arid climate. A 1944 treaty provides for annual delivery of municipal and agricultural water from the US to Mexico, leaving the river with no flow through Mexico. The agreement to dedicate environmental flows to support restoration establishes a global precedent and model for other nations. While upstream water demands limit full restoration of the delta ecosystem, restoration and monitoring implemented to date, as well as creative funding and water ownership models that are driving binationally supported restoration, provide a framework for the restoration and protection of an international river corridor and estuary in a politically challenging border region.

Restoring ecosystem function: The conundrum of woody encroachment in South Africa

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Woody encroachment and thickening is a global phenomenon, altering the composition of plant functional types within biomes, and changing ecosystem processes and feedbacks. Current consensus is that global change, in the form of increasing atmospheric CO₂ concentrations and changing rainfall patterns, together with local land management strategies such as fire suppression and stocking densities, are the drivers of the emerging landscape patterns. Sweet thorn Acacia (Vachellia karroo) is an endemic to southern Africa, but it is encroaching into grassland systems and threatening livelihoods. However, the species’ status as a non-listed invasive (National Environmental Management: Biodiversity Act 2004, Act No. 10, Alien and Invasive Species Lists) limits control and eradication options. Together with our lack of insight into how ecosystem processes are changing, this phenomenon poses a conundrum to management and decision making from the farm to national level. Using a case study in Adelaide, Eastern Cape, we use the open path eddy covariance technique in a paired tower design together with remote sensing (MODIS and MISR-HR products) to quantify the impact of woody thickening on water, carbon, and energy fluxes and rangeland productivity. We present the results of the 2018-2019 growing and dry seasons and the longer-term patterns in changing ecosystem feedbacks.

Integrated partnerships for securing natural resources in the Western Cape, South Africa

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The tremendous diversity of plants and animals within the Cape Floristic Region is under constant threat due to the ever-increasing development footprint, particularly in the lowlands and spreading rapidly up to the Cape West Coast. Through the Dassenberg Coastal Catchment Partnership, private owners, communities, and government aim to secure water resources and build climate change resilience through biodiversity conservation. The focus area of the partnership is 34,500 hectares and 50 percent is made up of private and communal land. A number of plant species thought to have been extinct for more than 50 years actually have remaining populations growing on the seasonally wet lowlands within Critically Endangered ecosystems here. These unique wetland habitats are choked by invasive Australian Acacias. The cost of clearing these dense infestations is very high and most landowners are not able to cope with the constant costs, despite their best efforts. It is only through public-private partnerships that significant impacts can be made towards the restoration of these Critically Endangered ecosystems and the multitude of threatened species they contain. By clearing invasive alien vegetation through partnerships in this integrated effort, about 250 jobs are created yearly. This is done by employing more than 20 teams through the partnership of the 12 members. West Coast LandCare is a partner in this integrated effort and funds at least three of these teams yearly.

Can intraspecific cooperation enhance restoration success and help meet multiple human goals?

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Globally, ecosystems are being degraded at an alarming rate. Rather than purely focusing on the conservation of existing habitats, attention in recent decades has turned to restoration science as a viable strategy for reestablishing habitats that have been lost. However, restoration is not always successful, and even when it is it is often expensive. Recent work has shown that maximizing positive species interactions in marine systems, rather than simply limiting species competition, as is the convention in terrestrial restoration, can enhance restoration success at no added cost. Furthermore, incorporating
coastal habitat restoration into infrastructure schemes is a way to use restoration to meet multiple human priorities. Here, we present case studies from the USA and the Netherlands investigating species interactions between oysters and saltmarsh and mussels and seagrass, respectively. The first study demonstrates that the restoration of saltmarsh and oyster reefs together as a shoreline stabilization strategy in North Carolina, USA, enhances coastal resilience and the delivery of other important ecosystem services more significantly than saltmarsh restoration alone. The second study is a manipulative field experiment testing whether the presence of reef building mussels, which are habitat modifiers in the Netherlands, can create more optimal conditions for the establishment of planted seagrass. If restoration is to become a viable strategy for maintaining coastal ecosystems, we need to investigate every avenue for enhancing success, including more research on the costs and benefits of incorporating intraspecific facilitation in different contexts and with different species.

Marine restoration and MER CES Key Habitats/Species: Approaches, timescales, bottlenecks, and up-scaling

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In the context of legislated marine restoration goals and new and ongoing initiatives, and as part of the background preparation work in a wide variety of MER CES project restoration actions, a detailed review of restoration efforts was undertaken on targeted European habitat/species. Part of this review has focussed on principal techniques and methods used in restoration actions, innovative approaches, major barriers/deal breakers, solutions to up-scaling to the level of degradation, and relevant timescales to restoration. The targeted habitat/species included kelp forests in Norway, Cystoseira forests in Spain, seagrass meadows in Norway, the Baltic (both Zostera marina) and the Mediterranean (Posidonia oceanica), Pinna nobilis in Croatia, coralligenous habitats in Spain, red corals in Italy, sponges in Italy, deep sea corals in the Azores and deep-sea seamounts in Italy. Techniques ranged from regeneration to transplantation and facilitation (e.g. by introducing mussels with seagrass) using different life-history stages or methods. Restoration is still in its infancy for some species and new protocols are being developed for deep waters. Time scales to restoration vary widely between ecosystems from months to years (kelp, sponges, some seagrasses), to decades (some seagrasses and corals), to multi-decades or centuries (deep-sea corals). Deal-breakers commonly depend on target species characteristics, the methods and techniques used, site parameters, but also the continued absence of threats. Up-scaling presents a number of challenges but will need an approach using a family of restorative activities (e.g. threat removal, unassisted regeneration, remediation, good management) combined with technological innovations, science-industry solutions, and citizen science/volunteering support.

Species recovery programmes as an important component of ecological restoration: How restoration practitioners can learn from the botanic garden community

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The drivers for ecological restoration have increasingly to do with carbon sequestration and other ecosystem services, one consequence of which is that most restoration programmes comprise relatively few plant species with little or no emphasis on biodiversity conservation. This is a missed opportunity because many rare and threatened plant species could be incorporated into restoration programmes as part of species recovery strategies. While a few countries have well developed species recovery systems, most do not, and the situation is quite acute in the tropics where comparatively little action is undertaken. Moreover, most threatened species occur outside protected areas and, so far, efforts to address their conservation have been largely neglected. The Ecological Restoration Alliance of Botanic Gardens (ERA) is a global consortium of botanic gardens actively engaged in ecological restoration and species recovery. Botanic gardens, arboreta, and seed banks play a vital role in restoring degraded ecosystems, incorporating a wide range of indigenous species for biodiversity conservation, as well as carrying out targeted species recovery actions for threatened species. In this paper, we will give examples of how rare and threatened plants can be incorporated into ecological restoration programmes – a win:win for ecological resilience and for biodiversity conservation.

A multi-criteria analysis approach to strategic planning for wetland rehabilitation in South Africa - progress and pitfalls

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The South African Department of Environment, Forestry and Fisheries is home to the Working for Wetlands Programme, a national wetland restoration initiative. The recently identified strategic framework for the WfWet programme has underlined the need for a more refined planning process with catchment-scale planning. Catchment-scale planning seeks to promote ecosystem-scale outcomes, long-term custodianship, and embedding of rehabilitation in broader local institutions and frameworks. The WfWet strategic planning framework aims to provide a platform for development and strengthening of partnerships with landowners, other institutions, organisations and individuals. The main vehicle for the strategic planning process is the Provincial Strategic Plan, which is developed on a 5-year cycle. The Strategic Plans are data-driven, with stakeholder involvement, and followed a multi-criteria analysis approach. In order to provide the Provinces with sufficient data to present priority catchments for wetland restoration to their stakeholders, the authors were tasked with developing prioritisation criteria, and sourcing the datasets required to score these criteria. The planning unit used for the prioritisation of catchments was the quinary or sub-quaternary catchment. A number of datasets were consulted in order to attribute characteristics to each quinary that relate to three categories of prioritisation criteria:

▪ Rehabilitation potential: soil erodibility and wetland condition;
▪ Wetland importance: biodiversity, wetland ecosystem services, and socio-economic vulnerability;
▪ Partnerships.

These characteristics were scored, weighted, and summed for each catchment, and the catchments ranked. The author will present the method used, and results for two very different Provinces in South Africa, the Western Cape, and the Northern Cape.

An investigation into the fire regimes of the upper Tsitsa River catchment

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South African grasslands are rich in flora and have co-evolved with fire. Fires have been the primary tool used to manage grasslands for livestock production for many years, however, there is debate about how they impact and alter landscapes. There are two schools of
thought in the literature, one that states fires are detrimental to landscapes, causing excess soil erosion and changing soil properties, and the other being that fires are beneficial to ecosystems, maintaining vegetation structure, preventing bush encroachment, cycling nutrients, and allowing for new plant growth. This study focused on the effects of Fire Return Intervals (FRI) on soil properties in order to better understand the role that fire plays in geomorphic processes in the upper Tsitsa River catchment. Fire frequency was determined using Landsat satellite imagery, and testing was carried out at 60 sites on soils exposed to different FRIs. It was found that soils that were exposed to a high fire frequency (1-2-year FRI) exhibited a higher degree of water repellency than soils that were exposed to a low fire frequency (3-4 year FRI). The degree of soil water repellency between the sites was not significant, showing that fires are not affecting soils to the degree previously thought and that literature might suggest. There are multiple variables to consider, however, results suggest that fires may not be as detrimental to soil properties and erosional factors in the Tsitsa catchment as previously thought, and erosion may be a product of grazing practices and soil type.

Quarries as safe havens for pioneer and migratory species – the potential positive value these habitats have for conservation

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The potential value to conservation of quarries, more commonly seen as scars on the landscape, is often misunderstood. Modifying the landscape can result in changes in the microclimates, soil conditions, and in many cases standing water, which can initiate the formation of new habitats. Habitats, managed and maintained properly, can support a wide variety of biodiversity. This can be significant in regions or landscapes which have already experienced severe habitat loss due to intense land use practices. Quarries can therefore attract a range of species otherwise unable to survive in the surrounding countryside. Given that access to these sites is often restricted, disturbances are therefore limited to the operational activities within the active portions of the quarry. As a result, these habitats provide shelter to species needing a temporary environment to complete their lifecycle, raise young, or just replenish their reserves and rest along their seasonal migratory path. However, quarries can even have an influence beyond their borders. In some cases, these anthropogenic environments can help to increase species numbers and help to stabilize populations. As we increasingly study these habitats, our scientists are discovering the surprising richness of biodiversity within quarries. BirdLife International, in partnership with HeidelbergCement, has been investigating the possibilities for new habitat creation and how best to incorporate them into the quarries’ operational cycles for the protection of biodiversity. Together, we have been developing a range of best management practices so that species can call your local quarry home.

Long term water security begins at the source: A case study of the Greater Cape Town Water Fund

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In the summer of 2017/18, Cape Town, South Africa’s second largest city, experienced the cumulative impact of one of the worst droughts on record. The reservoir levels dropped to critically low levels and unprecedented water restrictions were implemented to avoid a situation where the taps would run dry. Cape Town’s human population and associated economic activities grow, while climate models show future decreases in rainfall accompanied with higher temperatures, increasing the risk of water shortages. Current forecasts suggest that an additional 300-350 million liters of water per day will be needed by 2028 to ensure supply meets demand. Over R8 billion in public funding is being considered for augmenting water supply through investments in desalination, Table Mountain Group Aquifer drilling, water reuse and increased surface water storage to meet
the required demand. Over two-thirds of the sub-catchments upon which the region depends for its water are affected by alien plant invasions, reducing the amount of water that reaches the rivers and dams by 55 Mm$^3$ per year. The Greater Cape Town Water Fund Business Case launched in 2018, shows an investment of R372 million will generate annual water gains of 55 Mm$^3$, increasing to 100 Mm$^3$ within 30 years at one-tenth the unit cost of alternative supply options. The results of this business case demonstrate that restoring ecological infrastructure is a cost-effective and sustainable means of augmenting water and securing a long-term supply.

**Berg River Restoration project: A sustainable trail from source to sea**

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The Western Cape Department of Agriculture (WCDOA) is committed to working towards the restoration of the Berg River to a healthy river system that will promote human wellbeing and support ecosystem functions. More than 4 million people are dependent on the River in terms of food production, water supply, recreation and the value add in the agricultural sector. With over 22 000 hectares of irrigated crops on 600 farms, the River contributes to over R2 billion/year and supports more than 18 000 full time jobs.

The first step in this restoration project is to get the farmers on board as it is private land and without their buy-in nothing could be seen as sustainable, then the massive task of clearing the river of alien biomass is the next step. This task is work in progress and approximately 35% of the river has been cleared at a cost of more than R50 million. After this step the restoration begins, and several partners have step forward to assist in this vital task. Presently we have a dedicated nursery cultivating plants from origin from the river and these are being planted in the riparian zone. The first wetland area of a few kilometres in length that was restored has proven how effective our work has been in the improved water quality and containment of floods. Restoration is vital in this project but to maintain this sustainability the three pillars of sustainable development will be critical. Key words: River health, agri-tourism, sustainable development, economy and partnerships.

**Global multicriteria and multibiome priority maps for restoration and their associated vast contributions to biodiversity conservation and climate change mitigation**

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If achieved, global restoration targets would constitute the largest anthropogenic land-use change to be realised over one human generation and can potentially provide major contributions to societal goals of mitigating dangerous climate change and halting species extinctions. Evidence suggests that restoration benefits are highly variable in space, but these studies focus on local to national or regional scales and often to single goals or ecosystem types. Here we present the first global spatial prioritisation maps for restoration and assess their associated impacts, illuminating trade-offs and synergies across benefits for biodiversity conservation and climate change mitigation, as well as for reducing land-use opportunity costs. We developed a tailored spatial optimisation algorithm, identified 2.9 billion hectares of lands available for restoration, their associated climate change mitigation potential, and impacts of ecological restoration on extinction risks for over 20,000 vertebrate species and agricultural opportunity costs. Restoration would deliver a vast and cost-effective potential contribution of restoration to these global challenges, but these benefits and their costs have a very high spatial heterogeneity. Trade-offs are pronounced, with the best solution for climate change achieving only 61% of the potential benefits for biodiversity. Nevertheless, our analysis shows optimal compromise solutions, and found one which achieves 94% and 91% of the maximum benefits for biodiversity and climate change, respectively. Our maps can inform the implementation of existing
regional, national, and global targets, as well as providing input for upcoming global negotiations on post-2020 conservation targets.

Transdisciplinarity and social learning through socio-ecological research in the uMngeni Catchment, KwaZulu-Natal, South Africa

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The uMngeni Catchment is beset by wicked problems which require non-linear solutions through innovative governance and the co-production of knowledge by multiple actors. Addressing challenges as complex and interlinked requires a research design that transcends conventional disciplines. Complementary and contrasting disciplines, in terms of their epistemologies and ontologies, must be mobilised, with natural scientists working closely with social scientists. This project has adopted a transdisciplinary approach to explore how ecological infrastructure can be employed to improve water security and address multiple challenges in the catchment. This includes pollution from agriculture and inadequate sanitation systems, the impact of alien invasive plants, poor management of solid waste, high levels of poverty and unregulated land use. Transdisciplinarity has emerged as a response for research and science to: be relevant and solve ‘real world problems’; address complex socio-ecological problems drawing on multiple forms of knowing; and to integrate this knowledge for transformation. In the uMngeni Catchment, the greatest challenges relate to synthesising knowledge produced, finding common terminology and methods to explore, discuss and construct concepts, and ensuring ongoing communication, as each team of researchers work in their particular domain. Our learning process suggests that the greatest opportunities for transdisciplinarity are where knowledge is co-produced between researchers and local communities around common issues, and where common goals are the focus of the research process.

Catchment connectivity – a society-water-space trialectic

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Understanding the connectivies between the social, economic, biophysical, and political dimensions of the uMngeni Catchment across different landscapes is critical for building improved water governance and water security. Lefebvre’s (1991) concept of a trialectic is employed to map out the multiple relations in the hydro-social cycle of the uMngeni Catchment. The paper explores how ecological infrastructure can be used as a ‘lever of change’ within this set of relations of the water-society-space trialectic to improve water security. Research was conducted in four case studies, all pilot projects of the uMngeni Ecological Infrastructure Partnership. In the Upper Catchment critical issues are the pollution of Midmar Dam due to poor service provision and agricultural run-off. Baynespruit, in the Middle Catchment, is impacted on by discharge of industrial effluent, illegal dumping and poor stormwater management. Here constructed wetlands and the rehabilitation of riparian zones are being employed as ‘experiments’ to assess the value of EI in mitigating pollution. The Palmiet Catchment is located in the urban core of Durban. It is exposed to high levels of pollution due to a range of land uses which impact on the river, including industrial pollution, poor maintenance of sewerage systems, and poor service provision in informal settlements. Mzinyathi River is located in the Qadi Traditional Authority, an area undergoing rapid densification. This densification takes place outside of formal planning processes and is having significant impacts on the catchment. These case studies are used to assemble the water-society-space trialectic to show connectivity.
Native woodland restoration to counteract carbon land emission in Iceland

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Restoration has become one of the key measures to mitigate climate change. With increasing emphases not only on carbon sequestration but also carbon emission from degraded land, calls for better strategies and prioritisation are critical. Iceland with its volcanic soil (Andosol) is an example of large-scale ecosystems conversion following settlement in the 9th century that resulted in approximately 50% of the island now classified as having considerable to severe erosion. To date attempts have been made to revegetate and restore ecosystems on this badly degraded land. However, improved understanding of the degradation processes highlights the need to focus restoration activities on degraded lands that are potential carbon sources, but which have not yet crossed a threshold leading to severe soil erosion. Downy birch (Betula pubescens) is the only native woodland forming species in Iceland, and its distribution has declined from estimated 20-30% of the country at settlement to 1.5% at present. Recent examples show a rapid spread of birch where conditions are favourable, even into nutrient-poor barren landscapes. Thus, it is imperative to identify areas in which minimum interventions may initiate this process. The aim of this study is to utilise existing data with known geographic locations on birch distribution and land classes to analyse the potential for birch woodland restoration with minimum interventions. We will use Iceland as an example of how prioritisation and natural regeneration together with limited input can simultaneously combine the three UN conventions on climate change (UNFCCC), biological diversity (CBD) and desertification (UNCCD).

The role of large herbivores in restoration: Insights from seven years of biodiversity research at a copper mine adjacent to Kruger National Park

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Restoration studies rarely consider the influence of large herbivores in driving succession, even though herbivory was an integral part of the evolution of many systems being restored. Rehabilitation areas of a large copper mine adjacent to the Kruger National Park (South Africa) provided a unique opportunity to study the potential role of indigenous mammals in the restoration of a semi-arid savanna ecosystem. A rock dump and tailings facility there are accessible to the full suite of mammals indigenous to the area. Following basic restoration, plant communities of these areas change from a few non-local, seeded species to a diverse community of local species, and soil disturbance and propagule dispersal by local herbivores may promote this. However managers are concerned that overgrazing retards plant succession and causes soil erosion. Between 2011 and 2019, surveys of plants, birds, bats, rodents, reptiles and dung beetles provided insights into the role that herbivores play in establishing and maintaining biodiversity. A network of camera traps confirmed that rehabilitation areas are regularly utilized by a diversity of mammals, ranging in size from Grey Duiker to African Elephant. Twenty-two species were recorded, versus 34 at benchmark sites in the neighbouring protected area. However, community composition was markedly different. Similar differences were found for the other taxa studied. Repeat plant and bird surveys revealed that communities are fairly stable, despite an extreme drought. Overall, these results suggest that novel ecosystems, with an altered assemblage of the regional species pool, have spontaneously developed on these man-made structures.
Resources, restoration, rights, relevance and resilience: The role of facilitating access to natural resources from within a protected area, South Africa

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Natural resource use from protected areas is controversial globally, due to conflicting value systems and perceptions of the role of conservation (what is nature and who is it for) including disputes on defining ecological sustainability criteria. Conservation approaches have transformed from being exclusionary to using an integrated socio-ecological lens, and this has been supported by international and national policies and legislation. The South African National Parks (SANParks) Resource Use policy (2011), and the Kruger National Park (KNP) Resource use programme facilitate the sustainable use of natural and cultural resources within parks using three sustainability objectives: the maintenance of ecological integrity and economic viability and the promotion of social relevance. Early KNP conservation approaches included forced removals and restricted access policies, resulting in humans being removed as drivers of ecosystem processes within parks (traditional hunting, harvesting of food and medicine, managing fire and using water). Some believe this has led to ecosystem degradation within parks as a result of underuse (degradation meaning unnatural change). These policies also led to social, political, and economic degradation of people's rights and opportunities to access and derive benefits from conservation, leading to an erosion of people-nature connections, people-parks relationships, and a reduction in socio-ecological resilience. Our study reflects on extractive resource use projects currently being implemented in the KNP (mopane worms, thatch, medicinal products, and meat) in the context of how and to what degree these projects have restored natural and social system functionality.

How much is back and what are the consequences for habitat availability?

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During the last three decades the Brazilian Atlantic Forest (BAF) has shifted from a deforestation-dominated scenario to a net forest gain after 2002. However local studies show there are concomitant deforestation and forest recovery heterogeneously distributed along the BAF. It is essential to understand the consequences of large-scale forest recovery in a context of intense forest cover (FC) dynamics. We divided the entire BAF into equal-sized landscapes in order to analyze the changes in FC, landscape connectivity, and consequently, in habitat availability along the biome. The Brazilian Atlantic Forest (BAF) lost 1.8 million hectares of forest from 1985 until 2002 but recovered 0.18 million ha. This result is a combination of high rates of forest restoration and deforestation (~350 Kha of both deforestation and restoration per year) heterogeneously distributed along the BAF. The forest recovery avoided the reduction of FC in 36% of the BAF and allowed a net improvement in FC in 97% of the landscapes. In 30% of the BAF the forest recovery increased both FC and landscape connectivity. However, in 65% of the landscapes the forest recovery occurred in isolated areas and did not improve landscape connectivity, whereas 3% of the landscapes suffered both forest loss and reduction of landscape connectivity. The lack of spatial planning for large scale restoration associated to concomitant deforestation reduced the benefits of forest recovery to landscape structure. Thus, large scale restoration efforts must be spatially planned to improve landscape configuration and promote biodiversity conservation in restored areas.
Rehabilitation of opencast coal mines in the Mpumalanga Highveld, South Africa: Challenges and opportunities

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The Mpumalanga Highveld is endowed with high potential, arable land that produces much of the country’s rain-fed maize. Ironically this part of the country is also endowed with rich, shallow coal reserves that can be easily mined by strip-mining methods, causing significant surface disturbance. Mines are typically required to reinstate these areas to resemble as closely as possible the pre-mining land capabilities. This is to ensure continuity of agricultural production and to provide food security into the future. Unfortunately, in the main, this has not been achieved, due to the loss of arable land. The loss of arable land capability is matched by an increase in grazing or wilderness land capability, with the transformation lowering the overall productivity and ecological sustainability of the land. Loss of arable land relates to topographical variation, loss of topsoil through under-stripping ahead of mining, and the undesirable changes in soil texture caused by over-stripping. It also relates to increased compaction caused by the heavy mining equipment for soil stripping and placement activities, especially when soils are too wet. Simple, effective rehabilitation guidelines for strip mines in South Africa have been available for over 30 years, but in many instances these guidelines have not been followed. Proper planning at the project (EIA) phase and execution during the construction and operational phase can significantly reduce loss of high potential arable land. This paper looks at the main causes for mines not meeting their post-mining land capability commitments and recommends approaches to improving rehabilitation success.

The role of seeding density, species composition, and abiotic constraints to competitively exclude Phragmites re-invasion in Great Salt Lake wetland restorations

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Invasive species are a global environmental challenge that have contributed to degradation of wetland ecosystems. Phragmites australis is of particular concern in wetlands, particularly in the Great Salt Lake wetlands of the U.S. Intermountain West, as it rapidly outcompetes native species that provide important ecosystem functions. While seed-based restoration is a promising restoration strategy following P. australis control, recruitment following seeding is often unpredictable and largely unsuccessful. Seed sowing density is an important consideration, though few guidelines exist for optimal seeding density in wetland restoration. Furthermore, competitive exclusion of invaders depends not only on initial seeding density, but also the composition (i.e. functional roles/traits) of native species and environmental conditions. To address these context-dependencies, we conducted two mesocosm experiments investigating: 1) the influence of P. australis density and the density of a mix of diverse native species on recruitment, and 2) the effect of water and nutrient availability on competitive interactions. For experiment 1, mesocosms were sown with P. australis seeds at three densities and a native seed mix at four densities. We found that higher native seeding densities resulted in increased native biomass, but only when P. australis propagule pressure was greatly reduced. In the second experiment, we identified the species and sowing densities that were better able to exclude P. australis across a range of environmental conditions. Taken together, these results provide a better understanding of the context dependency of competitive interactions in wetland restoration, which can be used to maximize wetland restoration outcomes with limited seed supplies.
**Restoration and stepping-stone corridor building in Cape Town: A school-node based, collaborative approach**

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Cape Town is a biodiversity hotspot where high levels of inequality and an Apartheid past maintain the landscape as socially isolated bubbles perpetuated by social, spatial and mobile divisions. Therefore, Cape Town is characterised by high ecological and social Beta diversity where location specificity and sensitivity makes movement of humans, plants, and animals between areas highly complex. Small isolated reservations of remaining vegetation within the city are vulnerable to degradation but strategically key because they host locally endemic species not hosted elsewhere (Fletcher 2018, Fahrig 2018). Presently, they require connectivity to other populations for sustainable long-term conservation. Pauw and Louw (2012) suggest that schools are key to building sunbird stepping-stone corridors that restore pollen flow between isolated remnants of vegetation. Public spaces and garden biodiversity are key to insect-scale connectivity. Working across sensitive differences in the social and ecological context of Cape Town required a novel approach to corridor building where schools act as social nodes for initial social integration across social divides, and from there expand into a network that builds up into an eco-corridor. In this cooperative approach across multiple local community groups and NPOs, schools are used as key centres of biodiversity restoration. This is further expanded by incorporating the restoration of surrounding public open spaces and private gardens. Schools are points of call for knowledge exchange and innovation. Surrounding public spaces are areas for sharing and expanding that biodiversity resource, building, developing and deepening restorative relationships between peoples and between people, plants and animals.

**Rodent deterrent seed coating technologies for restoration seeding**

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Seed planting is a common method for restoring damaged landscapes. In many ecosystems, the establishment of planted seed is limited by the consumption of seed-eating animals. Seed coating technologies may hold the key to increasing restoration success by providing seeds a way to escape granivory. The seed surface can be coated with products that make seeds less desirable to seed predators. The Great Basin provides an excellent study system to observe seed-granivore interactions and test the effectiveness of seed coatings. In this region, kangaroo rats are the primary granivore and strongly affect plant establishment: We coated seeds in several products with known rodent repellent properties and tested them in two-choice feeding trials using kangaroo rats (Dipodymus sp.). Kangaroo rats strongly avoided eating coated seeds when alternative food options were present, even if the coating contained no active ingredient. This indicated that the physical barrier created by the seed coating contributed to deterrence more so than the rodent repellents in the coating. Two-choice feeding trials simulate how animals behave under conditions when food choices are plentiful, meaning that the active ingredients may play a greater role when food sources are scarce. For this reason, we conducted a 1-choice feeding trial in which kangaroo rats had access only to coated seed for a time. Under these conditions, kangaroo rats consumed some types of coated seed more than others.

**Evaluation of four seed mixes to improve botanical biodiversity in a solar field**

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In 2011, Longwood Gardens in Pennsylvania installed a three-hectare, 1.6-megawatt solar field. Half was previously agriculture and half was a low-quality meadow. Following panel install, four seed mixes were installed and evaluated to determine if any mix could serve as an effective, ecologically diverse seed option for solar fields in the region. Mixes were low grass (94% Festuca sp. and 6% Trifolium hybridum), cool and warm season grass (67% Festuca sp., 16% Agrostis sp., 10% Eragrostis hirsuta, 9% Dichanthelium clandestinum), warm season grass and forb (47% Chasmanthium sp., 10% Sporobolus heterolepis, 10% Eragrostis hirsuta, 16% Agrostis sp., 6% Conoclinum coelestinum, 11% Solidago sp.), and colonizing grass (45% Chasmanthium latifolium, 20% Dichanthelium clandestinum, 20% Agrostis sp., 15% Eragrostis spectabilis). All treatments were applied to both previous land use areas. Drill seeding was used between panels, areas under panels were hand seeded, and all areas had Avena sativa as a cover crop. All areas were mowed approximately three times a year when plants began to shade the panels. Three years following, most species had little or no establishment. Eragrostis hirsuta and Conoclinum coelestinum performed the best where seeded. Seven years following, treatments resulted in little differences. Generally, forbs were crowded out by grasses and forbs that did naturalize were present before treatment installation. Fully shaded areas were dominated by the invasive Microstegium vimineum. Overall, there is no one-size-fits-all solution for seeding a solar field to improve botanical biodiversity. Results indicate success depends on past land use, microclimates, and management after seeding.

Gender-responsive forest restoration: Supporting ongoing initiatives in Brazil

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Despite the well-known social and economic benefits of forest restoration, ecological restoration projects in Brazil’s Atlantic Forest frequently ignore gender issues, risking exacerbating gender inequalities and limiting the sustainability and long-term effectiveness of restoration outcomes. In order to catalyse gender-responsive initiatives on both national and subnational levels, the Atlantic Forest Restoration Pact in Brazil supports projects targeting enhancement of women’s access to decision-making and benefit-distribution processes in forest restoration. The main goals of this support are: (1) developing the capacity of communities, practitioners, landowners, decision makers, and other groups of interest aiming for the integration of gender and restoration; (2) promoting effective gender-related communication between researchers, policy-makers, and practitioners; and (3) stimulating gender-responsive approaches whilst participating in strategic forums for forest restoration. The supported ongoing initiatives include at least six projects across five Brazilian states. Lessons from these existing efforts point to the following recommendations for promoting gender equality through forest restoration in Brazil: the role of ‘guardians of forests’ or ‘victims of climate change’ should not limit the participation of women and traditional peoples in restoration projects; ecological restoration initiatives should be seen as an opportunity to promote inclusion and reduce social inequalities; gender-responsive approaches should be the first step towards
expanding social participation in forest restoration; women should be included in all phases of forest restoration, from decision-making process to field activities; ongoing forest restoration projects can be adjusted to aim for gender equity and, therefore, increasing the efficiency, sustainability, and social justice in forest restoration programs.

Positive, negative, or neutral: An assessment of the role domestic law and policy plays in watershed and coastal restoration in the United States

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This presentation investigates broadly what role domestic law is playing in the implementation of international and national goals to achieve ecological restoration objectives. In the specific context of United States law, this presentation asks three questions:

- Does existing law facilitate ecological restoration activities?
- Does existing law interfere with achieving ecological restoration? If so, how?
- Or does existing law make no real difference in achieving ecological restoration efforts?

Starting with a discussion of international goals (including the sustainable development goals and the Aichi targets), this presentation explores how the United States has domesticated into its existing laws and policy international goals and objectives to restore freshwater systems, coastal waters, and marine waters. The presentation is structured to:

1. Share a description of key aspects of the existing law and policy framework (e.g. Chesapeake Bay Restoration Act of 2000, Estuaries and Clean Water Act of 2000);
2. Review the implementation of the laws and results of restoration project taken under these laws based on a literature review of government reports and academic literature and;
3. Offer commentary about whether certain components of the existing laws offer models that might be appropriate for other States in their efforts to implement international restoration goals or offer cautions about how to proceed with creating laws to improve restoration efforts.

Where restoration related laws have not been fully implemented, the presentation discusses implementation challenges. The presentation concludes with thoughts on future research related to understanding the relationship between domestic laws and restoration.

Assessing ecological outcomes of wetland restoration under resource constraints in South Africa

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South Africa’s wetlands restoration programme, Working for Wetlands, funded through the government’s Expanded Public Works Programmes, has been in existence for over 19 years. The programme has invested over R1.1 billion in the restoration of over 1500 wetlands, in the process creating 34 000 jobs and many small businesses and imparting relevant and marketable skills to participants. Typical of government-funded programmes, resources for evaluating the ecological outcomes of wetland restoration are limited, yet it is hugely important to demonstrate the value for money invested and making a case for unlocking alternative sources of the much needed funding. We developed an improved method of assessing ecological outcomes of wetland restoration and applied it to nine sites across a diversity of restoration issues and land-use contexts. We assessed the condition of hydrology, geomorphology, and vegetation per identified wetland hydrogeomorphic unit pre- and post-restoration. For most units, overall ecological condition improved by 10-30%,
with the greatest contribution of restoration generally being to the hydrology component. Cost-effectiveness, in South African Rands per ha equivalent restored, was also determined and this varied considerably across hydrogeomorphic units. However, cost-effectiveness, a proxy measure of how justifiable the restoration investment is, must be interpreted in the context of the contribution that a site makes to ecosystem service provision. This study is formative and envisaged to improve wetland restoration practice, including planning, feeding into implementation protocols; as well as monitoring and evaluation in relation to specific restoration objectives.

**Developing a conceptual framework for restoring ecological function through rewilding: The Guam case study**

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Rewilding has emerged as an approach aiming at restoring extirpated functions through the introduction of locally-extinct or analogous species. While most efforts focus on the long-term survival of introduced species, little focus is done on aiming to optimize functional restoration spatially across ecosystems, which is essential for the ecological success of such ambitious projects. We use the island of Guam as an ongoing example of a potential rewilding project, which has seen all its native seed dispersers functionally or completely extirpated by the invasive brown treesnake (Boiga irregularis). The absence of seed dispersers is linked to reductions in species diversity and changes in native forest structure, as well as slowed regeneration of degraded forest. Stakeholders aim at rewilding the island with the Micronesian starling (Aplonis opaca), an effective seed disperser with a remnant population still on the island. Using the case study, we developed the “Spatial planning of rewilding efforts’ (SPORE) framework, combining spatially-explicit ecological models, spatial data, economics, and participatory approaches to identify effective management scenarios for functional restoration. This framework allowed us to identify (i) areas to prioritize for functional restoration to restore the native forests of Guam, (ii) potential costs of controlling the brown treesnake in these areas to allow for the rewilding of the Micronesian starling in regard to all possible management combinations, and (iii) conservation priorities of the different stakeholders and local actors through a participatory approach. By its flexible nature, the Spore framework could successfully be applied in a wide range of systems.

**Decolonization and democratization of livelihoods: Restoring human-land relations through co-management of natural resources**

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Learning processes in environmental management are often oriented to change and transformation and frequently involve the emergence of new forms of human activity. Nevertheless, little is known about how such change can be supported, especially in non-formal learning processes. We report on insights from the natural resource management (NRM) resilience building project in the highly biodiverse Legalameetse nature reserve in Limpopo province, South Africa. The paper explores how the use of cultural historic activity theory (CHAT) can mediate transformative learning for supporting co-management of protected areas. This paper reveals how deep historic injustices such as colonization and apartheid regimes have eroded the custodianship of NRM from local land users and communities in South Africa. The investigative question was how can the use of CHAT, in an expansive learning process support people to collectively (re)conceptualize and address the intricate interplay of social, economic, political, and cultural factors that drive environmental degradation? Guided by systemic thinking and sociocultural traditions of CHAT, the paper shares novel ways of mediating learning processes with communities that have successfully (re)claimed their land and that are learning to co-manage it with
government agencies for conservation and livelihood benefits. In conclusion, the paper argues for developing and using mediation tools that recognize deep socio-cultural and historical knowledge as key drivers in developing sustainable NRM practices for resilient landscapes and livelihoods. Furthermore, developing and using mediation tools should be conceived not only as an interpretive process, but also as collaborative authoring of events and frameworks for understanding socio-ecological complexity.

Creating collective socio-ecological learning spaces for transformative learning and custodianship building in natural resource management practices

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Over two decades ago, the South African government created the Working for Water (WfW) programme, which is the largest of all restoration programmes in the country. WfW objectives were to restore ecological infrastructure through clearing of invasive alien plants and jobs creation for unemployed citizens. There was no explicit focus on institutionalization of these ecological restoration programmes within local landowners and catchment residents. Furthermore, there was a lack of scope for capacity development to build custodianship for marginalized communities to be actively involved in management of restoration programmes such as WfW. This paper shares insight from the Blyde Restoration project (BRP) located in the Blyde catchment, Mpumalanga Province of South Africa. The BRP project was aimed at building capacity development for custodianship and collaborative management of ecological restoration projects by managers and local catchment residents. The paper demonstrates how systemic social learning approaches can be used as a methodological approach to support the emergence of transformative learning and collective capacity for restoration and protection of ecological infrastructure. The paper argues that deliberate creation of socio-ecological learning spaces, through co-inquiry processes can support resilient restoration practices and strengthen custodianship building for landowners and users who still view the restoration programmes such as WfW solely as job creation projects. In conclusion, the paper argues that restoration practices should be everyone’s problem, not just the government’s responsibility. And this requires substantial efforts to be focused on transformative learning approaches which are systemic and dialectical, in order to achieve integrated natural resource management practices.

Disturbance, dominance & disaster: Heavyweights in structuring herbaceous savanna communities.

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Alterations of historic disturbances are pervasive in their impacts on vegetation. This is especially relevant in managed grasslands sensu lato, where often only depauperate herbivore suites persist. Annual (from 2006) monitoring of herbaceous vegetation in the savannas of the Kruger National Park (KNP), South Africa, revealed that ten years of herbivore exclusion had no effect on plant richness, and little effect on dominance. To
examine more widely the thesis that grazing impacts richness via its effects on plant dominance, we conducted a meta-level analysis comparing results from 252 grazing exclosure experiments globally. Contrary to prevailing theory, we found that the effect of grazing on richness is negatively correlated to the effect of grazing on dominance, and not to MAP. In 2015/16 KNP experienced one of its worst droughts on record. For the decade prior to this, sampling plots were dominated by a single herbivory-resistant, unpalatable grass species. We built on this finding to explore the impact of extreme disturbance on these herbaceous plant communities. In the first two years post-drought (2017/18), the community dominance shifted to palatable grasses and forbs, with a simultaneous increase in plant diversity. This was seen in both grazed and ungrazed plots. The drought, with severe negative short-term impacts, transformed the savanna, potentially increasing available herbivore forage and biodiversity in the long-term. The positive, unexpected impact of drought supports the notion that large disturbances can enhance habitats, and that restoration efforts need not focus only on replicating pre-disturbance ecosystems.

Effects of marine restoration on ecosystem services

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Since the inception of the Marine Ecosystem Restoration in Changing European Seas ('MERCES') Project in July 2016, more than 130 restoration activities have been initiated across 12 European Countries with the aim of restoring regionally and internationally threatened and important marine and coastal habitats. Nevertheless, whilst restoration activities are widespread globally, the extent to which restoration actions result in a change in the delivery of ecosystem services is largely unknown. In this talk we will explore the link between marine habitat restoration and ecosystem service delivery within the European seas, drawing from MERCES and 80 additional restoration projects. We compare and contrast the delivery of ecosystem services between degraded and restored habitats; explore the link between specific restoration activities and ecosystem service delivery and consider the spatial scale of the benefits. Finally, we assess the degree to which changes in ecosystem services are quantified and monitored, or not. Trends, as well as gaps, in knowledge will be discussed and illustrated through case studies and spatial maps.

Placing marine ecosystem restoration in the context of international policy and global targets: Synergies and trade-offs

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The recent UN General Assembly Resolution for the UN Decade for Ecosystem Restoration (73/284) is one of a number of resolutions from a variety of conventions and multilateral environmental agreements (e.g. the Convention of Biological Diversity) highlighting the potential for marine ecosystem restoration to bring about the transformative change required. Furthermore, marine ecosystem restoration has the potential to help deliver upon a number of the 17 Sustainable Development Goals (SDGs) and 169 targets. However, in order to move forward and maximise the political will and opportunities currently present, there is a need to clearly understand and articulate the contribution marine ecosystem restoration can make to the delivery of global goals and targets. In order to facilitate this, we explore the pathways, opportunities, synergies, and trade-offs between marine restoration and global aspirations and commitments. We will highlight the role of marine ecosystem restoration as an ‘accelerator’ - providing opportunities to simultaneously meet multiple global goals and targets in a cost effective and ecologically sound manner. The results of this study will provide high level guidance to support national and regional marine ecosystem restoration prioritisation.
The operational dimension of ecological restoration: How to move from conceptual planning to the practice of planting trees with farmers and communities?

Felipe Marauê Marques Tieppo, Victor Augusto Melo Rodrigues, Felipe de Drummond Alves, Tercio Khoeler, José Almir Jacomelli Junior, Juliana Marcia Andrade
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How to guarantee 40,000 hectares of forest restoration over 10 years in thousands of third-party farms? Indeed, the primary challenge is to propose a model supported by a societal framework approached from a bottom-up perspective. This is key to ensure landowners' engagement as well as socioeconomic benefits. The objective is proposing a framework that, by placing people in the core of the strategy, is likely to avoid failure in restoration projects in private properties. The case study, the Fundação Renova and its complex governance, brings an opportunity to establish a cross-sector dialogue alongside a deep knowledge of the territory towards an inclusive model. To make it possible, we have been working with a framework that is flourishing with some positive results. Some actions we have taken so far were to establish local governance, help farmers understand their environment, aggregate knowledge through partnerships, care about the landholders' socioeconomics, payments for ecosystem services; providing cutting-edge techniques, and supporting a local-based restoration economy. So far, we have been working with over 700 landholders. The number of partner institutions and landholders participating have been increasing, farmers already participating have been giving in new areas, farmers are mobilising their neighbours. We expect this model to strengthen local communities by reconciling land vacation for production and conservation of natural resources.

Improving biodiversity in highly intensive farmland: Effects of agri-environment schemes using native seed mixtures on plant diversity, birds, and butterflies

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Within the frame of the EU Common Agricultural Policy, most countries subsidize the establishment and maintenance of perennial flower strips on arable land within Agri-Environmental-Schemes (AES) to counteract the loss of biodiversity. However, the use of non-native or cultivar seed mixtures is still common practice in many countries because they are cheap, easily available, and experiences with native seed mixtures are rare. Recently, about 1.800 ha of perennial flower strips have been established within the scope of an AES in Saxony-Anhalt. By sowing of 29-30 native forbs on edges of arable fields, the AES is aiming to support typical fringe community plant species and farmland birds as well as butterflies of fringe habitats. Our surveys comprised vegetation (2017, 2018), birds (2017), and butterflies (2018) on 20 single wildflower strips, 20 aggregated wildflower strips, and 20 arable fields without wildflower strips. We found that establishment rate of sown native forbs was high (on average 75%). All wildflower strips developed a species- and flower-rich vegetation, whereas plant diversity on arable land was very low. Sites with wildflower strips showed significantly higher abundances of butterflies compared to arable fields without wildflower strips. Perennial wildflower strips that comprise about 6-10% of a field can significantly enhance local population densities of farmland bird species. That effect was more pronounced on aggregated wildflower strips. Wildflower-rich seed mixtures can be established successfully under a variety of conditions, supporting characteristic species in agricultural landscapes. Thus, our study revealed import results for a new state-of-the-art in developing AES.

Use of legal and regulatory frameworks for the effective restoration of water resources

212
Restoration of water resources requires an integrated approach that implements the legal and regulatory frameworks available. The Department of Water and Sanitation (DWS) has over time developed a way that should enable the institutions such as CMAs to effectively implement IWRM. These include the effective implementation of the Powers and Functions of CMAs (inherent and duly delegated), the classification system, implementation of the resource protection limits and discharge systems aimed at ensuring that the resources can comply with the Resource Quality Objectives (RQOs) and subsequently reach a desired management state. The IUCMA is delegated the administrative function of Water Use License Application (WULA) administration, thus the effluent quality limits have to be reviewed. Similarly, the general and special limits of the General Authorization (GA) have to be set at a Water Management Area (WMA) level to ensure that the resources are protected while the already impacted resources improve to comply to the RQOs. This paper outlines the strategy developed at the IUCMA for implementation so as to ensure that the water resources are restored for sustainable management, development, and socio-economic benefit.

Perceptions of French practitioners on applying the cultural landscapes concept in ecological restoration

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The exchange between practice and science is essential to advance the discipline of ecological restoration. The importance of taking into account local sociocultural and landscape contexts has been scientifically recognized, but it is not clear yet if this is applied. The concept of Cultural Landscapes (CLs) can help in solving this problem because it encompasses local practices at landscape-level land management. Here we assessed the perception of restoration practitioners on the CL concept and its application to restoration projects conducted in France. We conducted semi-structured interviews with 20 practitioners using a sociological approach. Additionally, we compared their perceptions on CLs in restoration with how they describe their restoration practice. We found that 15 respondents already take CLs into account in their practice. Yet some of them did not claim to do so; they apply the CL concept without being aware of it. Practitioners believe that local stakeholders can potentially feel more involved if CLs are taken into account in restoration. They also proposed ways to better take CLs into account in restoration, often suggesting that it would be necessary to: (1) clarify the means to define a reference CL; (2) consider the varied roles of local stakeholders; (3) comply with regulatory instruments and look for sources of advice. Although the CL concept is applied by most respondents, its understanding was not evident. We suggest that more efforts should be made by conducting studies and transferring knowledge to practitioners regarding the integration of the CL concept into ecological restoration.

New approaches to the effective conservation of genetic diversity in native seed collecting with ash, Fraxinus excelsior, in the UK as a case study

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Well planned seed bank collections play a vital complementary role to in situ conservation and ecological restoration by preventing extinctions, providing seed for habitat recovery, and providing accessible, well-documented germplasm for research and experimentation. It is vital that such collections capture the genetic diversity of a target species over the geographic area in which it will be used. The Millennium Seed Bank Partnership, led by the Royal Botanic Gardens, Kew, comprises a range of seed collecting projects worldwide. The UK National Tree Seed Project has placed particular importance on the capture of intra-specific genetic diversity for native trees and shrubs. The project provides a useful case study for common challenges to capture genetic diversity, whether for long-term conservation or more immediate use in restoration. The UKNTSP has developed a detailed sampling strategy which, in the absence of detailed knowledge of population genetics, uses biogeographic zones as a proxy for genetic diversity and adaptation. The outcomes of this sampling strategy were evaluated using a modelling approach using simulations and geographic distribution data for the species Fraxinus excelsior. The model estimates that UKNTSP ash collections have captured >90% of all alleles present in Britain. The approach can be used to help design, justify, or evaluate seed collection outcomes for any species or application.

Perceptions of French practitioners on applying the cultural landscapes concept in ecological restoration

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Understanding abiotic and biotic drivers of plant establishment processes to anticipate future ecological resilience

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Global climate change is expected to decrease the resilience of many ecosystems, reducing their ability to recover to prior states following disturbance. Direct effects may include increasingly unsuitable conditions for post-disturbance recruitment and survival, which will have significant effects on restoration success. These effects can be largely inferred
based on differential species establishment across climatic gradients. However, primary effects of climate shifts will be not only on the underlying abiotic environment, but also on disturbance regimes, species invasions, and species interactions, including both competition and facilitation. Anticipating these impacts requires a mechanistic understanding of the processes underlying plant community dynamics. Here, we provide the conceptual basis for evaluating these effects. We provide a case study from semiarid woodlands of the western USA, where warmer temperatures coupled with annual grass invasions are increasing the frequency and extent of wildfires. Post-fire woodland recovery requires successful tree regeneration, but seedling establishment is largely limited to favorable under-shrub microsites that modify the harsh abiotic environment. Nurse shrub recovery is expected to be diminished by warming and annual grass invasions in some portions of the landscape, decreasing the availability of favorable microsites for tree regeneration, even where climatic conditions are generally suitable. A process-based understanding of how biotic interactions and multi-species responses to disturbance vary across the landscape can be used to assess ecological resilience and anticipate ecosystem responses to future environmental change to both prioritize restoration efforts and determine the most effective strategies.

**Seed networks for upscaling native seed supply in Brazil**

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Brazil has committed to restore 12 million hectares of degraded lands by 2030, however, there is a shortage of native seed supply. In this research, we assess the outcomes of six Brazilian seed networks in the Amazon, Cerrado, and Atlantic Forest Biomes, and estimate the plant material demanded to achieve the national restoration goal. Seed networks have operated through non-governmental and governmental organisations that link local communities who have produced seeds with restoration markets. Overall, these initiatives have produced 386 tonnes of seeds and engaged 1,046 collectors over the last 10 years. Each collector produced on average 45.5 kg of seed per year, receiving approximately US$270 yearly as cash income, regardless of the year, network or region. We also estimated - based on 2,152 germination tests of 122 species – a germination rate of 39.9 ± 7.9%. Running a Markov Chain Monte Carlo with 10,000 rounds we found a minimum germination rate of 17.75% for the mix of 122 species. Our finds show implementing Brazil's targets will require from 18,876 to 88,861 tonnes of seeds, and between 9,796 and 14,994 million seedlings depending on the restoration methods adopted. Although there are caveats in these estimates because of lack of knowledge about seed ecology and the complex field interactions and responses, restoration clearly requires a broader investment compared with the current structure and technology available. Although the community-based model is a potential productive arrangement, for spreading initiatives it is essential to overcome the limitations in knowledge and uncertain policies and markets.

**Gathering lessons learnt from WWF's experience worldwide: An overview based on 8 FLR long term field projects**

Daniel Vallauri, Stephanie Mansourian, Anita Toledo Barros Diederichsen

WWF, Marseille, France

WWF has supported Forest Landscape Restoration (FLR) development since 2000 and shares the goal of restoring 350 million hectares of forest landscapes by 2030. Today more than 200 WWF staffs are involved in an active FLR community. WWF run dozens of field projects (various scales, durations, forest types, and contexts). The program also includes education efforts (EFN Reforestation grant), lobbying for private or governmental engagement including issues initiated by partnerships, participates in platforms (GPFLR,
SAFRA, NGP, Trillion Trees) and supports ambitious policies (AFR100, Bonn Challenge). Restoring at the landscape scale is a long-term planned process, requiring multifaceted interventions (both ecological and social), and overall is a much richer but more difficult task than just planting trees. Providing good FLR guidance and implementation to meet commitments made by governments may be the main challenge of the coming decade. FLR practitioners only learn by doing. Thus, facilitating exchanges among field practitioners and grounding all activities on lessons learnt in the field is crucial for WWF. In 2018, WWF launched a lessons learnt exercise based on the analysis of its ‘long-term’ projects (10 to 20 year) to restore landscapes in Tanzania, Madagascar, Nepal, Malaysia, Brazil, Paraguay, Argentina, Mexico, New Caledonia, and the Lower Danube. The exercise is ongoing. It has already analysed five projects, producing specific reports and 10 to 15 high level lessons for each project. Others are under way (to be completed in 2019). This presentation will capture and share some key lessons learnt and emerging needs.

Conditioning native plants to increase stress tolerance and improve restoration success

Justin Valliere, Jacqueline Zhang, Rasoul Sharifi, Phil Rundel
University of California, Los Angeles, Culver City, United States

Multiple plant stressors, such as drought or herbivory, may negatively impact restoration success. A growing body of research suggests exposure of plants to a stressor may improve tolerance to subsequent stress events later in life. We sought to understand if such a phenomenon could be exploited in order to improve plant stress-tolerance and contribute to the restoration of native plant species in southern California. In the first experiment, we exposed seedlings of native perennials to drought, and then we compared the response of these plants to a second drought event to that of well-watered controls. We also transplanted replicates of both treatments to a restoration site to test if exposure to drought as a seedling could improve plant performance in the field. In the second experiment, we explored if clipping native bunchgrasses prior to outplanting could improve tolerance of subsequent grazing. In both experiments we observed a high level of variability across species, with species exhibiting the full range of positive, neutral, and negative responses to temporal variability in plant stressors. For example, previously drought-stressed seedlings of some shrub species showed increased growth in the field relative to controls, while other herbaceous perennials showed the opposite effect. This suggests that simple applications of stress treatments could improve plant growth and stress tolerance, but the success of this method is likely very species-specific. Restoration practitioners should consider conducting pilot studies with target plant species to better understand if these practices could assist in achieving restoration goals.

Riparian rehabilitation in the upper Berg & Breede River, Western Cape, South Africa

Johann van Biljon, Georgina van Biljon
Intaba Environmental Services Pty Ltd, Wolseley, South Africa

Intaba Environmental Services has been involved in rehabilitation and re-vegetation projects in the Western Cape, South Africa, since 2009 with specific focus on the river riparian on private land in the upper Breede and Berg River (Western Cape) since 2012. This has been in partnership with the Dept. of Environmental Affairs & Development Planning (DEADP) and Department of Agriculture (LandCare), Western Cape. Approximately 356,000 plants have been propagated at Kluitjeskraal Nursery (Wolseley, Western Cape, RSA) and planted over 14 sites within a 3-year time frame (2016-2019). Sites on the Berg River are located in Franschoek, through Paarl, Wellington to Hermon. Sites on the Breede River are located from Wolseley to the Breede Valley towards Worcester. The objective of such an initiative has been the active rehabilitation of degraded areas to improve ecosystem functioning and catalyse further succession within the broader catchment. This is regarded as the largest project of its kind within South Africa for rehabilitating riparian
land. There have been numerous obstacles and challenges to overcome as we facilitate the return of nature. Main challenges have been: 1) drought and irrigation, 2) landowner participation, and 3) capacity of staff. The following topics will be expanded: 1) drought and irrigation - attempts to increase plant survival while decreasing irrigation requirements, 2) successful landowner relationships, and 3) capacity building of staff. The high variation in conditions between sites required site specific rehabilitation plans and an adaptive mitigation approach to challenges that were faced.

Using secondary forest studies to develop species selection guidelines for active forest restoration

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There is an increasing focus on forest ecosystem restoration through the planting of a high diversity of native tree species. However, a major constraint to the development and implementation of high-diversity reforestation strategies is the lack of information on the growth and survival of tree species during the first decades of forest regrowth. Species selection trials can play a role but are very expensive and only provide data on species performance during the first few years after planting. In this talk, we evaluate to what extent the monitoring of forest regrowth in a well-replicated chronosequence of secondary forests can provide information on the performance of tree species during different phases of forest regrowth and, in extension, region-specific species selection guidelines for active forest restoration. From eight annual censuses in 45 0.2-ha plots in 0-39 year-old forests, we obtained data on the potential growth of over 100 tree species and their survival in relationship to tree size and forest age. For over 50 species, we could assess their response to neighborhood competition. We then discuss how a combination of this data with data on potential use, wood density, maximum stature, and landscape-scale abundance can be used to select potentially suitable species for active reforestation in strongly deforested areas within the region. In areas with more widespread natural regeneration of secondary forests, this data can be used to identify species that are valuable from a user or conservation perspective, dispersal limited, and suitable for enrichment planting.

Testing multiple substrates for terrestrial biodiversity monitoring using environmental DNA metabarcoding

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1Curtin University, Centre for Mine Site Restoration, Bentley, Perth, Australia, 2Curtin University, Trace and Environmental DNA Laboratory, Bentley, Perth, Australia

Biological surveys are challenging, expensive, and time consuming, yet crucial for ecological restoration. Metabarcoding is a developing complementary technology that can enable biological auditing from DNA in the environment and may provide cost-effective monitoring to detect flora, fauna, and microbial communities. Metabarcoding involves the use of next generation sequencing to sequence barcode regions of the genome to determine the community composition of a sample. This study aims to test multiple sample substrates (soil, ant middens, scat, plant material, arthropods in pitfall and vane traps) to determine what organisms can be detected from each and where they overlap. Samples were collected in the Pilbara and Swan Coastal Plain regions of Western Australia and transported to facilities in Perth where the DNA was extracted, amplified, and sequenced targeting multiple gene regions. Results indicated that soil samples, despite showing promise for biological auditing in some climates, yielded little plant or animal DNA, likely because high temperatures and UV radiation in the study areas degraded the DNA. Bulk samples, such as arthropods from traps, and scat samples detected greater diversity. With these findings in mind, scat and arthropod samples were then collected from chronosequences of mining restoration to investigate the use of metabarcoding in restoration monitoring. By sampling chronosequences of restoration we hope to examine whether metabarcoding data can distinguish between reference and restoration sites. We
aim to provide a guide for terrestrial metabarcoding sample collection in biological surveys and provide an example of how this method may be applied to restoration monitoring.

**Integrated restoration planning: From science-led to science-management-society led planning in the Tsitsa catchment**

**Benjamin Van Der Waal**, Harry Biggs¹, Mike Powell¹, Michael Braack², Michael Kawa², Nosi Mtati¹, Miss Kyra Lunderstedt¹, Tally Palmer¹, Kate Rowntree¹, Margaret Wolff¹

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The Tsitsa Project is a dynamic restoration and sustainable land management project in the Eastern Cape province of South Africa. The project was initiated due to badly degraded grasslands upstream of proposed water infrastructure developments with a real threat of rapid siltation. The project has evolved from a science-led ‘trapping sediment to prevent reservoir siltation’ in 2014, to a science–management-society led project in 2019 that focusses on equity, livelihoods, and sustainability. A significant improvement on previous restoration projects has been the inclusion of a community voice with regard to the spatio-temporal prioritisation of activities. The development of the project has not been a straightforward process with many tensions, training sessions, and ever-evolving meetings between managers, scientists, and local land users. The planning process has increased in complexity from a few remotely sensed biophysical layers, to local communities requesting regular meetings to ensure their inputs are well represented. This has led to various changes in the project plans, including shifts to a restoration approach that aims at avoiding further degradation. Planning time frames have also changed to incorporate a 6-month horizon in addition to the existing, 5-10-year horizon, with increasing feedback from implementers, managers, land users, and scientists. This increased attention to social processes within planning has required more coordination, trust, and patience, but the outcome is a holistic approach with buy-in from local land users to those at the ministerial level, with greatly improved long-term prospects. This talk will give examples of the growth process to date.

**Rehabilitation of mine tailings in Southern Africa**

**Piet Van Deventer**
Private, Pretoria, South Africa

Rehabilitation of mine tailings is not necessarily a new science but rather a collection of established technologies and experiences with new approaches and in some cases, it includes new experimental and research results. This presentation discusses a multi-phase rehabilitation approach on the most abundant tailings materials in South Africa by means of case studies and site-specific analytical results. The first and most important objective of tailings rehabilitation is to stabilise the surface to prevent or minimise wind and water erosion. The most appropriate principle is to follow a multi-phase approach and the first is to identify the site-specific attributes which have a major or composite influence on the end product. These are (in alphabetic order):

- Climate
- Geochemistry: dispersiveness, EC, K fixation-deficiency
- Landscape functionality *
- Microbiology: enzyme activity
- Mineralogy: AMD
- Organic carbon: C:N ratio, soil microbiology
- Slope geometry: slope angle and length
- Soil quality and health
- Species selection
- Surface covers: top soil, rock armour, rock cladding, amelioration
- Texture: particle size distribution
The following phase is to prioritize these attributes according to their real time environmental quality in terms of their influence on the long-term functionality of the rehabilitation end product. Thereafter it is up to the rehabilitation scientists to determine the follow-up phases.

Key concepts: objectives of rehabilitation, end product, multi-phase approach, site-specific data, long-term functionality.

**Assessment of estuary pressures and health key to the prioritisation of restoration activities on a national scale**

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Globally estuarine ecosystems’ abilities to sustain functionality and productivity are rapidly deteriorating owing to increasing human pressures. Unless policy-makers and managers intervene, this valuable natural capital will be lost to society. For interventions to be effective, knowledge on the extent of human pressures on estuaries is critical. This study systematically identified and assessed anthropogenic pressures on South African estuaries and their associated impact on ecosystem health. The outcome of the assessment revealed that a third of the country’s freshwater flow no longer reaches the coast, severely impacting at least 20% of estuaries. Wastewater discharges into estuaries amounts to about 840 million litres per day with 33% of estuaries severely affected by pollution-related activities. More than 3 730 tonnes of fish are caught annually in estuaries, severely impacting at least 20% of systems. Destruction of estuarine habitat results in severe impacts in at least 29% of estuaries, with agricultural activities contributing to 10% of change. About 15% of estuary inlets are artificially manipulated which, when combined, affects more than 60% of estuarine area. Alien vegetation has infested at least 40% of estuaries and severely impacted 6% of systems. The assessment provides a useful framework for the prioritisation of restoration actions. Arresting the decline in health on a national scale requires strategic, cross-sectoral resource-use planning and restoration that addresses the allocation of freshwater, wastewater management, fisheries, and urban, mining and agricultural development. Estuaries prioritized for restoration, particularly for water quality improvement, will provide some quick wins for increasing estuary health.

**Southern African cities in a changing climate – investigating the transformative adaptation potential of the Sihlanzimvelo stream management programme**

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Transforming cities in the global South to deal with the social, economic, environmental and political complexity exacerbating climate vulnerability is becoming increasingly urgent. ‘Transformative adaptation’ (TA) is a relatively new concept that is widely used, but poorly explored and understood in the climate change field. The aim of this research is to better understand the pathways to TA in water management in southern African cities. An initial literature review recognized six criteria for achieving TA. Stakeholders from potentially transformative water management projects in Durban assisted in the co-exploration of TA with the research team, and collectively identified case studies with TA potential in the City. The TA potential and pathway of the case studies were investigated through focus groups, interviews, and three learning engagements. One of the case studies is the Sihlanzimvelo Programme – a municipal-driven, community-based waterway restoration and management programme in high density public land. This Community Ecosystem Based Adaptation programme is regarded as potentially transformative due to its green engineering solutions; socio-economic, environmental and social benefits;
climate change adaptation; and reduced costs to the municipality by protecting infrastructure from flood and stormwater surge damage. Enablers of TA include: sustainable implementation and changes; sustainable fundamental changes in thinking and doing; economic empowerment and ownership; holistic, complex system thinking in addressing issues; proof of concept; and the possibility to upscale to be more inclusive. Limitations inhibiting the programme from reaching full transformative potential include rigidity in approach, top-down decision-making, political interference and limited buy-in from important actors.

Building a comprehensive compensations strategy for the eastern Cesar department – Colombia

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Using the opportunity that compensation obligations for mining projects opens, a regional compensation strategy is being constructed for the western slope of the Serranía del Perijá, in the Cesar department, Colombia. Hence, a comprehensive methodology has been devised based on ecological connectivity that includes conservation, restoration, agroforestry systems, as well as a participative training program. Perijá Mountains descend from steep highlands slopes to the flooding planes of the Cesar River, ecosystems range from sub-Paramo, Andean forests, Tropical Dry Forests and Tropical Savannas, with an elevated number of endemic species. The first compensation phase, starting in 2010, was implemented by five mining companies, in Tucuy and Sororia Creek basins and included the conservation of 2,000 hectares, restoration of 200 hectares and productive systems. The selection of conservation areas was made based on cover. Since then, the planning of compensation programs of one of the mining operations has improved by using a landscape approach, modeling connectivity corridors, selecting areas by cover, size, and geometry of patches as well as edge effect. A sustainability approach has been introduced to productive alternatives. Participation, including consultation, planning, training, organizational support, and technical advice is now part of the design process. To date conservation agreements have been signed for the conservation of 800 hectares, restoration of 300 hectares, and agroforestry systems in 106 hectares. The compensation plans for an additional 9,650 hectares are being completed in an area of approximately 100,000 hectares in nine basins; implementation will begin in 2019, lasting from 10 to 15 years.

The status quo of mine rehabilitation policy frameworks in Southern Africa

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Recent democratisation of many African states and consideration of human rights of residents within the vicinity has resulted in exceptional environmental legislation, which has influenced the development, alignment, and resultant change in policies towards African mines and environment. Pressure from NGOs is starting to become more prevalent and has affected county-specific legislation to conform more closely to international expectations. The objectives of the Sustainability Goals and NGOs such as the ICMM, drive internalised standards and are also gaining traction in strategies of African mining companies, and form the basis for decision-making of governmental departments. The main challenges relating to successful policy implementation remain 1) a clear understanding of rehabilitation completion criteria, 2) under-appreciation of the complexity of integration of various scientific fields, 3) marginal projects that result in hit-and-run mining operations, 4) legacy mining issues from ownerless or government mines without funds to clean up historical impacts, and 5) capacity of governmental departments to deal with the enforcement and technical complexities of rehabilitation in African
countries, and 6) lack of empowerment of local people to act as change agents and to voice concerns. Policies also hinge mainly on the constructs around closure quantums and rarely consider the true cost of mine rehabilitation, which proliferates a culture of short term and one-dimensional environmental management. Awareness around environmental performance of mines has, however, rapidly fast tracked as a result of the power of social media. Therefore, mining companies and government departments will be held more accountable to the adopted policies.

**Ecological restoration as a tool to increase resilience to climate change: Learning with small farmers of the Colombian Andean-Amazon Piedmont**

**Silvia Vejarano, Melissa Abud, Ilvia Niño**
WWF Colombia, Bogotá D.C., Colombia

The Colombian Andean-Amazon Piedmont is one of the richest ecosystems on the Planet and also one of the most endangered. Deforestation of river basins and micro-catchments in the upper reaches has local consequences, but also affects the flow and dynamics of major tributaries. Therefore, WWF Colombia started working towards maintaining key attributes of several micro-catchments based on the results of climate change vulnerability analyses. Traditional farm systems in the area are based on small scale cattle ranching, which depends on clearing forests and using water sources irrationally. WWF used Ecosystems-Based-Adaptation theory and Forest Landscape Restoration (FLR) as tools to develop actions towards increasing the sustainability of local production systems. The main difficulty in the process was to show farmers the significance of being part of the project, for which it was necessary to make them realize the increasing necessity of adapting to climate change. The main lessons derived from the process were:

- Translate the scientific climate-change jargon into concepts the locals understand.
- Permanent and fluent communication between all implementation partners, technicians conducting the analyses, local field officers, local technicians and farmers and their families is essential.
- Validating with locals all aspects of the methodology including definitions, actions on the farms and the development of climate change indicators, among others.
- Assessing the risks and threats at the farm level with the local technical teams before validating them with the spatial analyses.

**Restoring degraded forest ecosystems in South India for creating better habitats for wild Asiatic elephants (Elephas maximus): Design parameters, methods, and monitoring**

**Ramesh Venkataraman, K Anand, CR Hanumanth**
Junglescapes Charitable Trust, Bangalore, India

Bandipur National Park is a Protected Area and an important tiger and elephant reserve located in the Western Ghats of South India, a global biodiversity hotspot. Lokkere Reserve Forest abutting the national park is an important buffer habitat and migratory corridor for wild animals, mainly Asiatic elephants. These buffer forests have been highly degraded due to long-term anthropogenic pressures and lower protection status. This presentation discusses efforts over the past nine years in restoring these forests to create healthier habitats for elephants. Project design combined general restoration goals with specific requirements of elephants including potential for foraging, water, shelter, movement ranges, habitat connectivity, etc. Restoration was planned over 10 square kilometres to ensure adequate habitat range. Grass cover, a primary need for elephants, was restored through soil moisture retention measures and dispersal of seeds and rhizomes. Contour trenches and gully plugs helped prevent run-off on hill slopes. As elephants have a multi-floral diet, vegetation surveys helped identify native plants browsed by elephants. Vegetation restoration mainly followed assisted natural regeneration principles, with
species gaps addressed through seed and sapling introduction. As water is a key requirement for elephants, multiple small water bodies were made across the project area. Revival of fast-growing pioneer tree species helped improve canopy cover. Restoration activities were implemented by indigenous community members with good traditional knowledge of elephants. Habitat usage by elephants was monitored based on advice of elephant biologists, through visual sightings, and indirect evidence. Increase in habitat usage was observed, corresponding to the restoration progression.

**Monitoring insect diversity and assemblages to assess restoration progression in an 800-ha restoration plot in south India**

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The presence or re-appearance of desired faunal species is one of the main indicators of restoration progression as per the revival wheel methodology prescribed by the SER restoration standards. One of the largest groups of fauna in a restored terrestrial plot are insects and they are considered reliable indicators of ecosystem recovery. First, insects are highly sensitive to changes in habitat conditions and hence more accurate indicators of restoration progress than avian and mammalian species which show higher adaptability to disturbed conditions. Second, diverse insect assemblages depend on a wide range of micro-habitats and ecological niches. Hence their presence is a strong indicator of the revival of ecosystem diversity. Third, insects play a key role in the recovery of the fundamental aspects of a disturbed site i.e. soil, moisture and vegetation cycles, which form the basic building blocks of a restoration project. This presentation discusses an initiative to survey insect diversity and use this as a monitoring tool in a large-scale restoration project in a dry deciduous forest ecosystem in the Western Ghats of India, a biodiversity hotspot. The six-month study of insect diversity helped assess linkages between the species identified and their habitat and food/prey preferences. This in turn helped assess recovery of associated micro-habitats, vegetation, and prey diversity. Key ecosystem services provided by these insect species were also documented. The study of extended ecosystem linkages associated with prey species provided interesting insights. Over 160 insect species from 12 orders and 54 families were observed, providing a useful baseline.

**Experiences and lessons learned of forest restoration together with the pulp and paper sector in Brazil**

**Daniel Arrifano Venturi**

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About a third of South America’s population lives in the Atlantic Forest (AF) ecoregion complex, which comprises Brazil, Paraguay, and Argentina. In Brazil, the forest supplies water for some 60% of Brazil’s population – 145 million people. It is a buffer against soil erosion and sequesters 2 billion tonnes of carbon dioxide – more than four times Brazil’s annual emissions. According to Brazil’s Forest Code, landowners need to preserve natural vegetation on 20% of their land (“legal reserves”) as well as in “areas of permanent protection” designed to maintain ecosystem integrity – as buffers around water courses or to prevent erosion on steep slopes, for example. The New Generation Plantation participants’ operations in Brazil, which manages more than 2 million hectares, are FSC certified, which provides assurance of legal compliance – and goes further by requiring companies to identify and manage areas of high conservation value. In many cases, the set-aside areas regenerate naturally, particularly when they adjoin existing fragments of native forest. Other parts, though, are too severely degraded for that to happen. Here, the companies are using their silvicultural expertise to actively replant the rainforest. Pulp and paper industries are strategic stakeholders to promote gain of scale in restoration initiatives in the Brazilian AF, since companies are required to protect and restore native forests due to legal compliances. The experience of ground work under implementation by
the private companies is providing valuable contributions and lessons learned that can be shared with other stakeholders among the landscapes.

**Opportunities and challenges for the gain of scale on restoration activities in the Brazilian Atlantic Forest**

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The Atlantic Forest (AF) is a tropical ecoregional complex distributed throughout the Brazilian coast, reaching Argentina and Paraguay territories. It presents high species endemism and severe loss of forest cover, currently estimated at 85%. Restoration is necessary in order to retain biodiversity and crucial ecosystem services provided by its remnants. Despite this, large-scale initiatives are still lacking, and information about projects remains diffuse. To make a gap analysis of opportunities and challenges in AF restoration, we collected data about restoration initiatives from 24 institutions and interviewed six Brazilian specialists. Altogether, 81 initiatives were mapped, of which 66% focus in small-scale restoration and 56% in restoration supply production. Fewer projects address economics of restoration and compliance with environmental liabilities. Paper and pulp industries are strategic stakeholders to promote gain of scale in restoration initiatives in the AF, since companies are compelled to protect and restore native forests due to legal compliances. Over 70% of the initiatives are placed in the South and Southeast regions, depicting the lack of restoration investments in the Northeastern AF. Specialists mention key themes for the gain of scale in AF restoration: i) Financing for forest restoration projects; ii) Incentives and financial mechanisms to reduce costs of forest restoration projects; and iii) Regulation of political forecasts; and agreeing that sustainable landscape planning is an opportunity for scaling up restoration. Also, restoration technical capacity building, alignment to international climate change commitments, and incentives to enhance natural regeneration processes were detected as gaps and opportunities to restore the AF.

**Creek restoration to support riparian habitat and extended flow**

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The South Platte River Basin (Colorado, USA) accounts for over half of Colorado's economic activity, contains seven of the top ten agricultural producing counties in the state, and includes many areas for recreation. Water flows in tributaries in the South Platte River Basin are variable and ephemeral, with many reaches dry for large portions of the year. Historical channelization has exacerbated this problem, creating steeper banks and more incised channels. With less water getting onto the banks, the flood plain and available riparian habitat are reduced. In 2015 we initiated a watershed improvement project in the lower portion of the South Platte River Basin at Denver Botanic Gardens Chatfield Farms. Partnering with six other organizations and agencies, using a mix of federal, state, county, and private funds, we installed three in-stream structures to re-wet historical oxbows, improving hydrology from historical stream channelization. In addition to improved plant and animal habitat, restoring flows provides longer water storage in the system and increases the duration of flow in the creek. In our third season post-installation, water was flowing in the creek a month longer than what would have been available from just upstream sources. We also planted over 1,000 willows, cottonwoods, and other native riparian species and initiated a long-term monitoring program for vegetation and water quality. We have seen extended channel flow and increased animal use in restored areas. Based on the success of this minimally invasive technique, we aim to expand to other areas in the South Platte River Basin.
Survival of urban wetlands in Cape Town through wetland restoration

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The low-lying areas of Cape Town, known as the Cape Flats, were historically covered in marsh and floodplain wetlands fed by permanent and ephemeral streams flowing off the mountain catchments. Although these wetlands, known locally as ‘vleis’, housed large hippo populations that drew nutrients into the system, these vleis were surrounded by nutrient-poor, sandy soils. Most of the vleis and rivers on the Cape Flats have been modified, with vleis drained and the rivers canalised as a consequence of urban expansion. In being fed by storm water systems, most urban lowland wetlands contain water year-round and are typically eutrophic with constant sediment, pollution, and waste input. Several endangered, endemic frog species are associated with these vleis and exhibit specific breeding behaviours of mass emergence from their over-summering sites to mate in the wetlands. The changes in nutrient, sediment, and flooding regimes of these vleis have resulted in the proliferation of the indigenous, cosmopolitan wetland plant, Typha capensis, which has knock-on effects for the frog’s breeding and also for available forage sites for wading birds. The Muizenberg East Conservation Cluster comprises fragmented patches of strandveld and wetland (natural and artificial) areas within the urban mosaic. Importantly, during development planning, interconnecting corridors were left so as to ensure continuance of natural ecological processes and linking of two nature reserves. This presentation will highlight the management interventions aken to ensure sound terrestrial and wetland functioning within an urban mosaic.

Identifying ecological threshold breaches in wetlands: Development of a framework to improve wetland prioritisation and restoration in South Africa

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Thresholds in ecology refer to a point where even a small change in conditions can lead to a shift in an ecosystem to an alternative ecological state. Once a threshold has been crossed, an ecosystem may not easily return to its pre-threshold state and, as a consequence, this may result in a change in composition, structure, and functionality. When assessing a wetland ecosystem for the purposes of planning restoration it is essential to develop an understanding of ecological thresholds and the resilience of the system in its present state. If basic processes such as hydrology, geomorphology, and vegetation community dynamics are highly altered, it may be prohibitively expensive or even impossible to restore the system. In contrast, a less degraded system that has yet to breach a threshold may be a better candidate given that it has better restoration potential. We present an overview of the development of an assessment framework and indicators that can be used to identify thresholds in degraded wetlands and assess their significance to the restoration potential of the wetland. The framework considers thresholds of change in relation to three important components of wetlands, namely hydrology, geomorphology, and vegetation community dynamics and provides a set of field-based indicators that can be used to identify thresholds.

Using SNP genetic data to create provenance maps for seed sourcing

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Global restoration targets require the collection of increasingly large quantities of seed. Choosing the geographic origin of seed (the provenance) is a key step in restoration and is vital to restoration success. Understanding spatial genetic structure in plant species used in restoration is essential to avoid undesirable genetic effects (e.g. inbreeding or outbreeding depression, maladaptation) and to provide resilience in restoration plantings. The emergence of next-generation genomics tools provides insights into genetic variation among populations and enables delineation of plant provenances and signals of adaptation in a timely and cost-effective manner. In this study, we collected samples from across the range of two plant species – one hemiparasite and one sympatric non-parasitic plant – with the aim to examine to effect of different life history traits on the geographic distribution of genetic variation. We applied a genotyping-by-sequencing approach to investigate genome-wide patterns of genetic diversity, gene flow, and local adaptation. Our results were used to predict patterns in species’ adaptive variation, identify genetic provenance zones, and create a provenance map for seed sourcing. In both species we identified strong patterns of differentiation in eastern populations. In addition, genome-wide scans for selection identified a number of outlier loci putatively under selection with fewer loci under selection identified in the parasitic plant. These results demonstrate the value of combined spatial modelling and genomics analysis in delineating provenance zones and informing seed sourcing for restoration.

Soil organic carbon and nitrogen content of density fractions and the effect of meadow degradation on soil carbon and nitrogen fractions in alpine Kobresia meadow

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This research was conducted on non-disturbed native alpine Kobresia meadow (YF) and severely degraded meadow (SDL), Dari County, Qinghai Province. By a density fractionation approach, soil samples were divided into light (LF) and heavy fractions (HF). Fractions were analyzed for organic carbon (OC) and nitrogen (N). The results showed: (1) OC concentration in HF and LF was 3.84% and 28.63%, respectively, while nitrogen concentration was 0.362% and 1.192%, respectively, at the 0–10 cm depth. C:N ratio was 10.6 in HF and 23.8 in LF. (2) OC in HF was dominant through the whole soil profile. OC in HF increased from 78.95% to 90.33%, while OC in LF decreased from 21.05% to 9.68% with depth. (3) Soil total OC amounted to 47.47 in YF and 17.63 g·kg⁻¹ in SDL, where OC content in HF decreased from 37.31 to 16.01 g·kg⁻¹ while OC content in LF decreased from 10.01 to 1.62 g·kg⁻¹. Results of OC and N content show meadow degradation led to the loss of 57% OC and 43% N in HF and 84% OC and 79% N in LF compared to the native ecosystem. (4) The main reason for loss of C and N in LF during meadow degradation was not attributed to the decrease of OC and N concentration in LF and LF, but to the decrease in LF dry weight. Loss of N was far lower than loss of C in HF. This may suggest that there is difference in protection mode of C and N in HF.

Restoring abandoned salt pans as waterbird habitat

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Southern African estuaries and saltpans function as important areas for many waterbirds, including Palearctic migratory bird species. The Swartkops Estuary and adjacent saltpans near Port Elizabeth, a Global Important Bird Area (IBA), largely owes its diversity and abundance of waterbirds to the presence of extensive artificial saltworks. The saltpans here are one of the most important mainland breeding sites for seabirds in the region. However, these saltpans have been abandoned due to theft and vandalism of the pump stations,
leaving behind four large dry and salinized concentration pans. Consequently, the number and diversity of waterbirds in the IBA has decreased. To restore this important waterbird habitat, estuarine water is to be pumped into the dry pans on a seasonal basis. They will be filled in winter to provide safe nesting sites (i.e. islands in the pans) for the birds and allowed to dry again over summer to provide feeding areas. A restoration plan is presented as well as details of the monitoring necessary to determine the success of the restoration. Baseline data were collected before the pans were filled, including biotic characteristics such as bird abundance, and abiotic features including sediment (electrical conductivity, moisture content, organic content and grain size) and groundwater characteristics (depth to groundwater and salinity). These variables were measured again after the pans had been filled to monitor the success of the management objective. Although the conservation of waterbirds is a global issue, this needs to be addressed locally through management and conservation of wetland habitats.

**Cap and trade funded coastal wetland restoration-carbon sequestration projects: Examples from California and the northeastern United States**

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There are two active carbon markets in the United States – the California market and the Regional Greenhouse Gas Initiative (RGGI), a cooperative program between ten northeastern states. Both cap and trade programs are providing funding for coupled coastal wetland restoration – carbon sequestration projects. In California eligible projects have included coastal wetland and mountain meadow restoration, while RGGI-supported projects vary across states. Using case studies from California and New Jersey, this presentation will discuss how funding from these programs is linked with restoration projects. This presentation will cover the stoichiometry between carbon sequestration and the emission of other greenhouse gases in coastal wetlands, identify synergies between restoration and carbon sequestration opportunities, and discuss how permanency issues are being addressed.

**Case studies of modified South African estuaries and implications for ecological restoration in these systems**

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In “developing” countries estuaries support the basic needs of coastal communities for subsistence and livelihoods. Even transformed systems have to deliver a diversity of ecosystem benefits to a diversity of beneficiaries. Progressive management approaches are needed to ensure this. This work identifies abiotic and biotic processes to be considered, and key management principles to be adopted in estuarine restoration initiatives. Subtropical estuaries in South Africa were investigated, covering different estuary types varying in the degree to which they have been impacted by different anthropogenic activities. Comparison of system types, pressures, ecological trajectories, and ecosystem services allowed investigation of the potential to restore and manage transformed estuaries to provide ecological benefit. All study systems were transformed with concomitant loss of ecosystem services. In some cases, transformations have been extreme with near-complete habit alteration. However, some systems have functional habitats that offer ecosystem benefits. Management approaches in the modified estuaries
differ, influencing their ecological states and ecosystem benefits derived. This study offers key insights to guide successful ecological restoration in estuaries. A key consideration when dealing with modified estuaries is deciding on management to either restore or rehabilitate. This cannot be done without considering national biodiversity objectives and wider-scale resource planning. Management objectives for transformed systems may differ from those for natural systems. Managing modified estuaries to targeted objectives that are not necessarily natural must be done with caution but presents some opportunity to improve the collective estuarine resource and to derive greater benefit from systems which might otherwise be neglected.

**Threshold dynamics in the use of mobile bomas (livestock corrals) for rangeland rehabilitation**

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Bomas (livestock corrals) create hotspots (or glades) within tropical savanna or grassland matrices and can be used to rehabilitate degraded rangeland. High soil and foliar nutrient content within the site are maintained by feedback mechanisms – notably, increased use by wild herbivores. The duration of boma occupancy varies and more frequent relocation (shorter occupancy) could increase the area rehabilitated per unit time. However, little is known about the minimum – or threshold – occupancy duration necessary to establish the feedbacks that maintain hotspots/glades. This study consisted of five replicates of five treatments: bomas occupied for 0 (control), 4, 7, 14 and 28 days. Vegetation and animal dung (a proxy of use) were monitored at several time points. The threshold for graminoid and total herbaceous cover appeared to be crossed by all treatments >0 days. But the 4-day treatment did not show a significantly lower percentage of either short-lived grass cover or species richness (indicators of glades) than the control. Use by wild herbivores in the 14- and 28-day treatments was significantly higher than in the control, but the 4- and 7-day treatments were not. These results show that the thresholds are dependent on the focal variable. Although bomas occupied for shorter periods reduce bare ground and increase herbaceous cover effectively, they may not attract enough herbivores to instigate feedbacks required to maintain the elevated soil and foliar nutrient contents characteristic of glades over longer time periods. These findings also emphasize the importance of monitoring multiple variables for assessing restoration success.

**Introducing genomics in restoration ecology: How many seed zones does Carex bigelowii have in Norway?**

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The introduction of genomic methods in ecological restoration is promising as a tool for achieving restoration goals. However, there are only a few case studies showing how genomics can be implemented to restore biodiversity. Here we use seeding as a case, focusing on the active restoration of the former military, arctic-alpine Hjerkinn area, the largest restoration project in Norway. A commonly advocated approach to seeding in restoration is to use seeds from local populations because they will be genetically similar to the original populations. However, there are no guidelines for how local seeds should be selected, and several aspects like intraspecific genetic diversity, inbreeding and adaptive genetic variation complicate the use of seed mixtures of local origin without using molecular methods to confirm the genetic suitability of seeds. We use ddRADseq-derived SNPs to investigate the genetic structure of the sedge Carex bigelowii in Norway, hypothesizing that previously delimited seed zones are not encompassing important genetic variation found between two ecologically distinct subspecies or within the subspecies. We discuss our results, considering conceptual discussions on restoring
different levels of biodiversity, and in the context of ongoing discussions on selecting appropriate strategies and seed sources for restoration. The emerging field of landscape genomics, analyzing the genetic basis underlying local adaptation surely adds new tools to the restoration tool box.

Managing alien invasive species to restore aquatic ecosystems in South Africa

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Freshwater ecosystems in South Africa contain diverse communities that exhibit high degrees of endemism particularly with regard to dragonflies, crabs, amphibians, and fishes. For example, 90\% of the native fishes that inhabit the Cape Fold Ecoregion are found nowhere else on earth. As is the case globally, freshwater ecosystems are in a state of crisis because of the increasing demands that the human population has on these systems. As a result, most are subject to multiple stressors, including habitat modification, pollution, flow reduction and the introduction of alien invasive species (AIS). Of these stressors, the introduction of AIS are considered one of the least reversible, and in South Africa their control and management is a legislated priority. As a result, the country has invested significant resources in restoring invaded ecosystems through combating invasions through direct removals and biological control. In this paper, we provide a review of the extent of alien fish and plant invasions in aquatic ecosystems and use current examples of the response strategies to mitigate impacts and, in some cases, restore ecosystems.

Scale challenges emerging from the implementation of landscape restoration policies in Ecuador

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With landscape restoration targets gaining international importance, there is a growing need to pay attention to how multi-sector restoration policy frameworks are reconciled with the reality of rural communities who depend on landscapes to sustain their livelihoods. Local governments often stand between restoration policy targets and rural livelihoods and need to find ways to reconcile competing land use claims. Currently, little is known about how restoration policies and decentralisation processes influence local governments’ capacity and decisions to increase the share of natural infrastructure in the local land use mosaic. Ecuador is one of the Latin American countries with the largest diversity of policy frameworks, implementation mechanisms, and initiatives to promote ecological restoration. This article presents the restoration experiences of two local authority associations (locally-known as mancomunidades) in the Chocó Andino (Pichincha Province) and the Bosque Seco (Loja Province). Based on over 50 semi-structured interviews and observations at the national and local level, the multi-sector and multi-level governance challenges that emerge from the implementation of restoration policies have been identified that influence the ability of local governments to engage in local restoration action. The two case studies from Ecuador show that future restoration work needs to pay more attention to the building of local capacities for both territorial land use planning as well as restoration-oriented livelihood interventions at the farm level. The findings contribute to a better understanding of the problems that local governments encounter during the implementation of public restoration action and the ways in which these are solved.
Targeted action to restore populations of threatened plant species in the Cape Floristic Region

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South Africa’s floristic diversity is incredibly rich with some 20,942 species recorded, two thirds of these are endemic, and found nowhere else in the world. South Africa contains one of the world’s six floral Kingdoms and hosts three biological hotspots, including the Cape Floristic Region. In 1726, Dutch Minister and Naturalist, François Valentyn said of the Cape Lowlands: “There is nothing more amazing than to see whole fields of flowers growing wild here of which the colours are so unusually bright and fine that it is pity that they cannot be drawn from life by a skilled artist.” Sadly, this is no longer the case, as much of the natural vegetation in this area has been lost or fragmented and associated vegetation types are now Critically Endangered. Nearly a quarter of our plant species are threatened, and we are losing species at an alarming rate, and so, with limited resources and time available, priorities have to be set and action taken for species that require immediate attention for conservation and restoration. SANBI is implementing Target 8 of the South African National Strategy for Plant Conservation through an integrated conservation programme that aims to facilitate a comprehensive approach of integrated conservation strategies, including ex situ living collections, and in situ restoration projects. Examples of this work and of restoration protocols and processes used to restore threatened species will be presented, highlighting the need to prioritise, and work together, to both safeguard and restore these species before they are lost forever.”

Coastal reef restoration in temperate waters: Counteracting fish habitat loss with the construction of artificial stone reefs

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Coastal marine ecosystems are facing increasing levels of degradation worldwide as a consequence of anthropogenic activities. The extraction of marine substrate is particularly damaging as it permanently alters the seabed structure, and recovery is unlikely to occur without human intervention. In Denmark, large-scaled extraction of marine boulders occurred for over a century until it was banned in 2010. Since then, a number of restoration projects have been initiated in an attempt to recover this important habitat type and its functions. In this study, we restored a series of coastal stone reefs in Flensborg Fjord, South Denmark. Field sites were monitored with the use of remote underwater video stations (RUVS) in a before-after control-impact (BACI) experimental design. Artificial reefs were constructed either as a large dense reef or as multiple scattered reefs in an attempt to address the ongoing “Single Large or Several Small” (SLOSS) debate in conservation biology. Our results show that the reef restoration efforts had a significant positive effect on total fish abundance. Species richness was also higher on artificial reefs compared to control sites. In terms of reef design, the single dense reefs promoted the abundance of commercially important species, e.g. codfishes (Gadidae), whereas overall species diversity was higher on scattered reefs. Our study provides pertinent information for future marine habitat assessments and emphasizes the importance of considering reef design when constructing artificial reefs. Efforts to recover important fish habitat worldwide are increasing, highlighting the need for effective restoration methodologies.
Plant composition and soil moisture play determining roles in improving ecosystem multifunctionality during restoration processes on the alpine steppes of the Qinghai-Tibetan Plateau

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Alpine steppe is one of the most widely distributed and crucial grassland ecosystems on the Qinghai-Tibetan Plateau (QTP), which has experienced severe degradation during the past 40 years owing to anthropogenic activities and associated climate change. However, few studies have paid attention to the ecosystem multifunctionality (EMF) of restored degraded alpine steppes. In this study, four types of alpine steppe (degraded steppe, cultivated steppe, fenced steppe, and intact steppe) were investigated to explore the most predictable ecological factors affecting EMF in the Golog Tibetan Autonomous Prefecture of Qinghai Province, China. Our results showed both grassland cultivation and fencing could significantly promote EMF of the degraded alpine steppes. The aboveground biological community was more significantly correlated with EMF of the alpine steppe than belowground biological community, and plant species composition was more important than species richness in improving EMF of alpine steppes in the process of ecological restoration. Abiotic factors could alter biological composition-EMF relationships in the alpine steppe ecosystem. Overall, restoration actions could improve the EMF of degraded alpine steppes on the QTP via aboveground biological composition and soil moisture. These findings can provide a scientific basis for sound restoration management of the degraded steppe ecosystems on the QTP and other similar ecosystems worldwide.

A preliminary study on aquatic vegetation restoration in the northwestern Arabian Gulf

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This paper presents an approach to evaluate the potential area and economic benefit of Sargassum bed restoration. The approach was applied to Kuwait's highly turbid waters where rapid coastal development causes marine ecosystem degradation. The case study showed that water depth was a primary environmental factor governing Sargassum distribution in the study sites. The relationship between Sargassum coverage and water depth indicated optimal water depths where the maximum coverage was observed. Notably, the optimal depths were different among the sites due to different turbidity levels at each site. In addition, the availability of stable hard substrate was another key factor responsible for the local sporadic distribution of Sargassum beds. Based on the optimal depths, we estimated the potential area for Sargassum beds restoration where optimum growth of Sargassum is expected. The results showed that a total area of 4.26 km² was potentially inhabitable for Sargassum in terms of light availability (depth) but was not currently vegetated mainly due to the absence of a hard substrate. This estimated potential area is comparable to as much as twofold of existing Sargassum area (2.19 km²). Furthermore, we estimated potential economic return generated by Sargassum bed restoration in the potential area in terms of production of a commercially important shrimp. The economic return was estimated to be annually 12.8 million USD or approximately 3.02 USD per unit area (m²). This study offers beneficial information for decision-makers to assess the feasibility of the habitat restoration as a part of mitigation in coastal development plans.

The impact of grazing systems on structure and function of alpine grassland for sustainable restoration and management

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The alpine grassland on the Qinghai-Tibetan Plateau has long been subjected to grazing by local livestock, yak, and Tibetan sheep. The alpine grassland grazing ecosystem provides vital ecological services for the region and fundamental living supports (economic services) for the local residents. However, grassland degradation due to artificial disturbance (over-grazing) and climate change has resulted in profound losses of both ecological and economic services of the alpine grassland. In order to explore the most sustainable grazing management, we have conducted a series of manipulated grazing experiments to evaluate the impact of different grazing systems on the structure and functions of the alpine grassland. The experiments involve grazing intensity, annual/seasonal grazing regime, and different livestock species (yak and Tibetan sheep) under moderate grazing. The results showed that: (1) Grazing intensity dramatically influenced species composition and community structure; (2) Heavy grazing intensity not only decreased community biomass but also reduced forage quality because of the loss of palatable grasses and augmentation of weeds; (3) The seasonal grazing regime had less effect on plant composition when compared to continuous grazing; (4) The structure of the plant community was relatively stable under moderate grazing irrespective of livestock species; (5) Yak grazing increased soil total carbon (STC) but decreased soil total phosphorus (STP), whereas sheep grazing decreased STC but increased STP, and neither of the two livestock species had an impact on STN.

The recovery of forest structure in a semi-arid mine dump: Estimation based on Worldview-2 satellite data

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Structural parameters are key indicators for the resilience and diversity of restored forest ecosystems. However, there is a lack of studies to illustrate the recovery of the structural parameters due to the absence of long-term monitoring after restoration. This study used Worldview-2 satellite data and developed an Evolutionary Algorithm-Neural Network Model to estimate coverage, biomass, and spatial structure in a semi-arid mine dump. The results show that the spectral and textural information from Worldview-2 image could effectively estimate the three structural parameters with determinant coefficients of 0.91, 0.86 and 0.62, respectively. With increase of restoration age, the structural parameters of the restored forest increased. After 23 years, the average coverage, biomass, and spatial structure reached 0.80, 27.5 kg/m² and 0.45, which were 266.6%, 245.5%, 300.0% higher than the reference sites. Among different reforestation patterns, the single forest of Pinus tabuliformis Carr. or Hippophae rhamnoides Linn. have highest coverage (0.98) and biomass (45.8 kg/m²) but the lowest spatial structure 0.22. The mixed forest (Populus L. and Pinus tabuliformis Carr.) has the highest coverage, biomass and spatial structure of 0.90, 34.9 kg/m² and 0.78. These results suggest that restoration interventions could effectively restore the forest structure in a semi-arid mine dump. However, there exist trade-offs among coverage, biomass, and spatial structure. The pattern of mixed forest is beneficial for forest regeneration. This study also demonstrates that the satellite imagery-based model and data have potential advantages for monitoring recovery and guiding the improvement of restored forest and possibly other restoration sites.

Anticipating secondary invasions: Cautionary tales for ecosystem restoration

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Invasive plants are often removed without plans for follow-up management, be it further clearing or active restoration. However, most ecosystems have multiple rather than single plant invaders, which can lead to one species taking over after another is removed. There is
a need for general principles regarding invader interactions across varying environmental conditions, so that secondary invasions can be predicted, and managers can allocate resources towards pre-treatment or post-removal actions. By reviewing removal experiments conducted in three Hawaiian ecosystems, we evaluate the roles of environmental harshness, priority effects, productivity potential, and species interactions in influencing secondary invasions. We generate a conceptual model with a “surprise index” to describe whether long-term plant invader composition and dominance is predictable versus stochastic after a system perturbation. Under extremely low resource availability, the surprise index is low, while under intermediate-level resource environments, invader dominance is more stochastic, and the surprise index is high. At high resource levels, the surprise index is intermediate: invaders are likely abundant in the environment, but their response to a perturbation is more predictable than at intermediate resource levels. We suggest further testing across environmental gradients to determine key variables that dictate the predictability of post-removal, invader composition.

Multiple feedbacks can create resilient degraded states and stall restoration

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Feedbacks between ecosystem function and dominant species can lead to internal reinforcement and persistent ecosystem states in both native and exotic-dominated systems. In addition, multiple feedback pathways can co-occur, making stable degraded ecosystems difficult to restore. How then, do we disentangle which ecosystem feedbacks are the most important to address for successful restoration? We explored multiple feedbacks in more degraded versus intact sites within a subtropical mesic forest that had been previously cleared for grazing and planted with exotic pasture grasses. In the mid 1980’s, managers planted almost 400,000 native nitrogen-fixing Acacia koa trees to jumpstart succession toward a more diverse native-dominated forest for endangered bird species. Although trees have closed canopies in the 33 years since planting, almost no native plants have recruited in the understory. Thus, exotic grasses remain dominant and secondary succession is not occurring. We propose that multiple feedbacks that exist in intact forests (e.g., birds->seeds->fruiting understory->birds) are missing from degraded sites. We also suggest that new feedbacks have emerged in A. koa/grass sites that stall succession and thus passive restoration. We use a mixture of observational studies and experiments to verify these feedbacks and test their relative importance. Although we find evidence for the existence of multiple mechanisms, we conclude that factors that constrain native seedling recruitment related to grass biomass and lack of suitable recruitment sites need to be addressed first for secondary succession to take place. Finally, we consider active management that may help restore tree and understory diversity to A. koa/grass sites.

Genetic identity and genetic purity: Who cares?

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Assume that you as a plant professional are in charge of restoring a compromised landscape as it was pre-disturbance, or at least revegetate it to similar ecological form and function. You find seeds in the marketplace that appear applicable to your project at a price you can afford and order them delivered. You end up with a very nice pile of bags, bins, or boxes. Do you care if they are labeled correctly with the proper species, germplasm notation, and provenance (i.e., genetic identity)? Do you care if the delivered seeds possess the genetic traits (and include minimal off-types or contaminants) representative of the natural populations or germplasm selections that you specified (i.e., genetic purity)? If you
do care, do you have the resources available to accomplish your own investigation before planting to verify genetic identity and genetic purity? If you don't have the resources, you might want to learn about seed certification schemes for native seeds applicable in your part of the world that provide traceability of origin and collection and that ensure compliance with high standards for cultivated multiplication. Sampling and testing may also be required so that the seed purity and viability is known. In this presentation, we will briefly present to you existing examples of seed certification frameworks worldwide, address the basics of the certification process and what is really necessary, and welcome your input and opinions on this topic.

Proactive projects: Prerequisite for real revegetation of western USA rangelands

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Tens of millions of acres of public rangelands in Western USA are seriously degraded, resulting in low productivity along with increased vulnerability to wildfires, erosion, and endangered status for native plants and wildlife. Currently, most public agency sponsored revegetation on these rangelands is emergency seeding in response to cyclical wildfire events. This unpredictable cycle leads to a boom or bust marketplace for revegetation seed as supplied by private sector seed collectors and farmers, engendering higher overall prices and seed shortages of critical plant species and their ecotypic germplasms needed for specific wildlife habitat recovery. The end result is compromised vegetation reestablishment efforts and thus further rangeland degradation. To break this untenable cycle, a non-public agency driven resolution has been initiated for presentation to those in the U.S. Congress with stature and influence in management of public wildlands: “That federal funds at the rate of $150 per acre be earmarked to plan, prepare, and seed at least one million acres of proactive revegetation projects per year on public rangelands in the Western USA.” Planned projects reduce wildfire frequency and severity through mitigation of weedy fuels such as cheatgrass and establishment of more fire-resistant vegetation. Planned projects assure the availability and affordability of the best possible plant materials needed to generate balanced, diverse, and productive rangeland ecosystems. Planned projects greatly improve such ecosystem services as purifying water and air, controlling erosion, providing nutrient recycling, supporting animal life, and supplying resources for human use and recreation.

Connecting experts in biological and meteorological sciences to advance knowledge of pest management for restoration in a changing climate

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There has been considerable progress in elucidating the physical aspects of climate change that directly impact restoration of ecological systems. However, these impact assessments rarely account for climate induced changes associated with biological pests. The lack of collaboration between the pest (insects, weeds, diseases) management and climate science disciplines could be contributing to the problem. Therefore, we assessed research-based relationships, identifying possible barriers to and gaps in successful collaboration. We developed an algorithm capable of identifying author affiliation and associated disciplines. We found that pest management and climate scientists most often authored papers in their respective disciplines (>90%), but rarely in the opposing disciplines (<1%). Atopica, an international research group, is one of the few examples of how interdisciplinary collaborations have led to the co-production of knowledge to better understand and manage a pest, common ragweed (Ambrosia artemisiifolia), responding to climate change. Researcher-to-researcher relationships, such as Atopica, are an often
The effects of vegetation restoration on soil carbon and nitrogen dynamics in a typical karst degraded area

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Rocky desertification has been identified as the most severe ecological problem threatening ecosystem services in karst areas in southwest China. To combat this severe form of land degradation, southwest China has been selected as a major target of a series of restoration projects since the end of the 1990s. However, the effectiveness of such conservation efforts on soil organic carbon (SOC or soil C) and nitrogen (N) still remained unclear. Based on multi-scale field investigations and fixed sites observations, the dynamic patterns of soil C and N under karst ecosystem restoration in southwest China were studied. Results showed natural vegetation restoration was more beneficial to soil C sequestration than managed vegetation restoration, while the tree-grass complex systems are preferable to the plantation forest. The levels of soil N pool before restoration, N sequestration rate, and the soil Ca²⁺ level were the most important factors affecting the rate of soil C sequestration. Results also revealed that a shift from N limitation to P limitation occurred from the early to the late stages of the secondary vegetation succession. The exudation of oxalic acid into rhizosphere soils enhanced potential N mineralization rates indirectly through inducing microbes and NAG activities, consequently overcoming soil nutrient constraints. This study indicates that management of degraded karst ecosystems should increase nitrogen import in the early succession stages, and the tree-grass complex system should be carefully considered in the restoration practice, which may promote ecological stability and sustainability of the ecologically vulnerable karst landscape.

Strengthening the resilience of agroforestry parks and the livelihoods of communities bordering the Pô Kaboré Tambi National Park and the Dandé quarry in Burkina Faso

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Building on from the global partnership between BirdLife International and HeidelbergCement, NATURAMA has developed a collaboration with CIMBURKINA, the subsidiary of HeidelbergCement in Burkina Faso. A 12-month pilot project (August 2017-July 2018) implemented around 10 villages bordering the Po Kaboré Tambi National Park (PNKT) focused on building capacity on the best practices of sustainable management of agroforestry parks and the improvement of the livelihoods of local populations. The goal of the NATURAMA-CIMBURKINA collaboration was to replicate such activities around the limestone extraction site of Dandé (west of the country). The project at PNKT has positively influenced the development of a five-year
revolves around four components: the improvement of partners' intervention capacities, the reversal of natural resource degradation trends, the improvement of the socio-economic conditions of women and young people, and the monitoring and evaluation of results. The strategy at PNKT called "Trees, Insects and Birds" was a combination of best practices for increasing agricultural biodiversity and conserving pollinators. This has led to:

▪ Improve the biodiversity of agricultural lands for the purpose of securing forest products (wood and non-timber);
▪ Make farmland habitats more suitable for pollinating insects: diversity and availability of floral resources (nesting sites for insects, modern beekeeping, reduction of chemicals) and birds' habitats (reforestation, assisted natural regeneration);
- Improve policies and management practices of pollinators and birds in agroforestry parks through information, awareness raising and advocacy.

**Inclusion of intra- and interspecific facilitation enhances seagrass restoration**

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Restoration is increasingly utilized as a strategy to reverse the loss and degradation of coastal habitats globally. Restoring foundation species that create habitat and facilitate the settlement and survivorship of other organisms is crucial for rebuilding ecosystems. Current methods in restoration practice emphasize minimizing competition and interactions among transplants despite an extensive body of literature demonstrating that positive species interactions are critical for the recovery of foundation species following intense disturbance. Here, we experimentally tested how both intra- and interspecific species interactions can be applied in seagrass restoration by incorporating i) interspecific facilitation (clam additions) into seed plantings, and ii) both intraspecific (aggregated vs. dispersed plantings) and interspecific facilitation (clam additions) into shoot plantings. In the seed planting study, addition of clams increased seed germination success, shoot growth, and shoot reproductive effort. In the shoot planting study, both shoot aggregation and clam addition increased seagrass success, but each benefiting from different aspects of seagrass biology, and they did not have additive effects. We found that planting seagrasses in an aggregated rather than dispersed configuration enhanced transplant survivorship as well as patch expansion. Bivalve presence also increased survivorship. Our results highlight that incorporating species interactions into restoration designs with small adjustments can significantly improve restoration outcomes.

**Status and challenges of ecological restoration in coal mining areas in China**

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China is a country with coal as its main energy source and the coal output exceeds 3.5 billion tons per year. Each year, about 60,000 hectares of land is damaged and the subsided land has accumulated to nearly 4 million hectares due to coal mining activities. Ecological restoration of coal mining areas in China has experienced a development process from land reclamation with the main objective of economic utilisation to ecological restoration with the main objective of ecological protection, from sporadic spontaneous governance to organised governmental regulatory control, and from no law to follow to having laws to follow. This presentation will systematically introduce the temporal and spatial changes of coal development in China over the past 40 years; analyse the features of ecological damage, as well as the difficulties and priorities of ecological restoration in different regions; explain the achievements of ecological restoration in the past 40 years; and list some typical cases of ecological restoration success. Finally, it presents in detail the challenges in theory, technology, funding, policy and management faced by ecological restoration to China's coal mining areas under the new era in which the country's ecological environment is protected ahead of economic expediency. In the future, international cooperation is the key to achieve ecological enhancement and restoration of mining areas in China.

**Forest Landscape Restoration, Community Based Forest Management, and the role of social learning in Sub-Saharan Africa: Insights from Malawi**

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As the forest landscape restoration (FLR) paradigm gathers momentum and countries commit to restoring 350 million of hectares of deforested and degraded lands by 2030 under the Bonn Challenge alone, community-based natural resources management (CBNRM) will play a major role in achieving long-term restoration success. Yet CBNRM still faces major challenges to delivering sustainable ecological and social benefits. Some failures have resulted in a CBNRM backlash and recentralization of forest management. Common-pool resources theory and case studies show that successful CBNRM institutions take longer (decades) to build than common project lifespans, highlighting the need for learning and adaptive management. But what happens after CBNRM-based restoration projects/initiatives fail? Do key stakeholders learn from failures to resuscitate restoration? Under what conditions? What are the potential triggers for formal and social (self-) learning? How can such social learning be fostered? What are the implications for CBNRM-based policies for achieving the ambitious FLR goals? We used insights from theory on social learning and adaptive resource management experiences and data collected from quantitative social surveys and qualitative key informant interviews, focus groups, and observation, along with some forest-condition data from the early 2000s to mid-2010. Local/traditional leadership quality, the extent of scarcity-based adversity, economic incentives, existing social capital dynamics, and ecological resilience of common tree species were some of the factors that promote such restorative social learning. Findings highlight the need to consider and foster social learning for sustainable CBNRM-based FLR, describe the implications for policy and future research, and broader implications for Sub-Saharan Africa.

Germination analysis of natural and ecologically-restored sites in phosphate mining fields in Zin Valley, Israel

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Phosphate mining occurs over 200 km² of the Negev desert, Israel. However, the effects of the ongoing restoration efforts of the mines have not been studied. Plants and their seed banks have a major role in ecosystem processes, hence requiring major consideration in studying ecological restoration. I focused on three mining sites restored in different years at Zin valley and compared plots. I hypothesized that: (1) there is a lack of seed bank in the restored plots; (2) the altered soil composition at the restored plots inhibits germination. I set up two greenhouse experiments using soil samples collected from the different mining sites: (1) comparison between natural and restored areas treated with planting mixture or vermiculite; (2) addition of native seeds to test their germination potential on restored soil. Results indicated that the lack of a seed bank was the major limiting factor for restoring the plant community and that soil composition did not hinder germination. For two mining sites, abundance was significantly lower in restored plots compared to natural plots and their community composition differed significantly. For the third mining site, no significant differences in abundance or community composition were found. When comparing restored plots of various restoration years, community composition differed significantly. My results indicate that restoration efforts in our area should focus on preserving the seed bank to allow better dispersal of seeds in restored plots. Active seeding in restored plots offers an approach towards vegetation reestablishment.
Spatial modeling of the impacts of current and future ecological restoration scenarios on soil erosion modulus at the catchment scale

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South Africa is an arid and semi-arid country with various characteristics that make the land highly degradable. Water erosion represents a major land degradation process in the country with over 70% of South Africa affected. The sediment generated from a catchment is usually either deposited within the catchment or transported to water bodies causing several off-site problems such as water pollution and dam siltation. Apart from the identification of appropriate land use and soil erosion control measures it is necessary to identify the source of sediment delivered to a point (sink) in the watershed using methods such as factor multiplication models under GIS environment. Since land surface-water interaction contains a set of complex processes, the key challenge of spatial modeling is to capture the interaction between land and water systems in order to link the spatially diverse character of the land surface with the time varying characteristics of the water flow and constituent transport through the landscape. The RUSLE2 requires rain erosivity, erodibility (K-factor), cover management factor (C-factor), and slope length (LS-factor) factors. Short-term and long-term ecological restoration had an impact on C-factor and K-Factor, respectively. The research is a comparative study between China and South Africa. The two catchments considered are Yan’gou (Loess Plateau), China and Welbedacht (Upper Caledon River) located between South Africa and Lesotho. The study showed the importance of considering the biomass in the C-factor determination rather than the vegetation cover through vegetation indices.

Peatland degradation and ecological restoration indicators in a semi-arid environment: Development of a monitoring framework

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Peatlands are rare and unique wetland types in Southern Africa. They play a major role in supporting biodiversity, even in a semi-arid country such as South Africa. Peat is an accumulation of partially-decayed organic matter from wetland vegetation under inundated conditions and low oxygen content. The major peatland ecosystem services range from biodiversity to carbon sequestration and water purification to hydrological regulation. The peat fire is one of the major environmental disasters that leads to the entire loss of the peat layer and releases smoke and harmful gases that affect surrounding communities. Moreover, peat fires also affecting climate by releasing large emission of CO₂ to the atmosphere. Although the source of peat fires is still a research challenge, peat dryness is confirmed to be the first step to fire susceptibility. Peatland wetting status is an important measure to determine the peatland degradation level and techniques that can be used for eco-hydrological restoration. In this study, three peatland systems in the semi-arid environment of South Africa (Lichtenburg, Molopo and Molomane, North West Province) with different degradation levels were considered. An evaporation method was adopted to assess the peat water content using dielectric, thermal, and optical methods. The combination between the thermal infrared (TIR) and near infrared (NIR) has been used to determine the fire risk threshold. The magnitude of thermal energy emitted from the...
land surface across different landscapes can be retrieved using the TIR data. Additionally, soil moisture has been used as indicator for the peat fire location suitability.

**Application of next-generation sequencing for molecular reconstruction of plant diversity using environmental DNA**

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Biodiversity across the globe continues to decline, threatening highly valuable ecosystem services. Rapid assessment and monitoring methods of species richness and abundance are required to understand the origin of the threats and enable a conservation plan. Kuwait has an arid desert ecosystem with a small flora of only 400 species. The biodiversity and ecosystem are endangered by environmental factors, overgrazing, and human activities. Next Generation Sequencing (NGS) technologies allowed us to identify plants to species level and distinguish plant diversity found in soil environmental DNA (eDNA) samples. The molecular investigation methods assisted in identifying the plant diversity found below-ground level and comparing it with that above-ground, using eDNA samples collected from both species rich and poor habitats in Kuwait by applying high-throughput sequencing methods. This study contributes towards the future of molecular ecology assessment for monitoring biodiversity and applied in ecological restoration projects in Kuwait.

**Assessment of the current condition of populations of Lagochilus proskorjakovii Ikram (Lamiaceae) in Nuratau mountain ridge, Uzbekistan**

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The high-mountain ecosystems of Central Asia are a biodiversity hotspot with unique plant communities and many endemic species. Intense human pressure and global warming has caused habitat destruction in these areas, increasing the number of endangered species. In Uzbekistan, the number of red-listed plant species has risen in the last 30 years from 163 in 1984 to 324 in 2009. L. proskorjakovii (Lp) is an endemic species to the Nuratau ridge, an area with high human pressure. The overall goal of this research is to assess the status of Lp in the wild. We focused on the four populations of Lp with each population representing one study site (1.0-10 ha). At each site we described the plant community and inventoried all plant species occurring in one randomly selected 25 m × 25 m plot. Our results showed that populations of Lp in their native range are affected by harsh environmental conditions, such as highly eroded soils, rock slides, large rocky slopes, intense winds and few pollinators. In addition, populations of Lp are under pressure from anthropogenic factors such as overgrazing and harvesting for medicinal raw material. The average density of Lp in the four populations varied from 0.35 to 0.6 individuals/m². According to the classification of Zhivotovsky, the populations are mostly mature. These results indicated that the species might become extinct in the wild in the near future. For this reason we have planted seedlings in natural populations of Lp for restoration. Many thanks to UNU-LRT for support.

**Potential of different spectral models for detecting and mapping salt-affected landscape in drylands**

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238
Salt-affected soil is an environmental problem in drylands due to human activities and climate change, which adversely affects human wellbeing, food security, and sustainable development. Thus, there is a critical need for it to be tracked periodically. Compared to traditional methods (EC-Lab), remote sensing (EC-predicted) offers a synoptic view, covering a vast territory and extracting accurate information with an acceptable economic factor, especially for the long-term monitoring. The aim of the present study is focusing on validation and comparison for the first time among eight different physical models for soil salinity mapping in arid landscapes. The OLI image data was radiometrically standardized, and the models were implemented to derive soil salinity maps. A total of 100 soil samples were collected, representing different salinity levels, and each sampling location was geographically localized using accurate GPS. The laboratory analysis was accomplished for validation purposes. Statistical analysis was applied between predicted salinity maps and the measured ground truth. The results obtained showed that predictive models based on VNIR bands and vegetation indices are inadequate for soil salinity prediction due to a serious signals confusion between the salt-crust and the soil optical properties in these spectral bands. The statistical tests revealed insignificant fits ($R^2 \leq 0.41$) with a very high prediction error ($RMSE \geq 0.65$). While the model based on second-order polynomial functions and integrating the SWIR bands provides results of best fitness in comparison to the ground truth, yielding an $R^2$ of 0.97 and low overall RMSE of 13%.

The effects of altered habitat type on Anuran diversity and assemblages in Mount Mulanje, Malawi

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Habitat fragmentation and increased environmental heterogeneity often lead to losses in species diversity. As continuous forests become increasingly limited, it is important to determine conservation and biodiversity values in forest fragments and surrounding landscapes. Currently, there is little data on how Anuran species react to the alarming growth of habitat heterogeneity in tropical East Africa, nor on the value of remnant forests. This study evaluated the alpha, beta and gamma diversity of frogs in a fragmented landscape on Mount Mulanje, Malawi, East Africa, and assessed the impact of habitat fragmentation and diversity of a landscape matrix of various habitat types. Nine sites were sampled: three intact miombo forests, three eucalyptus plantations, and three secondary forests. Twenty-nine species were found throughout these landscapes. Intact forests contained significantly greater species richness (~93%), with approximately 62% of species found in surrounding habitats. The degree of canopy cover and area size appeared to determine species diversity in these landscapes. Fragmented and anthropogenic habitats cannot substitute for continuous blocks of forest; however, the heterogeneity of these landscapes can form a diverse habitat system for the conservation of Anuran communities.

Ecological restoration of degraded lands of the Monte desert: Response of Prosopis trees to silvicultural practices

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The current degradation of desert ecosystems determines the use of management practices such as reforestation with native woody species for their ecological restoration. In addition, pruning has been suggested to optimize productivity and improve potential use for local people. Our objective was to examine the annual response to pruning by individuals planted in two degraded environments of the Monte desert: a) individuals of Prosopis flexuosa and P. chilensis in dunes areas (DIVISADERO=DIV) (33.76S, 67.75W) and b) individuals of P. flexuosa from two different provenances planted in the rocky foothills (CRICYT=CRI) (32.89S and 68.87W). Pruning consisted in the extraction of lateral branches,
leaving the main stem of 50% of the individuals. We measured the following allometric variables: equivalent basal diameter (DEQ), crown diameter, and total height. We selected 32 P. flexuosa and 32 P. chilensis trees (measurements: 2003-2012) in DIV. In CRI we selected 48 P. flexuosa trees by provenance (total N=96). Pruning was carried out at two times: the beginning of the trial and at 9 years (measurements: 2005-2017). There were no differences in height of the pruned species (DIV), nor between the different populations of P. flexuosa (CRI). We only found differences for DEQ in trees pruned at 9 years of establishment (CRI). We recorded a rapid recovery of crown diameter in pruned trees of the CRI, but not in DIV for either of the two Prosopis species. Pruning does not produce a clear increase in growth in the initial stages but it does in older trees.

Local governances and their importance for institutional mobilization as a condition for gaining scale in the restoration of degraded river basins

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In order to restore degraded river basins it is necessary to identify and understand the dynamics between different local actors. Previous studies show successful cases of forest restoration triggered by the creation of management systems comprising participants from the civil society and from the government. These committees are strategies to improve and legitimize to the farmers the planned actions. The goal of this work is present the collaborative management system proposed and introduced by Renova Foundation for the restoration of the Doce River Basin, Brazil. With this aim, in 2017 the Renova Foundation started to work with a territorialized management that involved agriculture and environment agencies from Minas Gerais and Espirito Santo states, Brazil, representatives from farmers and from the farm workers unions from both states, representatives from the federal environmental fiscalization agency (Ibama) and members from the Rio Doce River Basins Committee. At first this group was in charge of managing payment for environmental services, but it rapidly evolved due the need to increase the institutional power and reach of the program to a wider management group, making it possible for actions to reach the main stakeholder, the rural producer. This group proposed a model of local arrangement at a sub-basin level with different formats and actors; it could participate in the dissemination and registration of producers in the forest restoration bids. As result, 270 rural producers joined the program in the first mobilization process in the basin.

Tree canopy removal releases shrub understory in mule deer habitat: Monitoring restoration success using drones in western Colorado, USA

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Decreasing mule deer populations in northwestern Colorado, USA, may be partly a consequence of habitat loss due to pinyon-juniper tree encroachment that reduces production of shrubs and forbs preferred by deer for forage. Mechanical thinning of woodland overstory has been demonstrated to increase cover of shrubs, perennial grasses, and native annual forbs preferred by mule deer and other wildlife. The Magnolia Experimental Site (Piceance Creek Basin, Rio Blanco County, Colorado) consists of 28 plots, 0.8 ha each, that were mechanically thinned in 2011 or left as a control. Field data collection included line-point intercept (300 pts along 13 transects in each plot) and 5-band multispectral imagery (ground sampling distance ≤ 6 cm) collected from an altitude of 100
m using a fixed-wing drone. LPI data collection required 28 person-days in the field; multispectral image collection required just 2 person-days. Shrub canopy cover has increased to an average 26.4% across all sites (range: 4.7 - 54.1%) and herbaceous canopy cover has increased to an average 42.1% (range: 20.2 - 65.7%). Using object-based image analysis, we found strong correlations between LPI and remotely sensed cover estimates for shrubs ($R^2 = 0.89$) and two shrub species that are key indicators of habitat quality: serviceberry (Amelanchier alnifolia / A. utahensis; $R^2 = 0.78$) and snowberry (Symphoricarpos rotundifolius; $R^2 = 0.88$). Monitoring of outcomes is a critical component of ecological and management-directed restoration. Estimating cover and species composition using very-high-resolution drone-based remote sensing imagery will provide managers with a more efficient, repeatable, and flexible monitoring protocol.

Monitoring forest restoration plantings established in landscapes transformed by the Fundão Dam disaster

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The Fundão dam breach resulted in drastic changes for the Gualaxo River floodplains in Brazil. This sudden transformation started with iron-ore tailings covering existing vegetation and surface soil. Stakeholders rejected the removal of composite ‘technosol’ deposits. Therefore, rehabilitation actions took place over reshaped floodplains and adjacent anthropogenic fields. The recovery plan included native tree plantations and required the use of 32 native species and a minimum density of 833 seedlings/ha. Monitoring these plantings will substantiate the development of effective rehabilitation protocols for these areas and for similar cases. We surveyed tree plantations at the end of their first growing season, using 85 randomly positioned plots (100 m² each). We assessed relations between surviving saplings densities and environmental conditions with generalized linear models. Our data show high mortality rates, resulting in an average density of 505 sapling/ha (CI 95%= 434-587). Surprisingly, the substrate type (i.e. technosol or natural soil) had no significant effect on sapling densities. Furthermore, among predictors we have tested, ‘mowing’ was the only factor with a significant effect (p=0.001) on sapling densities. The selected model predicted the sapling density to be 48.9% lower in sites with no mowing in comparison to sites where non-woody plants have been trimmed. The lack of mowing was found in 56.5% of our plots, where we observed overabundant green-manure legumes or Urochloa sp. To date, monitoring data show that planting and cultivating native trees is equally feasible in both substrates: technosol and agricultural soils.

Woody colonization on tailings deposits during active forest restoration

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After the Fundão dam disaster, more than 1,200 hectares of natural forests and anthropogenic fields were replaced by deposits that roughly consisted of iron-ore tailings. As a result, riparian areas were designated for forest restoration with the purpose of recovering (on tailings deposits), or offsetting (nearby tailings deposits) forested areas that were cleared by the tailings. Our aim was to identify and quantify the effect of major restraints to woody colonization in such extreme conditions. We installed 100-m² plots within native tree plantations (i.e. active forest restoration). Out of 85 plots positioned at random, 56 were installed on tailings deposits and 29 in adjacent, pasture fields. Woody colonizers were identified and quantified in the plots. We used generalized linear models
to analyse the association between woody colonization density and factors considered drivers of tropical forest recovery. We observed an average density of 305 woody colonizers per hectare (CI 95%=[211-440]). The effect of the landscape matrix composition was not significant (p > 0.1) with similar densities within forests and pastures. In contrast, we observed colonizers to be nearly 3 times sparser in tailings-plots compared to pasture-plots. This difference was significant for zoochorical species (p=0.002) but not for anemochorical species (p=0.133). For zoochoric species, the most parsimonious model predicted substantially fewer colonizers per hectare on tailings deposits (CI 95%=[0-133]) in comparison to former pastures (CI 95%=[191-409]). Therefore, restoration projects should consider that tailings deposits are likely hostile for animal seed-dispersal, which may affect community assembly as a whole.

A simple standardized protocol to evaluate the reliability of seed rain estimates

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Seed rain has key implications in restoration ecology. However, this process is challenging to measure and a lack of standardized measurements hampers accurate estimates. Accuracy of seed trap effectiveness and of seed sorting methods is vital to obtain reliable and reproducible results. We propose and describe a standardized protocol to evaluate the effectiveness of seed rain traps and of a seed sorting method. We selected seeds of four species easily purchasable: arugula, quinoa, sesame and sunflower, in order to have a gradient of seed size, weight and color. We worked with both sticky and funnel traps. This protocol was tested in a tropical grassland. To test for the accuracy of seed sorting methods we chose three previously trained observers who received a given number of seeds in an equal amount of soil. Trap effectiveness tests suggest that in the particular case of campo rupestre grasslands, we are underestimating seed dispersal of small smooth seeds that can be easily mixed with debris. Seeds on sticky traps were more vulnerable to predation and removal by wind or rain, whereas seeds in funnel traps were more vulnerable to rotting. We found no evidence of observer effect on seed sorting, but seed size had a significant effect. The tested standardized protocol can be easily implemented in any grassland type with sticky and funnel traps. It is fundamental to improve the reliability of seed rain studies using seed traps, and will allow more reliable comparisons with existing datasets.

Katy Prairie stream restoration: An illustrative use of stream restoration to create resilient ecosystems able to endure extreme weather events

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The geomorphic approach to stream restoration was recently applied on a large-scale basis within the United States of America, near Houston, Texas, at the Katy Prairie Stream Restoration project. This project included reconstruction of over 28 kilometers of stream. Goals of this project were to enhance overall stream function by addressing the fundamental processes of channel incision and bank erosion. Secondary goals included restoration of wetlands to improve water quality, enhance flood attenuation and expand near-stream habitat, re-introduction of wood into the channel to increase habitat, and systemic improvements to the landscape to provide compensatory mitigation credits. Geomorphic channel design techniques were utilized to restore the streams at Katy Prairie. The design included sediment transport analyses to design a stable, self-maintaining stream system. The design for the project focused on restoring floodplain access by reconnecting the stream to the floodplain, re-distributing energy throughout the cross section, and providing grade control to prevent future channel incision. The design also
focused on re-establishing habitat within the channel and throughout the adjacent floodplain by re-creating kettle wetland features. The resiliency of this site was recently tested during Hurricane Harvey. It is estimated that the hurricane produced an approximate 500-year flow event near the site. Results of monitoring indicate that the site withstood the event with minimal evidence of erosion or other indicators of instability. This talk will discuss the stream restoration design and specific techniques used to promote resiliency and the results of five-years of monitoring at the site.

Monitoring ecological indicators of a coffee agroforestry system in the Brazilian Atlantic Forest: Is it possible to conciliate agriculture with ecological restoration?

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A direct consequence of human population growth and the indiscriminate use of natural resources is the reduction of area and the fragmentation of native ecosystems, as they transform into agricultural areas. In this scenario, agroforestry systems (AFS) may be an alternative to reconcile restoration, conservation, and local agricultural production. However, there is a diversity of AFS, and its use as a forest restoration strategy is still uncertain, mainly because of a lack of ecological evaluations. Thus, we compared ecological indicators between coffee agroforestry systems, conventional restoration plantings, and reference ecosystems at Pontal do Paranapanema. For this, we analyzed mean values of natural regeneration density and richness; canopy cover and aboveground biomass at the sites. Aiming to understand the factors influencing the ecological indicators of forest restoration in coffee AFS, we performed generalized linear models using density of coffee and native trees, biomass, percentage of animal-dispersed trees, distance to the nearest forest remnant and richness of tree species as predictor variables, and percentage of canopy cover, density and richness of natural regeneration as response variables. The reference forests had the highest values for forest structure indicators, followed by AFS and finally by the conventional restoration. However, we found a greater diversity of tree species planted in the AFS and a natural regeneration similar to that found in the reference ecosystems. Despite coffee density in the AFS negatively influencing natural regeneration, the coffee AFS had greater ecological performance than the conventional restoration, being a viable alternative for forest restoration at tropical regions.

Stakeholder engagement strategy for sustainable land use in protected areas: A case study in Khustai National Park, Mongolia

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Mongolia currently has 99 protected areas that include different ecological and natural zones, a unique landscape or ecosystem, and provide habitat for rare and endangered species. There are problems such as off-roading and livestock grazing in the protected areas, leading to land use arguments between communities, local authorities, and administrators of protected areas. The aim of this research was to address these problems by investigating stakeholders’ collaboration and developing an engagement strategy in the Khustai National Park. The research utilised both quantitative and qualitative methods. Eleven key stakeholders were identified in four categories including civil society, non-governmental organization, governmental organization, and the private sector, using the stakeholder analysis. Herders and locals who are using land as pasture have a low influence on decision-making while local government has a high influence based on its mandate to give land to residents, but it has little interest in conservation and sustainable land use in the park. The main land use issue in the park was identified as rangeland degradation due
to the increasing number of migrating herders who settled near the park with livestock. Also, most conflicts between locals and the park administration are related to herding livestock in the core zone where wild animals graze. The study also showed that when designing the stakeholder engagement plan for the park the locals’ interest, differences between generations, and developing an ownership attitude for migrating herders are important. Based on the information gathered from the findings, an engagement plan for the national park was created.

**Strong patterns of intraspecific variation and local adaptation in plants of the Great Basin, USA, revealed through a review of 75 years of experiments**

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Variation in natural selection across heterogeneous landscapes often produces: 1) among-population differences in phenotypic traits, 2) trait-by-environment associations, and 3) higher fitness of local populations. Using a broad literature review of common garden studies published between 1941 and 2017, we documented the commonness of these three signatures in plants native to North America’s Great Basin, an area of extensive restoration and revegetation efforts, and asked which traits and environmental variables were involved. We also asked, independent of geographic distance, whether populations from more similar environments had more similar traits. From 327 experiments testing 121 taxa in 170 studies, we found 95.1% of 305 experiments reported among-population differences, and 81.4% of 161 experiments reported trait-by-environment associations. Locals showed greater survival in 67% of 24 reciprocal experiments that reported survival, and higher fitness in 90% of 10 reciprocal experiments that reported reproductive output. A meta-analysis on a subset of studies found that variation in eight commonly-measured traits was associated with mean annual precipitation and mean annual temperature at the source location, with notably strong relationships for flowering phenology, leaf size, and survival, among others. Although the Great Basin is sometimes perceived as a region of homogeneous ecosystems, our results demonstrate widespread habitat-related population differentiation and local adaptation. Locally-sourced plants likely harbor adaptations at rates and magnitudes that are immediately relevant to restoration success, and our results suggest that certain key traits and environmental variables should be prioritized in future assessments of plants in this region.

**Narratives across scales on barriers and strategies for upscaling forest restoration**

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Several countries worldwide have committed to forest and landscape restoration (FLR) through ambitious pledges. As the implementation of these commitments happens within countries, different actors from the global to the local scales need to negotiate the “what, where, and how” of specific forest restoration projects. We summarized barriers and strategies from current global literature on FLR. We present a description of the narratives
of different actors at national, state, and local scales regarding barriers and strategies for upscaling forest restoration in four Brazilian Atlantic Forests and compare observed narratives with those that prevail in the global literature on FLR. We based our results on three discourses commonly used in environmental policy arenas: ecological modernization, advocating market solutions, and green governmentality. We found similar narratives across scales that signal shared implementation strategies, but also differences that indicate conflicting aspects. An ecological modernization narrative prevailed in the narratives on barriers and strategies for all actors from the global to the local scales. However, national actors mirrored narratives used in the global literature that emphasize capacity building, within a green governmentality narrative, and the need of articulated governance arrangements to upscale forest restorative actions. These narratives appeared less at state scales and were almost absent at local scales. Similar narratives across all actors and scales indicate that productive restorative interventions, such as biodiverse agroforestry systems, may be successful for upscaling forest restoration. However, discrepant narratives show the need of inclusive governance spaces where the negotiation of FLR interventions can take place.

Can a seashore environment maintain long-term soil seed banks?

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Seashore environments are sometimes neglected by restoration programs as a source of biodiversity that can be largely affected by global warming, anthropogenic occupation, and salinity. Sandy soils and temperature fluctuations represent challenges for natural restoration by seeds and seedlings. However, we have scarce information about long-term soil seed banks in seashore environments. We investigated the longevity of seashore seeds in soil. Fruits of Allagoptera arenaria, Chaetocarpus myrsinites, Manilkara subsericea, Scaevola plumieri, and Coleocephalocereus fluminensis were collected at a Brazilian seashore, “restinga”, at Parque Estadual Paulo César Vinha in Guarapari, Brazil. Seeds were tested in the laboratory to verify germination percentage at 15, 20, 25, 30, 35, 40 and alternating 30/20 °C, 12 h photoperiod. The experiment was evaluated for 60 days. Other seeds was used for field experiments. We buried 20 bags of each species containing 100 seeds to test in situ longevity. The bags and sensors of humidity and temperature were buried in “restinga” soil at a 5 cm depth, close to the place of fruit collection. Bags of each species were retrieved every 3 months. In the laboratory, only A. arenaria and C. fluminensis exhibited germination at all temperatures tested. C. myrsinites, M. subsericea, and S. plumieri seeds did not germinate. Ninety days after burial, all species showed high germination in the field, except for C. fluminensis, which is dependent on light to germinate. We conclude that natural regeneration of “restinga” is dependent on seed germination and soil seed banks are not easily found there.

Targeted predation: Why habitat specialisation by the endangered Western Spiny-tailed Skink is a threatening process

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Understanding predator-prey interactions at a proposed translocation site is critical to ensure population persistence. Many Australian mainland translocations have failed in the past due to predators preying on vulnerable relocated populations. However, directly observing predation on small vertebrate fauna, such as the Western Spiny-tailed Skink (Egernia stokesii badia), can be difficult in a field setting. One solution that has a relatively long history of success is the use of clay models to understand how predators interact with the target prey. Clay replica models of E. s. badia, the only lizard of its size class at the study site, were placed at habitat sites (log piles) and non-habitat sites (no log piles) to
understand if predators actively target log piles to forage. Clay models were also placed at sites to imitate basking, foraging, and dispersing (on open ground) to determine which of these activities are potentially the most dangerous for skinks to undertake. Understanding these predator-prey interactions is critical to determine pre-release predator control, and what habitat characteristics such as the number of predator refuges and density of surrounding vegetation is important to ensure persistence at a log pile site post-translocation.

The strategic vested interest of the tourism sector in ecological restoration

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South Africa’s Tourism Sector is a vehicle for sustainable development. However, stressed and degraded ecosystems undermine current and future tourism developments. This poster presents two case studies highlighting links between aquatic ecosystems and tourism: a) Water quality and quantity in the uMsunduzi/uMngeni River system (in KwaZulu-Natal) and the implications for the Dusi Canoe Marathon - The event generates substantial direct economic impact, but this has declined over the past decade. Race participants identified the need to address poor water quality (leading to health issues) and fluctuating water levels as key issues to retaining existing and attracting new paddlers; b) Water quality in Loskop Dam (located on the Olifants River in Mpumalanga) and the implications for recreational fishing - recreational fishing is a significant tourism attraction. However, there is evidence that deteriorating quality of water entering the Dam associated with upstream industry and land use is linked to declining fish health and die-offs. This has a significant influence on the sustainability of recreational fishing and the economic viability of associated tourism operations. The tourism sector has a vested interest in the restoration of degraded ecological infrastructure. Ecological degradation at a catchment scale presents a threat to localized tourism activities that cannot adequately be addressed through restoration activities at a local level alone. However, given the importance of tourism to economic development, the sector has the potential to strategically influence decision making, financing, and investment in ecological restoration at a meaningful and effective scale.

Continuity is key: Riparian restoration should focus on length of forest buffers rather than width in order to conserve tropical river water quality

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In degraded landscapes with ever-intensifying competing human and environmental interests, restoration efforts must be as efficient and effective as possible. Restoring and conserving riparian forest buffers offer a myriad of ecological and social benefits, because riparian forests not only protect water quality and aquatic biodiversity, but also serve as biological corridors for terrestrial fauna and protect coastal resources. Although riparian zones are one of the most degraded and desired ecosystems in the world, there is no consensus in the literature about the minimum riparian buffer sizes to maintain river ecosystem functioning and water quality. This question is even more important and
unresolved in the tropics, as we showed by conducting the first literature review of Neotropical riparian buffer size effectiveness. Hence, we tested the most efficient sizes of riparian zones to be protected by ecological restoration and legislation, in order to maintain high river water quality. We did this in the Osa Peninsula, Costa Rica, an understudied hotspot of biodiversity, which hosts an extensive freshwater system. Physiochemical analysis, socioenvironmental variables, and land use classifications in nine different riparian buffer sizes were collected through field work and remote sensing at 194 points. Results indicate that the length of riparian forests have a larger effect on water quality than width, suggesting that riparian restoration should prioritize forest continuity over large widths. Effective river restoration efforts and policy must extend beyond single river reaches and consider the entire length of the ecosystem to foster resilient ecosystems, drinkable waters, and healthy communities.

**Soil quality is a good indicator for measuring restoration success**

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Restoration ecology provides a framework for developing strategies to rebuild the ecological processes lost in environmental degradation. On an extensive cattle ranch with low economic income in Brazil, owners chose to implement ecological restoration in selected areas. We verified variations in soil quality for four types of land use: Pasture in Use (Pu) (Cows Grazing), Passive Restoration (Pr) (Abandoned Pasture), Active Restoration (Ar) (Planting of Trees) and Forest (Fo) (Fragment of Atlantic Forest) using the General Indicator of Soil Quality (GISQ). The GISQ has a range of 0.1 to 1.0 with 1.0 being better quality and 0.1 worse quality. Chemical, physical, and biological attributes of soil collected in the superficial layer from 0 to 10 cm were used. The results show the classification: Fo (0.7), Ar (0.6), Pr (0.5) and Pu (0.3). The Forest is providing the important ecosystem service of soil quality, while on the other hand, for the Pasture in Use, ecological processes are being lost as soil quality is low. With some types of management or interventions such as planting trees or the simple abandonment of the area, the ecological processes act, modifying physical and biological attributes that contribute to an increase in the quality of the soil as a whole. Monitoring the soil quality of this degraded situation as it recovers to a non-degraded situation is a way to obtain data that show not only the success of the ecological restoration but also are a way of measuring the return of ecological processes.

**Hurricane impacts on top-down control of plant recovery in an estuarine salt marsh**

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Under climate warming, extreme climate events, such as hurricanes, are becoming more and more frequent. The impacts of these extreme climate events on recovery of degraded ecosystems, however, remain poorly understood. We investigated the impacts of grazing crabs on plant recovery in a salt marsh in the Yangtze River Estuary before and after a hurricane. The salt marsh was dominated by the native sedge Scirpus maritomer before widespread Spartina alterniflora invasion occurred nearly 20 years ago. Spartina was recently eradicated, but native vegetation has not recovered. We conducted a Scirpus planting and crab exclusion experiment at three different elevations in the salt marsh, and monitored the performance of planted Scirpus in crab exclusion and control treatments before and after a hurricane that landed in the estuary. Our results showed that before the hurricane, while planted Scirpus all survived in crab exclusion treatments, those in control treatments were nearly completely eliminated by crab grazing. This effect of crab grazing on Scirpus survival was apparent across all three different elevations. After the hurricane,
however, regardless of crab exclusion treatments, Scirpus rapidly increased in density and tended to colonize nearby unvegetated bare flats. Differences in Scirpus performance between crab exclusion and control treatments waned with time, especially in the high elevation. Limited top-down control by crabs following the hurricane was likely due to decreased crab density. These results provide rare empirical evidence for how hurricanes can impact a recovering ecosystem by affecting top-down control.

**Ecological restoration in Chile: Experiences and challenges**

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In recent decades, Ecological Restoration (ER) is being increasingly valued worldwide to recover degraded lands. Chile has not been unaware of this process. The main reasons for degradation in Chile are land use change and destruction of unique ecosystems characterized by their endemism. This work reviews the state of the art of Ecological Restoration (ER) in Chile, showing experiences of recent decades and future challenges. There are registered around 120 experiences in the country, implemented through research projects, NGOs, companies, and government entities. As a result of the mega-fires in the 2017-2018 season, around 50 new experiences were implemented. Most of them are small-scale and short-term projects and there are few cases where initiatives involved communities and cultural values are respected. Restoration at a landscape scale is still incipient. In this context and in accordance with international commitments, ER in Chile is being incorporated into current strategies, plans, and policies to address degradation. Governmental institutions are recently leading the process of formulating a National Restoration Plan. This process seeks to generate broad agreement from public and private alliances in a long-term and landscape-scale approach. Nevertheless several bottlenecks are identified to achieving these objectives. In this scenario, ecological restoration has a central role to contribute in this process and to improve the quality of human life in a climate change scenario.

**Priority areas for the restoration of native forests in Argentinian drylands**

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The drastic climatic conditions combined with an indiscriminate exploitation of forest resources from Argentinian dry lands has led to increasing desertification in these areas. As a part of the National Program for the Restoration of Degraded Native Forests, we identified priority areas to restore two large arid ecoregions in Argentina, the Monte Desert and the Espinal. We made a thorough assessment of several physical, biological, and anthropic indicators integrated in the field of geographic information systems and remote sensing with Multi-criteria Decision Analysis -specifically with Analytic Hierarchy Methods-. The criteria used were: native forest land management, number of management and conservation plans per river basin, drainage density, slope, trend of net primary productivity 2001-2017, influence area of human settlements and road network, 2000-2017 fire occurrence, livestock density, and land use, land cover changes, and soil carbon stock changes. We also analyzed the feasibility of implementing active and passive restoration practices in each area. As such, we obtained seven major priority areas for restoration (1.7 M ha). The Argentinian government used the defined priority areas to the call for restoration projects of native forests, which are currently under execution.
Prevalence of acquisitive root traits in a neotropical savanna 2 years after restoration suggests rapid soil C accumulation trajectory

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The Cerrado is a threatened biome with less than 30% of its original vegetation left. Restoration practices are challenging because exotic invasive species tend to outcompete slow-growing native species. Root stocks in Cerrado soils are important to maintain ecosystem functions such as carbon storage. We aimed to investigate how the restoration of fine root biomass stock occurs in a 2-year-old savanna restoration project. We measured fine root biomass, root diameter, and specific root length (SRL) in a savanna restoration site. We undertook the same measurements in two reference ecosystems, a native cerrado and an abandoned pasture dominated by exotic species. We found 2.3 Mg.ha⁻¹ of fine root biomass stock the restoration site compared to 5.0 and 9.8 Mg.ha⁻¹ respectively for the abandoned pasture and the native area. Furthermore, only 31% of the total fine root biomass was found in the top 10 cm in the restoration site, compared to 43% and 49% respectively to the abandoned pasture and native site. The restoration site also had plants with more acquisitive root traits, indicated by higher SRL and lower average root diameter compared to native and abandoned pasture. This study demonstrates that in the early stages of savanna restoration fine roots stock biomass has only returned to 25% relative to native vegetation and still remains 50% lower than in non-restored areas. However, the prevalence of acquisitive root strategies in restored areas suggests that rapid C accumulation is likely in the future and that they may be able to outcompete exotic invasive species.

The story of the Mosselbank River Conservation Team: Community involvement as a key to restoration success of the Eastern Tributary of the Mosselbank River

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The Eastern Tributary of the Mosselbank River, identified as a sensitive conservation area, is currently in phase one of rehabilitation. The river dissects a new Garden Cities development, Greenville, and is an essential urban river and water resource. However, the conservation area is not fenced as Garden Cities would like the community to enjoy and engage with their natural resources through educating the local community about the importance of preserving their local resources. We therefore established the Mosselbank River Conservation Team (MRCT) in 2017 to help achieve this. The team consists of local volunteers in the area that have a passion for their environment and for community development. They have no previous knowledge or experience in conservation and Garden Cities is in the process of developing their skill in environmental management so that they are able to be custodians of the river long after the developer has left the area. Currently, the MRCT assist in maintaining the river by cleaning up illegal dumping hot spots, doing litter runs, alien clearing, weeding, planting, and translocating plants. Furthermore, they assist in community clean-ups, environmental events, and workshops. It is essential to involve the community in the rehabilitation process to get their full support and buy-in in the community project. By utilising existing community leaders to educate the community, trust and ownership are installed in the residents. By installing a sense of caring, the MRCT is building a community of future green leaders and environmentalist to protect the critical wetlands in the area.
The economic risks associated with declining water quality as a result of rapid urbanisation and climate change: Berg and Breede River case study

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Urbanisation and climate change are likely two of the most defining occurrences of the 20th and 21st centuries. Urbanisation is often linked to the degradation of environmental quality, including quality of water, air and noise. Concurrently, due to anthropogenic impacts, including the effects of urbanisation and agriculture on climate systems, the climate and catchments are changing. Together, the negative impacts of climate change, catchment degradation and urbanisation pose significant challenges, especially in developing countries where resources to mitigate these impacts are limited. Focusing on the Berg and Breede River catchments in South Africa, this paper explores the increasing water quality risks due to climate change, catchment degradation and rapid urban development and the likely economic impacts that this will have on the agriculture sector, which is a key contributor to the regional and national economy, given that it is also an important contributor to export goods from South Africa. This paper also explores the risks associated with failing wastewater treatment works and discusses possible solutions to addressing these challenges within a developing country context, including investments in ecological infrastructure. While using the Berg and Breede River catchments as a case study, the findings from this research are applicable globally as many other catchments are facing similar challenges, particularly in relation to lessons learnt from the Cape Town water crisis.

Bio-auditing of topsoil health in mine site restoration

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Topsoil is a scarce and highly valuable resource in post-mining rehabilitation. However, the mining industry often has insufficient understanding or inadequate tools to assess the impact of topsoil storage methods on vitality of topsoil as a restoration resource. A key component of topsoil health is ensuring a competent microbial community, but soil functionality in restored soils has been found to be non-comparable to that of undisturbed native soils. Research is necessary to understand and manage the constraints imposed by inefficient topsoil storage in order to improve existing restoration practices. This study aims to determine how the diversity, abundance, and activity of soil microbes (fungi and bacteria) contained within stockpiled topsoil is influenced by factors such as storage time, for different regions and commodity types in mining provinces of Western Australia. Topsoil was collected from stockpiles and reference sites from seven mine sites (from the Pilbara to the South West) encompassing major commodity types (iron ore, nickel, bauxite, coal, and mineral sands). The chemical properties of each sample were determined, microbial respiration measured (Solvita one-day CO₂ test), and microbial composition elucidated through sequencing (16S and ITS), while an investigation into plant growth in each of the soils is currently underway. This study will contribute to the development of a science-based topsoil management tool to inform resource companies and restoration practitioners in design and management of effective topsoil storage strategies that maintain topsoil function for improved restoration outcomes.
When does grass invasion overcome the threshold of plant species loss in the Cerrado? Insights for restoration

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Tropical savannas are systems characterized by complex state-and-transition dynamics that are crucial to inform restoration interventions. Invasive grasses can alter savanna properties from individual to ecosystem levels, causing modifications in fire regimes, acting, therefore, as a strong force moving the ecosystem from a desirable state to another that is undesirable. Ecological restoration of an invaded ecosystem is more viable and likely successful when the ecosystem is still resilient, before transitioning to a stable degraded state. We investigated if native-species loss due to invasion by the African grass Urochloa brizantha in Cerrado vegetation is gradual or if a threshold exists, characterizing the transition between states. We established six plots (3 x 3 m) for each level of ground cover by the invasive species (0, 25, 50, 75 and 100%; 30 plots in total) and assessed native-plant richness and invasive-species cover within 1 m$^2$ subplots. We used generalized additive models (GAM) to demonstrate the negative relationship between ground cover by U. brizantha (live, dead, and total) and native-species richness. We found evidence of a negative tri- and bi-phase relationship, indicating a threshold at around 25 and 60% live cover or 35% dead cover of the invasive species. After these “red lines”, native-species loss is abrupt, and simply eradicating the invader may be not enough to recover the native plant community. Therefore, live and dead cover of the invasive species could be monitored and used as an indicator for the implementation of restoration efforts in these invaded ecosystems.

A new device for promoting the restoration of deep-sea habitats through species recruitment on artificial substrates

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Deep-sea habitats can be subjected to a several anthropogenic impacts that can cause habitat loss and reduction of biodiversity. Here we present a new device to facilitate the restoration of deep-sea degraded habitats based on the use of artificial substrates. The Artificial structures for deep-sea species Recruitment and ecosystem restoration (ASDER) are designed with a triangular-based structure (1m x 1m x 1m) that is the support for anchoring 3 Autonomous Reef Monitoring Structures (ARMS), which are cubic long-term collecting structures designed to mimic the structural complexity of three-dimensional habitats and attract colonizing invertebrates. The device can be easily deployed in different deep-sea habitats at different depths. The system is highly complex in terms of 3D structure and can be completely disassembled, thus allowing the recruitment of benthic organisms that have different habitat suitability. Once the ASDER is colonized by organisms (we expected that 6-12 months are sufficient), these video-monitored structures can be transferred to degraded areas and fixed to hard substrates in order to promote a faster recolonization of benthic organisms. The ASDERs are potentially useful and low-cost devices enabling promotion of active restoration initiatives in deep-sea ecosystems, which are expected to have very high costs. The test of the efficacy of this new devise has been carried out in the Dohrn Canyon (Tyrrenian Sea, Central Mediterranean). The pilot restoration study based on this devise is carried in the framework of the H2020 MERCES (Marine Ecosystem Restoration in Changing European Seas) project.
Deep-sea habitats can be subjected to a several anthropogenic impacts that can cause the reduction of overall biodiversity. This is particularly evident for deep-sea sites (i.e., canyons, open slopes, seamounts and cold-water corals) located in front of densely populated coastal areas. Here we present a new device to facilitate the restoration of deep-sea degraded habitats based on the use of artificial substrates. A triangular-based structure \((1m \times 1m \times 1m)\) is the support for anchoring different (1-3 units) Autonomous Reef Monitoring Structures (ARMS). ARMS are a small, cubic and long-term collecting device designed to mimic the structural complexity of three-dimensional habitats and attract colonizing invertebrates. The overall device can easily be deployed in different deep-sea habitats at different depths using a small/medium research vessel. Once these Autonomous Reef Monitoring Structures are colonized by organisms (after 6-12 months), these ARMS can be transferred to degraded areas characterized by low diversity to favor the recolonization of benthic organisms. These ARMS can be a useful low-cost device to support restoration initiatives in deep-sea ecosystems. The test of the efficacy of this new devise has been carried out in the Dohrn canyon, located in front of the City of Naples (Tyrrhenian Sea, Central Mediterranean). The pilot study of restoration based on this devise is carried in the framework of the H2020 MERCES (Marine Ecosystem Restoration in Changing European Seas) project.

The social aspects relevant to rural family integration with landscape restoration in the Mucuri Valley, Brazil

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Conservation and recovery of vegetation in spring surroundings are extremely important actions to guarantee the water bodies perpetuity in places with a range of degradation factors. Although accuracy of landscape restoration techniques is undeniably important, social aspects involved within working in social at-risk areas are highly relevant in order to perpetuate those actions. Within this perspective, rural extension agents of the Nascentes do Mucuri Project operate in the Mucuri Valley region, north of the Minas Gerais state, Brazil, in order to understand the experiences of rural families who suffer with drought events, and redesign the landscape restoration practices already known, adapting them to different realities, seeking to build a concrete environmental awareness parallel to water resources conservation. In order to better understand land use history and water-related problems faced in the field, firstly the extensionists develop a diagnosis during an informal conversation, listening to the rural population troubles. They are then able to characterize farmers and farms environmental and social conditions. Secondly, the team explains details about the project and legal requirements on permanent preservation areas and, with the farmers, they carry out a demarcation of areas to be protected, in a process of knowledge construction regarding productive reality and high relevance to mitigation of degradation factors. The great receptivity to the Project makes clear the importance of sociological and anthropological aspects to be associated with landscapes restoration in places of social risk.

Responses of bird communities to forest restoration in the eastern Brazilian Amazon

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Land use changes have modified the natural landscape in the Amazon rainforest, resulting in losses of biodiversity and affecting the functioning of ecosystems. Due to this reality,
some reforestation methods have been proposed and tested in degraded areas with the aim of reversing such environmental damage. In this study we evaluate the efficiency of three forest restoration methods to maintain bird community diversity. To accomplish this, we used taxonomic and functional approaches to measure diversity of birds. The study was conducted in a post-mining bauxite reforestation (until 8 years of age) and in preserved forest fragments located in Eastern Amazon, Brazil. We carried out bird counts in areas of forest remnants and under recovery processes by natural regeneration, traditional planting and nucleation. We found that bird communities showed greater species richness and functional diversity in forest fragments than in restoration areas. Among the restoration methods, nucleation presented the lowest species richness. However, species composition and functional diversity did not differ between methods. We conclude that the three recovery strategies evaluated showed a similar efficiency in bird community recovery within the analyzed period. In addition, diversity patterns of bird communities in the recovering areas were far from those found in forest fragments, indicating the need to monitor and maintain the long-term restoration and recovery programs.

**Framework underpinning procedures for canopy-forming brown algae restoration in Mediterranean ecosystems in a global change scenario**

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The restoration of canopy-forming brown algae is a new, rather unexplored, discipline in Mediterranean coastal ecosystems (6 documented studies). In this biogeographic region the genus Cystoseira plays, as marine kelp forests, a key role as an ecosystem engineer. Rapid environmental changes and extreme climatic events are causing unpredictable phenological shifts in these foundation species, leading to their regression or loss. The natural recovery is hampered by their limited egg and zygote dispersal. To implement large-scale actions, regulatory frameworks and practice standards are urgently required. Three restoration techniques have been implemented for Cystoseira species so far: i) transplanting juveniles or adults, ii) positioning fertile receptacles in the target area, iii) outplanting along the shore juveniles cultured in the nurseries. We propose an operational work-flow for optimizing: i) prioritization of restoration sites, ii) selection of donor sites and fertile material collection, iii) embryo culturing in the nurseries, iv) juvenile transport to the receiving sites and attachment on the rocky shore, according to bottom features and water depth, v) monitoring the restoration success. The aim is to maximize beneficial outcomes while minimizing costs in terms of time and resource allocation. Financial investments and stakeholder and community engagement, to change the awareness towards macroalgae and their role, are mandatory to achieve substantial restoration goals in marine ecosystems.

**Ecological niche modeling for prediction of conservation areas and extraction of umbu (Spondias tuberosa Arruda)**

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Forest resource management is important for extractive communities to enforce forest management in biomes of high bioclimatic sensitivity and endemic species, such as the Spondias tuberosa (Umbu), because of its resistance to drought. We analyzed the spatial distribution of S. tuberosa in the semi-arid region of northeastern Brazil to define priority areas for conservation and species of high extractive potential by applying Ecological Nicho Modeling (ENM). We used 23 bioclimatic and topographic variables and field data of spatial of that species. We selected 7 variables of higher effect on its spatial occurrence in the study region. The ENM was applied with the maxent software and the bootstrap technique. Two thresholds were used for defining conservation and extractive areas. The study results
indicate that the bioclimatic variables were considered the high explanation variables for the species spatial distribution, which evidence the effects of climate on the occurrence of that species. The most fragmented regions are the highest risk and susceptibility for that species, which are considered higher priority for conservation. Although the entire territory studied showed high extractive potential, it is necessary to improve the management of that species in agropastoral areas to enable the development of the species descendants. The lack of management of endemic species may result in irreversible consequences to the environment, fauna, and communities that depend on that species. The ENM may be used to improve public policies for the socio-economic development of the extractive communities and forest management in the study region.

Effects of root cutting on reproductive strategies of Leymus chinensis in the meadow steppe of northeast China

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This study aims to explore the vegetation restoration method of root-cutting for improvement of degraded Leymus chinensis grassland. Root-cutting treatments with spacing of 10 cm, 20 cm and 30 cm were carried out during the early, middle, late stages of the vegetative growth period for L. chinensis. So as to compare and analyze the sexual and asexual reproduction of L. chinensis, we studied these effects on population dynamics of L. chinensis: leaf, stem, spike, rhizome biomass, nutrient element content (total N, total P), energy accumulation, resource allocation, and reproductive allocation, thus providing a theoretical basis for the scientific management of L. chinensis grassland. The research results are as follows: When the spacing of the root cutting was 10 cm, the sexual reproduction of L. chinensis was inhibited, and its asexual propagation was promoted. When root cutting spacing was 30 cm, it not only promoted the asexual reproduction but also promoted the sexual reproduction of L. chinensis. Therefore, considering the effects of root cutting on the sexual and asexual reproduction of L. chinensis and the reproductive allocation of spikes, limited environmental resources will significantly increase the proportion of asexual reproduction, and it also decreases the proportion of sexual reproduction in meadow steppe. It is possible that the favorable environment promoted the sexual reproduction while an unfavorable environment promoted asexual reproduction and clonal plants are more dependent on asexual reproduction because sexual reproduction is more costly than asexual reproduction.

Key areas for Brazil's Atlantic Forest restoration considering groundwater recharge improvement

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In Brazil, groundwater is increasingly used to supply urban centers, industries, irrigation, and agriculture. Groundwater recharge is determined by a combination of variables such as soil type and management, vegetation cover, topography, and climate. Forest restoration can increase water infiltration and percolation, thus improving groundwater recharge. To guide policymaker decisions, it is necessary to establish priorities areas to be restored in the Atlantic Forest, a very degraded and the most populated biome in the country. Here we developed a spatially explicit index of groundwater recharge (GR) based on six parameters: land use, soil drainage, relief, slope, pluviosity, and rain seasonality. We calculated the GR index to the Atlantic Forest using thematic maps of these six parameters, which were reclassified, and each class was given a different weight ranging from 1 to 7 according to its recharge capacity. All maps were converted to raster format and
resampled to achieve 1 km² resolution. The layers were then multiplied so we could obtain the GR index per pixel. In addition, we simulated the restoration of all the restorable areas within the Atlantic Forest (replacing agriculture and pasturelands with forests) and calculated the GR index again. We compared both scenarios (current and “restored”) to identify areas where forest restoration most improved groundwater recharge. We found that the Paraná River basin was the hydrographic region most benefited in the biome. Our results highlight the importance of spatial planning and help decision makers to define priority key areas to be restored, seeking improvement of water provisioning.

The need for a holistic approach to river restoration exemplified with multiple stressors affecting brown trout (Salmo trutta) in temperate and boreal streams

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Riverine ecosystems are affected by interactive anthropogenic pressures, not least climate change. Rivers have complex structures, interspersed with lakes and fragmented by human constructions (e.g. dams). This challenges predictions on species responses to anthropogenic stressors, as well as the success of local in-stream restoration efforts. The aim of this study was to evaluate how brown trout (Salmo trutta) responds to multiple stressors in the context of the river network. We used 12000 electrofishing records from 283 streams across Sweden to investigate interactive effects on trout of anthropogenic stressors (land-use, number of dams, volume of regulated water, degree of water regulation), climate (July air temperatures and annual precipitation from 1961-1990), site position (Strahler order, distance from mouth and source, and from lakes), and number of lakes in the upstream catchment. We found that a high density of dams at the catchment level had stronger negative effects on trout at sites downstream and closer to lakes. Agricultural land decreased trout abundance downstream and in catchments with many lakes or urban areas. Warmer climates negatively affected trout but only in catchments with high volumes of regulated water. Our results indicate that multiple stressors act on brown trout, highlighting the need for holistic restoration efforts at the catchment scale. Measures that eliminate dams and decrease effects of agricultural land use will help rehabilitation of trout and benefit sites downstream in areas with many lakes and urban areas. Decreasing the volume of regulated water could also mitigate the negative effects of climate change.

Resilience of plant-soil systems in revegetated grassland along a temporal gradient in the Three-River headwater area of the Qinghai-Tibetan Plateau

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Resilience is crucial to promote ecosystem sustainability and maintain ecosystem functions and services. Clarifying variation in resilience can provide a foundational theory for the management of degraded ecosystems. Grassland cultivation is generally used to restore extensively distributed “Black Beach”, severely degraded alpine meadows on the Qinghai-Tibetan Plateau (QTP). In this study, we surveyed the revegetated grasslands on the QTP at different restoration times: 4, 6, 9, 12, 13, 14, 16, and 18 years post-restoration using a chronosequence approach with the aim of identifying the resilience of the
revegetated grasslands from the perspectives of plant and soil quality. We treated “Black Beach” as the baseline for restoration, and non-degraded healthy alpine meadow as the target for the restoration. We used the MDS method to identify the appropriate indicators and created an integrated assessment system that quantified the resilience of plant, soil, and plant-soil systems of the revegetated grasslands at different recovery years. The results showed that a non-linear resilience of revegetated grasslands was identified for the plant, soil, and plant-soil systems along the temporal gradients. Asynchrony existed between the resilience of soil and that of the plants along the temporal gradients. From the perspectives of plant, soil, and plant-soil systems, the recovery time of severely degraded grassland is at least 16-18 years to reach a relatively stable state. Revegetated grassland can be used as an effective restoration approach to improve the quality and resilience of plant and soil in the severely degraded alpine meadow on the QTP.

Buzz or silence: Do pollinators return after invasive alien plant clearing and restoration in Cape fynbos?

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Restoration activities can restore vegetation structure, but the extent to which ecosystem functioning recovers post-clearing are largely unknown, particularly in fynbos. Pollination Network (PN) studies have greatly contributed to the advancement of pollination ecology and more recently, the inclusion of invasive alien species in these PNs have allowed the assessment of community-wide changes with invasions. Global reviews suggest that Invasive Alien Plants (IAPs) transform native PNs. But does this effect remain after IAP removal? Numerous restoration studies have been conducted in South Africa, but none focusing on pollinators and their recovery. We will present data on flower visitation, seed set, breeding system experiments, and network-level metrics that will provide information on how pollinator communities respond to the removal of alien invasive trees, and the extent to which active and passive restoration influence pollinator network rewiring.

PermaReGEN – Bridging the community towards socioecological regeneration

Alice Dubuisson
World Citizen, Duranus, France

The UN Decade on Ecosystem Restoration aims to mobilise political support, scientific research, and financial muscle towards upscaling ecological restoration. Yet, restoring ecosystem integrity requires more than widespread ecological restoration alone, it necessitates the synchronized renewal of our socioeconomic interaction with nature. Timeframes, complexity, and scale behind the challenge urge the participation of all. Permaculture can help trigger this socioeconomic shift, all the while contributing to the regeneration of degraded ecosystems. Through systems-thinking design and the integration of processes/principles found in nature, Permaculture creates holistic living settlements that are highly productive, ingeniously conducive to self-sufficiency, locally enriching, symbiotic with their regional environment, and therefore permanently sustainable for all parties within the socioecological dynamic. Rising from a grassroots initiative, Permaculture is proliferating across local pockets worldwide - inspiring and converting growing numbers of people along the way. Affordable, community-based, and applicable globally, Permaculture is already engaging the missing gear needed to propel our restorative mission forward - the everyday person. The synergistic potential of upscaling both Permaculture and ecological-restoration in partnership on our crucial and colossal mission to restore ecosystem integrity is vast. PermaReGEN is a prototype proposal to develop this partnership. Its operational framework would be built on multidisciplinary cooperation, living networks, and strategic ecological roadmaps. Its aim is to bridge and
build community capacity up to the challenge. Its vision is to elevate global effort beyond ecosystem restoration, evolving into socioecological regeneration. This is an opportunity to turn a global problem into a source of solutions.

**Connecting to local mycorrhizal communities: Direct seeded plants have an advantage over tube-stock plants**

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Revegetation is a key activity in many ecological restoration projects. Commonly used revegetation techniques involve planting nursery-grown plants or sowing seed directly on site. However, the role of below-ground processes and agents in facilitating successful revegetation outcomes is often overlooked, even though agents like mycorrhizal fungi are known to enhance plant establishment and growth. Our study investigated whether root colonisation by locally occurring mycorrhizae communities differed between revegetation techniques, and whether such colonisation enhanced revegetation outcomes. We compared colonisation rates and species composition of root fungal communities in direct seeded plants, tube-stock plants and extant vegetation at a riparian site in southeastern Australia, and modeled the relationship between root fungal community attributes and plant size. Results indicated that revegetation technique did influence root colonisation. Fungal species richness and rates of mycorrhizal colonisation were more similar between direct seeded plants and extant vegetation than between tube-stock plants and extant vegetation. Direct seeded plants also harboured a fungal species diversity and community composition that was more similar to extant vegetation than did tube-stock plants. We found positive relationships between plant growth (measured as root collar diameter) and fungal species richness, diversity and compositional similarity to extant vegetation in direct seeded plants but not in tube-stock plants. Connecting effectively to the local mycorrhizal community appears to provide direct seeded plants with a growth advantage over tube-stock plants which are initially colonised by fungal species present in the nursery environment, which may not be locally adapted to the final planting site.

**Significantly different vegetation response to climate variability on post-mining land from unmined land: A case study from China**

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To restore self-sustaining ecosystems on post-mining land (PML), the impacts of climate change should be prudently considered in land reclamation planning. However, it has been commonly neglected that vegetation response to climate variability on PML may be no longer identical with that on adjacent unmined land (AUML) due to permanently changed hydrology regimes. Here, we report a case study of different vegetation responses to climate variability between PML and AUML in Pingshuo mining area, China. The relative contribution of climate variability to variation of vegetation productivity on both PML and AUML are computed with a nonlinear regression model, using climatic data and an enhanced vegetation index derived from Landsat images over 21 years. Results show that climate variability made a much higher relative contribution on PML (19.95% to 46.46%) than the AUML (0.70% to 1.75%). Rainfall and wind speed variability impacted the PML instead of the AUML. Additionally, vegetation on PML recovered much more slowly from extreme weather/climate events (=lower resilience). These differences are likely due to: (1) Changed hydrologic condition and microclimate regime on the PML exerted extra constraints on the vegetation. (2) Environmental stresses left by mining activities jeopardize ecosystem resilience on the PML, causing amplified responses to climate variability.
variability. Our findings highlight the necessity of further research on consequences and mechanism of (possibly) abnormal climate impacts on post-mining ecosystems in different biogeoclimatic zones, which is a key step towards developing effective strategies for coping with the double challenge of post-mining land reclamation and future climate change.

Effects of drought preconditioning on morpho-functional traits and field performance of Senecio subulatus seedlings in the Monte Desert, Argentina

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High quality seedlings are needed to increase the success of restoration projects in drylands. Nursery techniques can help reduce seedling vulnerability to drought and improve field performance. Drought preconditioning has been used in drylands worldwide to improve seedling establishment in drought-prone areas. In this study, we assessed the effect of drought preconditioning on the morphology, biomass partitioning, and non-structural carbohydrate concentration of seedlings of Senecio subulatus, a keystone ruderal species in the Monte Desert, Argentina. We then related morpho-functional traits with field survival and growth after transplanting to a degraded area. We applied two drought preconditioning treatments in the nursery (watered when soil water content decreased by 50% and 80% from field capacity - mild and severe preconditioning respectively) and measured seedling morphology and non-structural carbohydrates at the end of this period. Then, we planted seedlings in a degraded area and monitored survival and growth for one year. Severe preconditioning reduced stem diameter, biomass accumulation, and leaf weight ratio, and had no effect on the shoot-to-root ratio, as compared to milder preconditioning. Furthermore, severe preconditioning increased non-structural carbohydrate concentration in roots and decreased their concentration in shoots. One year after planting, seedling survival was high under both treatments (100%). Stem diameter growth was higher in seedlings under severe drought, and thus, stem growth did not correlate with initial seedling diameter. Drought preconditioning seems to be a suitable technique to improve field performance in S. subulatus in the short term. Further monitoring will confirm if the short-term trends are maintained.

Plant survival success on floating wetlands launched on small farm dams in the Western Cape, South Africa

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Farm dams often act as important stepping stones in the movement of biodiversity across transformed landscapes. Promoting biodiversity at farm dams improves ecological functioning, and exploring such strategies, e.g. floating wetlands, is encouraged. Floating wetlands studies have highlighted their potential to purify wastewater, attract biodiversity, and promote environmental awareness. It is important then to select appropriate plants for these wetlands to optimise their function. This paper investigated plant survival success on floating wetlands on small farm dams in the Western Cape. As plants experience various threats on open farm dams, three field visits were conducted over one year to understand plant survival and growth determinants. Plant survival rate was determined by expressing the number of individual plants that survived between the first and third visit as a percentage of the total number of individuals per species, whilst growth rate was measured using plant height, and expressed as a percentage of the size of the individual
plant at the time of the first and third visit. Visual observations suggested that aquatic birds appeared to be a major threat to plant establishment and survival. Changes in certain water quality parameters (e.g. wastewater type) appeared to be significant determinants of plant survival and growth. Cyperus dives, C. fastigiatus, C. textilis, Juncus effusus and Schoenoplectus scirpoides were recommended for use on floating wetlands in the Western Cape due to their high survival rates. It was also found that floating wetlands attracted other biodiversity, acting as mini-ecosystems in small farm dams all year round.

**Natural revegetation as a restoration tool in post-mining sites across a climatic gradient in the USA**

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In this study, we compared development of soil and soil biota in chronosequences on reclaimed and unreclaimed sites at three post-mining areas along a climatic gradient in the USA. At each site the chronosequence included a young site (5-15 years-old), an older site (20-30 years old), and a climax site. Post-mining sites were either reclaimed according to federal regulations or not reclaimed and recovering naturally. The natural climax vegetation was hardwood forest (Tennessee, Indiana), or shortgrass prairie (Wyoming). Microbial biomass, microbial respiration, ergo sterol, composition of the microbial community (using phospholipid fatty acids), community composition of soil nematodes and macro fauna, soil chemistry, and soil microstructure (using thin soil sections) were studied. The shortgrass prairie soil community was very simple, containing abundant root-feeding organisms, which may establish quicker than the more saprophagous soil biota that were abundant at the other sites. As a consequence, at reclaimed post-mining sites recovery was faster on the dry shortgrass prairie than at the forested sites. However, when we compared unreclaimed sites, the pattern was opposite; development was faster at the forest sites than at the shortgrass prairie. In Tennessee, unreclaimed sites even developed faster than reclaimed ones. This suggests that with suitable climatic conditions we can with advantage rely on natural regrowth, but on a dry site restoration, including transplant of local topsoil, can improve ecosystem development.

**Fish communities in post-mining lakes – towards a functional ecosystem**

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Lignite opencast mining dramatically influenced the natural environment of North-western region of the Czechia. After mining, both the ecological and aesthetic value of the landscape must be re-established. Hydric reclamation is generally considered as economic and natural and hence the proposed way of revitalization. In the Czechia, creation of eight post-mining lakes with an area of hundreds to more than a thousand hectares and the volume of tens to hundreds millions of cubic meters is planned. For aquatic ecosystems of such dimensions, the fish community is an essential component that will evolve either naturally or with the advised or inadvertent help of man. In the case of water quality, fish can play crucial, both positive and negative role, depending on the species composition and abundance/biomass. Creation of a new lake in an abandoned mining site represents a large ecological experiment. Within its course many factors can have a negative impact on water quality, the main indicator of successful reclamation towards the most significant socio-economic future use of the lake – recreation. To assure high quality ecological potential of the post-mining lakes, expert evaluation of the lake ecosystem parameters, followed by complex surveys of fish community development and controlled manipulation of the fish stock are highly recommended. In our presentation, controlled and manipulated succession of fish populations in the Milada Lake (250 ha, 25 m max. depth), Most Lake (310 ha, 25 m max. depth), and Vranice Lake (1000 ha, 20 m max. depth) are presented.
A systemic case study of participation in land and water governance in a former homeland of South Africa

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The South African democratic government's intention to improve participatory resource management, as stipulated in legislative documents such as the National Environmental Management Act of 1998 and the National Water Act of 1998, has not yet been realised. This is a particular problem in the notoriously neglected former homelands of South Africa. The question is: how are individuals able to meaningfully participate in the processes of planning and managing their resources? In trying to answer this question it is important to take note of the existing processes in any specific context. This research used systems thinking (as described in thinking in systems by Donella Meadows, 2008) to model the processes of land and water governance using the Tsitsa River catchment as a case study. These are processes initiated (or neglected) by local municipalities, government departments, NGOs, agencies, traditional leadership councils, as well as civil society organisations. The system was modelled through a desk top study of public participation and community engagement processes; backed up by interviews with stakeholders from across the system. This case study gives an overview of the paths for participation available to rural inhabitants in a variety of sectors.

Forest fires and resin tapping interact to affect subtropical and tropical pine forests

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Tropical and subtropical coniferous forests provide critical ecosystem services but many effects of anthropogenic disturbance factors have not received sufficient scientific attention, despite causing substantial degradation. We studied forest disturbance from fire and resin tapping in India and Indonesia. Using tree-ring methods in a chir pine (Pinus roxburghii) forest of Uttarakhand, India, we developed a multi-century tree-ring chronology and crossdated fire scars from trees at three sites near rural villages. Fires were highly frequent but of low severity, so most mature trees of this thick-barked species survived numerous burns. However, intensive resin tapping interacted with surface fire by allowing fire to burn into the wood of tapped trees, damage the cambium, and weaken the structural integrity to the point of breakage and mortality. In six Pinus merkusii forests of Sumatra, Indonesia, we assessed effects of escaped agricultural fires and fire interactions with resin tapping, which was associated with high mortality. The effects of anthropogenic fire and resin-tapping merit further investigation at landscape to regional scales with attention to developing practical, sustainable restoration strategies. We suggest developing a research network in Himalayan to East Asian coniferous forests to track interacting disturbances and their ecological and social implications.

Using patch structure to assess native suppression of invasion in a Mediterranean grassland

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Restoration plantings are often conducted in aggregated patches to recreate the spatial variety seen in natural vegetation and to create priority effects to allow for species persistence. While aggregated plantings may be more resistant to plant invasion, there
may be pronounced differences between the core and margins of the patch that allow for invasive species to use those margins as spatial refuges. In California annual grasslands, restored native grass patches may suppress invasive grasses that compete for late-season soil moisture. However, we need to know how the spatial dynamics of a patch affect long-term native resistance to invasion. We investigated a) the spatial patterns of invasive grasses in native-planted communities, b) how those spatial patterns interact with natives being given a ‘head start’ of 1 or 2 years, and c) how they are affected by precipitation treatments. Ten-year old experimental grassland plots seeded with natives or invasives under normal, wet, and drought precipitation treatments were allowed to be naturally invaded. Ten years after planting, we assessed plant cover with a spatially explicit composition sampling of the plots (centers vs. edges). Native-planted plots had high native cover, and low invasive grass cover in the edge as well as the core. These results were similar across precipitation treatments and regardless of natives being given one or two years of priority. Aggregate plantings of natives result in priority effects that allow long-term persistence and invasion resistance across a variety of precipitation patterns, and patch spatial dynamics do not create spatial refuges for invaders.

Plant biodiversity in reclaimed mine sites using combinations of reforestation and organic amendment approaches in Quebec, Canada

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Mining activities generate residues during the ore concentration process that result in large tailings impoundments on most mine sites in Quebec, Canada. The guidelines of Quebec's Mining act require minimal revegetation of tailings using grasses or shrubs. It is hypothesized that the reclamation of mine tailings using planted woody species and soil organic amendments could increase vegetation biodiversity, compared to the business-as-usual (BAU) minimal requirements with sown grasses. Split-split-plot experimental designs were established on tailings impoundments at Mont-Wright (iron ore, 52°46'N, 67°20'W) in 2015 and at St-Honoré (niobium, 48°32'N, 71°08'W) in 2012, both within Quebec's boreal forest zone. The objective was to determine among the different reclamation methods – comprising combinations of planted woody species with soil organic amendments (paper mill biosolids, chicken manure, or topsoil) – which one increased most the vegetation biodiversity on both sites, considering their respective climate contexts. Preliminary results show that at St-Honoré's site, amendments application enhanced the percent plant cover (N) and reduced the evenness (J'). Plantation of woody species had no significant effect on the diversity index (S, N, J' and 1-D). At Mont-Wright, the combination of the Norco treatment (mixtures of sown grasses and chicken manure) with topsoil produced the highest values of evenness (J') and diversity (1-D). The different results suggest that combining reforestation with organic amendment methods increases the short term plant biodiversity compared to mine reclamation BAU approaches.

Ecological Restoration of seagrass in the Central Mediterranean Sea: The effect on benthic biodiversity

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Ecosystem engineers play a key role in many coastal systems. Along the European Seas, recent investigations have highlighted a simultaneous and rapid disappearing of ecosystem engineers including seagrass meadows (Zostera spp, Posidonia oceanica), and mussel reefs (Mytilus spp., Pinna nobilis, Serripes spp. and Ostrea spp.). In the framework of the H2020 MERCES (Marine Ecosystem Restoration in Changing European Seas) project, we have improved our knowledge on the performance of restoration practices of the seagrasses, Zostera and Cymodoceaa spp., in the Western Adriatic Sea (Central Mediterranean). This area has been selected as a deputy system where testing interactions
between the transplantation of seagrass (Zostera and Cymodocea spp.) beds and Pinna nobilis, the large endemic bivalve of the Mediterranean Sea. P. nobilis can be considered an ecosystem engineer and plays a key ecological role influencing the faunal biomass and diversity. The area under scrutiny is characterized by the co-occurrence of highly valuable natural resources (bordering a regional Park), seasonal touristic pressures and anthropogenic structures (breakwaters aimed at preserving the beach), whose management has at times involved temporary damage to the seagrass beds. The experiment on the ecological restoration of seagrass started in October 2017 and is actually ongoing. The first results of this study suggest that high efficiency of the new restoration methods applied in the study area with an increasing of seagrass density up to 80% after 5 months from the transplanting and positive effects of the presence of the P. nobilis on benthic biodiversity attracting rare taxa.

Natural populations and cultivars of Elymus trachycaulus (Slender wheatgrass) respond uniquely to environmental stress

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Rangeland ecosystems are highly susceptible to land degradation, global climate change, and invasion by non-native species. Restoration success in these ecosystems is devastatingly poor and success rates in the United States are often less than 5%. One reason for these low success rates may be that seedlings at early developmental stages are highly susceptible to environmental stress and when exposed to stressors such as drought, heat, or competition often experience high rates of mortality. However, within a given species, cultivars bred for specific traits or accessions from natural areas may respond uniquely to environmental pressures. We conducted a series of laboratory and greenhouse experiments to assess how roots of individuals of a popular restoration grass, Elymus trachycaulus (slender wheatgrass), recover after exposure to drought, heat, and competition at early developmental stages. The recovery of grass roots for all cultivars was negatively impacted after heat exposure but responses to drought and competition varied by cultivar and accession. Understanding how seedlings from different accessions and cultivars recover after exposure to environmental stress could elucidate reasons for why some restored populations fail to establish. In addition, results from these studies could improve seed source selection for restoring plant communities threatened by various environmental stressors.

Investing in climate resilient infrastructure in Kenya

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Kenya experiences frequent droughts and extreme floods, resulting in significant impacts on the economy, social disruption, and even loss of life. In addition, the country has significant infrastructural challenges related to water resources as the growing population continuously requires more water. Addressing these issues demands comprehensive water resources management and planning, coupled with extensive investments in climate resilient water infrastructure. The Kenya Water Security and Climate Resilience project extends across the whole of Kenya and includes the development of six integrated basin management plans. The objective is to strengthen capacity of the water sector institutions, which will ultimately lead to the improved management and development of Kenya’s water resources for its growth and development. As set out in the 2010 Constitution of Kenya, the National Government is responsible for water resources management through the Ministry of Water and Sanitation as the sector taking the lead for policy development. In order to align the water sector with the Constitution (GOK, 2010) the 2016 Water Act was promulgated. The Water Act (2016) recognises that water-related functions are a shared
responsibility between the National Governments and County Governments, whilst promoting the principles of Integrated Water Resource Management. This offers the opportunity to provide a pathway towards a future that achieves a sustainable balance between utilisation and development of water resources and the protection of the natural environment. This also provides a platform to integrate ecological infrastructure in the planning stage of water resource management at a national scale.

**Soil carbon stock as a key indicator for IWM impact assessment in Ethiopia**

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In sub-Saharan Africa where land degradation severely jeopardizes food security and environmental health, land rehabilitation efforts often proceed without priority setting and comprehensive evaluation. Our study quantified the soil organic carbon (SOC) stock and its controlling factors in prevalent land-use systems in northern Ethiopia, as part of the impact assessment of the national Integrated Watershed Management (IWM) program. A total of 195 soil samples were collected from four land-use systems, considering topographical positions and including entire soil profiles. The assessment revealed that protected forest lands (exclosures) as well a rangelands under controlled grazing had higher SOC stocks (Mg ha⁻¹), by far exceeding those of croplands and bare lands. The latter two were similar in SOC content, which implies that cropland SOC status is below the critical level, which requires urgent interventions. Among the major soil orders, cambisols had the greatest SOC, surpassing those of regosols and leptosols, irrespective of the land-use system. The SOC stock peaked in the 0–30 cm topsoil, but the deeper profile contained on average 36% of total storage, revealing the necessity of including the frequently neglected sub-soil pool in carbon accounting. The rock fragment content was negatively correlated with SOC stock particularly in exclosures and thus has to be included in the assessment reports. Given the significant differences in SOC stock among the land-use systems and the overriding effect of soil order, both factors should be used for delineating the priority areas in further planning and evaluation of the large-scale IWM efforts.

**Are acquisitive or conservative traits favored following savanna restoration?**

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Ecological restoration in the Brazilian savanna is challenging due to the presence of exotic invasive grass species that outcompete slow growing native species. Therefore, restoration requires a fundamental understanding of the ecological characteristics of plants to ensure its success. Plant traits can be defined in a continuum from acquisitive to conservative resource use. Acquisitive foliar traits include short leaf lifespan and high carbon assimilation rates, while conservative traits include long leaf lifespans, with more sclerophyllous leaves. Here, we evaluated the functional composition and above-ground carbon storage of a 2-year-old savanna restoration site at Chapada dos Veadeiros National Park, central Brazil. The restoration site was previously a pasture dominated by invasive grasses before restoration through direct seeding of native grasses, shrubs and trees. For reference ecosystems we use native savanna vegetation and non-restored abandoned
pasture still dominated by African grasses. We measured above-ground biomass, leaf area, specific leaf area, and leaf thickness, and we weighed leaf traits according to relative species cover. Restoration resulted in higher herbaceous biomass than in native and non-restored pasture. Restored communities had a higher abundance of species with more acquisitive traits (lower LMA, leaf thickness, and leaf area). Leaves were less thick and had a smaller area in the restored vegetation relative to the non-restored pasture, but similar to native vegetation. A more acquisitive functional composition suggests less investment in leaf-longevity and consequently high biomass production. After two years, the functional characteristics of the restored vegetation appear to shift toward native vegetation compared to non-restored pastures.

The importance of ecological restoration and environmental education in the construction of an environmental territory for peace in Colombia

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The armed conflict experienced in Colombia for five decades has begun to be visualized in what is now known as post-conflict. This is defined as the phase that comes after the definitive signing of peace agreements and that involves a recomposition of society. It includes issues such as the demobilization of armed actors, citizen security, the development of peace agreements, and care for the environment. According to the system of events of armed violence in Colombia, the department of Cauca was the most affected by attacks related to armed conflict. In this project, the objective was to implement environmental education and ecological restoration strategies in 20 municipalities affected by the armed conflict in the department of Cauca, Colombia. With the participation of social actors of the different municipalities involved and prioritized by the United Nations organization, inter-institutional technical committees of environmental education (CIDEAM) were created to carry out ecological restoration projects. A positive effect was detected in the beneficiary population, 20 CIDEAM were created and 31 ecological restoration projects were carried out, restoring a total of 147.5 hectares degraded by illegal mining and the sowing of illicit crops and the construction of 13 community nurseries for the production of native seedlings. The social actors involved and the community of the different municipalities showed positive changes in the generation of employment through the implementation of environmental education strategies aimed at the restoration of degraded areas.

Is liana cutting an effective strategy for recovering degraded tropical forests? Analysis of a restoration chronosequence in the Atlantic Forest, Brazil.

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Lianas increasingly infest degraded tropical forest fragments, reducing biomass accumulation and arresting forest regeneration. Thus, liana cutting is being proposed as a cost-effective restoration strategy. Thus far, however, evidence for the effectiveness of liana cutting as an ecological restoration tool in degraded forest fragments is limited. Therefore, we evaluated whether liana cutting improves tree richness, forest structure, and natural regeneration. We measured eight ecological indicators in 0-, 2-, 10- and 16- year-old restoration sites submitted to liana cutting and native tree seedling plantings on the edge of a degraded Semideciduous Seasonal Forest, located in the Atlantic Forest, southeastern Brazil. Liana cutting and tree seedling plantings reduced tree canopy infestation by lianas, and increased tree richness and basal area of the restoration over time. In addition, all forest restoration sites, regardless of age, had lower liana density and basal area than degraded edges. On the other hand, tree abundance and richness in the natural
regeneration (height > 1 m, trunk diameter < 5 cm) were lower in the liana cutting sites than in conserved forest edges used as references, even for the 16-year-old restoration site. Our results showed independent ecological trajectories for the evaluated indicators and suggest that reestablishing levels of tree natural regeneration is a challenge when restoring liana-infested forest edges. However, in general, we conclude that liana cutting improves the structure and tree richness of tropical forest edges and that some of the benefits of liana cutting may persist (or increase) in the long term.

**Developing the Restoration/EMPr Practitioner occupation for SA**

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The Quality Council for Trades and Occupations (QCTO) is a Quality Council established in 2010 in terms of the Skills Development Act No. 97 of 1998. QCTO’s role is to oversee the design, implementation, assessment, and certification of occupational qualifications, including trades, on the Occupational Qualifications Sub-Framework (OQSF) for South Africa. The QCTO is currently developing a new occupation for SA, in the Environmental Science space, viz. the Environmental Management Programme Practitioner (EMPrP), alternatively called the Environmental Impact & Restoration Practitioner. This proposed new occupation falls in between the EAP and the ECO roles for projects, as the EMPrP is the key individual who will develop the EMPr in the future, a role which is being fulfilled mostly by EAPs currently. The EMPrP will also be responsible to develop the EMPr for any major environmental incident or offset project. This is a critical occupation in SA, to ensure that robust, practical and meaningful EMPr are developed to help rehabilitate and restore environmental damage caused by incidents or developments. In developing this occupation for SA, the project team has developed knowledge and practical modules required to obtain a relevant qualification in this occupation, and has defined the work experience necessary to be an effective EMPr Practitioner.

**Empowering local communities through targeted tree identification resources for tropical peat swamp forest restoration**

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Many people working on-the-ground in tropical peatland restoration have little formal scientific education regarding tree identification. Furthermore, local species names differ spatially, even between villages along the same river. People working on assisted natural regeneration (ANR) and reforestation activities, such as weeding, enhancement planting, and seed and seedling collection, can be empowered and facilitated through increased ability to identify fruit, seeds, seedlings, and trees. Tropical peat swamp forest supports a large floral biodiversity. After degradation, a non-forest, fern and sedge system dominates. Reforestation efforts often only focus on replanting the same 2-5 tree species. Efforts would be improved by re-establishing complex forests through ANR and reforestation of a broad range of tree species. BOSF-Mawas in Central Kalimantan has a landscape-scale vegetation monitoring program with 96 plots across eight locations representing different natural and degradation histories and a digital herbarium which includes the 109 tree species found within the plots. Based on these data, literature, and community consultation, a list of 46 promising reforestation tree species was developed. To improve the accuracy and success of ANR and reforestation efforts and empower local communities surrounding the Mawas area, we developed a tree identification book for these 46 species. In the national language, the book describes key identification characteristics for each species, provides photos of fruit, flower, seed, seedling, tree, and bark, and details the scientific and all known local names. Future work will involve continued distribution of this book and a second book that will cover the remaining sixty plus tree species.
The influence of land use and land cover on sediment dynamics in the Tsitsa River Catchment, South Africa.

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Low vegetation cover at the beginning of a rainfall season coupled with high intensity rainfall results in higher runoff and erosion in a catchment with consequences for grazing availability. The aim of this study was to determine the influence of land-use and land-cover on sediment dynamics in the summer rainfall grasslands of the Tsitsa River catchment, South Africa. This study is part of a greater research effort, the Tsitsa Project, aiming at developing and managing land and water in a sustainable way. The study involves two sub-catchments of different land management strategies - one dominated by commercial livestock farms (Little Pot) and one dominated by communal rangelands (Gqukunqa). The study assessed system response over one rainfall season (2018-2019). Grassland productivity was quantified through NDVI and field calibrated through in situ biomass and vegetation cover readings with repeat field campaigns capturing seasonal variation in phenology. Soil hardness was quantified through soil surface penetration and complemented with rainfall analysis and sediment yield data. Provisional results show that vegetation cover does not correlate with NDVI pixel values as closely as previously anticipated, and while vegetation cover responds to rainfall, biomass is not necessarily analogous with the vegetation cover present. The sediment yield from the Gqukunqa is significantly higher than the sediment yield in the Little Pot. Advice to policy makers is to manage vegetation cover to prevent erosion year around, especially during the early rainfall season when vegetation cover is at its lowest and rainfall is often high in intensity.

Just add water, but hold the salt! Monitoring the rehabilitation of the Lower Jordan River (Israel)

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In recent years, the Israeli authorities have been investing in the rehabilitation of freshwater ecosystems across the country in an attempt to restore their ecological functionally. One example is the rehabilitation project of the Lower Jordan River (LJR). Naturally, the LJR discharged, on average, ca. 700 million cubic meters of lake water, annually. Following damming of the lake’s outlet in the 1960’s, the only sources of water in the LJR were poor-quality effluents and saline discharges. This has resulted in the loss of the river’s natural flora and fauna and has led to a severe deterioration in the provision of key ecosystem services. The rehabilitation of the LJR begun in 2014. It includes the replenishment of effluents with natural lake water, as well as channel and riparian rehabilitation. This resulted in a significant improvement of water quality, but salinity remained high, as much as 4 fold higher than background levels. To monitor the ecological success of the rehabilitation project, we compared long-term data on macroinvertebrate community collections from three sections: above and immediately below the effluents and a reconstructed section downstream. Our findings show that between the 1970’s and early 2000, macroinvertebrate diversity has declined with increasing amounts of effluents being discharged into the river. Samples collected after 2014, shows a recovery response of the community, and in particularly of molluscs. Nevertheless, the high salinity and accumulation of fine sediments along the channel, still hamper the return of indicative taxa, such as mayflies and caddisflies.

Possible contributions of structure-from-motion photogrammetry and structural characteristics to monitoring in subtropical coral reefs in South Africa

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In this study, we investigate the potential of structure-from-motion (SfM) photogrammetry to monitor changes in coral reefs in terms of structural characteristics and cover. High-resolution images were acquired using a GoPro Karma Grip mounted on a drone, and processed using Agisoft Metashape. We aimed to determine the feasibility of using SfM to monitor changes in coral reefs in terms of structural characteristics and cover. Our findings show that SfM can provide a cost-effective and efficient method for monitoring changes in coral reefs in terms of structural characteristics and cover. This has important implications for the management and conservation of coral reefs in South Africa.
Understanding the complex dynamics of coral reefs necessitates monitoring habitat structural features. For 25 years, the coral communities of Sodwana Bay, South Africa, have been extensively monitored by analysing two-dimensional (2D) photos of the substratum, providing a wealth of information. Structure from Motion (SfM) photogrammetry however, produces three-dimensional (3D) digital models of areas, allowing structural complexity to be quantified. Habitat structural complexity underlies variation in ecosystem processes, niche availability, resilience, and community composition. This study evaluated the accuracy of size and area measurements, cost, time requirements, and relevance of information derived from photogrammetry and 2D image analysis by carrying out both methods on an artificial reef (of known dimensions) and on the monitoring sites of Sodwana Bay. This study investigated the representation of structural complexity within the current monitoring sites by comparing rugosity, measured using photogrammetry, between these sites and three alternative reef transects. Lastly the interaction between coral community composition, reef state and reef structural complexity was investigated by comparing rugosity and composition in a recently senesced, recovering reef community, and an established reef community using triplicate transects. Our results indicated that the photogrammetric approach demands more computer processing, but less labour, provides accuracy of a few millimeters, and high resolution structural metrics. Structural complexity varied between sites, with the greatest difference detected between senesced and stable reef communities. We provided insights into the relationship between community composition, coral morpho-types and structural complexity, which has significant implications for monitoring and maintaining the Sodwana Bay reef complex.

**Restoration of savanna flatwoods: A plant-soil feedback approach facilitated by wiregrass**

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Pine savannas are one of the most biodiverse ecosystems in the world. While abiotic factors and fire as a frequent disturbance (1-4 years) are associated with much of this ecosystem’s species richness, it is also associated with the microbiome formed by the residing species. Organisms such as pathogens or mycorrhiza could devastate or greatly improve plant productivity and in effect, this influences species composition in plant communities. This relationship is called a plant-soil feedback which has gained attention in recent years. Aristida beyrichiana, or wiregrass, is a bunchgrass native to the southeast United States and is considered a keystone species for its flammability and fuel structure which help fires spread in fire-dependent ecosystems. I hypothesize that wiregrass influences the microbial community to improve species richness and can facilitate species vegetation. My project investigates the facilitative properties of wiregrass through a greenhouse plant-soil feedback project by measuring biomass of six flatwoods species planted in soil microbe communities conditioned by wiregrass and those not conditioned by wiregrass.

**Wetland prioritisation for livelihoods: Avoiding further degradation**

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Rural communities depend heavily on the natural environment in which they are situated. The quality of natural capital, including wetlands, makes up a significant component of their rural livelihoods. The Tsitsa Catchment is a grassland-dominated, summer rainfall area in the northern-Eastern Cape Province, South Africa. The majority of the catchment is degraded, which has implications for land-based livelihoods. The Tsitsa Project strives to restore functional (but threatened) landscapes. National datasets are limited and do not provide sufficient information to support catchment-wide prioritisation. High resolution mapping of the upper Tsitsa Catchment identified wetland types, location, their current
condition (in terms of degradation), and their vulnerability to further degradation. These wetlands are present in marginal areas, where the environment is already under stress from a multitude of factors. These wetlands are commonly overlooked despite them being a key component in the provision of ecosystem services. Gully erosion and ongoing overgrazing contribute to the degradation and vulnerability of the wetland ecosystems. From community participatory mapping, wetland seeps were identified as a key water source and essential forage for winter months and drought. They also help sustain rural livelihoods by increasing water and food security. This spatial data set was used to create a three-phase prioritisation of wetlands at a catchment level. The first phase is to protect wetlands in a functional state mapped by local communities, the second phase is to avoid further degradation of threatened wetlands, and the final phase is to target those wetlands in need of rehabilitation.

**Geomorphic reclamation and landscape heterogeneity: Assessing outcomes for plant community diversity**

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Severe land disturbance is a consequence of surface mining worldwide. Conventional reclamation practices often consist of landform reconstruction characterized by uniform topography and linear slopes. Geomorphic reclamation methods improve on conventional practices by recreating heterogeneous landforms that blend into surrounding landscapes. Environmental heterogeneity created by geomorphic design is hypothesized to increase the number of available ecological niches, and thus increase plant species diversity when compared with traditional, linear-slope reclamation. We sampled plant communities at two reclaimed surface mines in Wyoming, U.S.A. using line-point intercept (LPI) transects to compare vegetative diversity, composition, and structure between sites reclaimed using geomorphic and traditional methods. Greater species richness and Simpson’s diversity were observed in geomorphic reclamation at one mine site, but did not differ significantly between reclamation treatments at the second mine. Shrub abundance was up to 10 times greater on geomorphic reclamation compared to traditional reclamation. Neither reclamation method achieved levels of vegetative diversity observed on nearby, undisturbed rangeland. Geomorphic methods have potential benefits for restoration of vegetative diversity and foundational species such as Wyoming big sagebrush (Artemisia tridentata ssp. wyomingensis) in the sagebrush steppe ecosystem. Our results suggest geomorphic reclamation may improve plant community diversity and wildlife habitat as a practical method for landscape-level restoration in post-mining sites.

**Reforestation for disaster risk reduction and land-use changes in 100 years on Rokko Mountain, Kobe City, Japan**

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Rokko Mountain is located behind the center of Kobe and has a long history of reforestation since 1895. Kobe was one of the first ports opened to foreign countries at the end of Edo Era. It suffered many landslides and floods at the skirts of Rokko because there was only poor vegetation on the mountain due to its long overuse history. We analyzed historical land-use changes in the Ikuta River basin using topographic maps in 1913 and 1951 and vegetation maps in 1979 and 2012. The basin consisted of 12.1% urban land use, 1.3% dry field, 7.2% rice paddy field, 14.4% bare land, 20.9% grassland, 43.8% forest, and 0.3% water body in 1913; 19.2% urban land use, 3.8% dry field, 0.7% rice paddy field, 13.7% bare land, 8.0% grassland, 54.3% forest, and 0.3% water body in 1951; 23.5% urban land use, no dry field, 0.3% rice paddy field, 4.2% grassland, 71.8% forest, and 0.2% water body in 1979; and 29.4% urban land use, no dry field, 0.2% rice paddy field, no bare land, 4.2% grassland, 71.8% forest, and 0.2% water body in 2012. The forest area has increased for 100 years due to the reforestation while the area of grassland and bare land dramatically
decreased. Kobe had a severe flood in 1967. There were no non-acceptable landslides or floods after that. The results also showed forest decreasing owing to urban sprawl. The conservation of the forests adjacent to the urban area is considered as the current task.

**Restoration of paddy field ecosystems by utilizing abandoned rice paddy fields**

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Rice paddy fields are moderately disturbed and contain both aerial and aquatic habitats. Therefore, paddy fields have become important habitats for many wetland organisms, including frogs, dragonflies, aquatic insects, and waterfowl. Over the three-thousand year history of Japanese rice cultivation, species inhabiting paddy fields have become adapted to the specific environmental conditions of the fields. However, recently in Japan, around 10% of the total area used as paddy fields was abandoned primarily due to decreases in the total number of rice farmers. In contrast, it is difficult to implement effective conservation measures in paddy fields used in rice cultivation while maintaining suitable productivity, an issue which is only exacerbated by the redefinition of many species inhabiting paddy fields as endangered due to the intensification of paddy farming. Therefore, we assessed whether the abandoned paddy fields could be used in the effective restoration of paddy field ecosystems. The highest species richness was recorded in wet fields of the first and second year after abandoning cultivation (relative to the species richness of cultivated paddy fields and dry abandoned fields). Species richness declined with years since initial abandonment. Based on our results, we concluded that protecting wet paddy fields in the early stages of their abandonment is likely the best way to conserve paddy field biodiversity. Barnyard grass was the only source of pest species found in these habitats, a problem which could be resolved by ensuring the proper flooding of habitats in the winter and through the application of rice bran.

**No safety nets in the face of climate change: The case of pastoralists in Kunene Region, Namibia**

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For the past decade, pastoralists in Kunene Region, Namibia, have endured recurrent droughts that have culminated in the loss of their primary form of livelihood – pastoralism. Most pastoralists are finding it difficult to sustain their livelihood, and their community has fallen into extreme poverty. As part of a study of restoration opportunities and barriers in the area, we examined pastoralists' perception of, and adaptation practices to, climate change in the Epupa constituency, Kunene Region, Namibia. Specifically, we asked how climate-related disasters such as drought and flood have impacted the livelihood of the pastoralists and affected their vulnerability to climate change. Furthermore, we examined the perception and descriptions of the biophysical impacts in order to explore Ecosystem-based Adaptation (EbA) strategies. A nested mixed method approach with semi-structured household interviews, in-depth structured interviews, and key informant semi-structured interviews were used to obtain an in-depth understanding of the perception of pastoralists concerning climate change. Though pastoralists have coping and adaptation approaches at the community level, these have become ineffective as climatic uncertainty and change persists. There are currently no biodiversity interventions at the community level, and pastoralists no longer get benefits from the environment due to reoccurring droughts. They have indicated their adaptation needs, particularly the provision of water supply to grow food. This is an open avenue to explore EbA approaches, specifically ecological restoration, while still addressing the need of the pastoralists. There is an urgent need to develop new practical adaptation strategies, including restoration options, to strengthen their adaptive capacity.
Survival and growth rates of two shade tolerant tree species in nursery conditions for tropical rainforest restoration

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Land use changes in forest areas inevitably create degraded areas that hinder the natural restoration processes of tropical rainforest ecosystems. Efforts to restore the rainforests are often hampered by the prolonged growth period of wildings in nurseries before they are transplanted to suitable sites. We aimed to reduce the growth duration of wildings in nurseries before transplanting to nature. We examined the growth and development of two indigenous, shade-tolerant tree species. Three treatment factors applied were: a) four subsoil media types, b) two humidity levels (all-day covered versus day-time covered with UV plastic sheets), and c) two sunlight intensity levels (70% versus 50% shade netting). The experiment was conducted for six months with the air temperature ranging from 29°C to 31°C. Growth parameters recorded were height, diameter, number of leaves, and above and below ground biomass. Our results showed that wildings preferred a combination of higher day-time relative humidity plus natural night air ventilation, achieving better growth rates under higher light intensity (1500 PAR vs. 1000 PAR), and subsoil supplemented with an organic amendment (vermicomposts) improved wilding survival. The wildings’ RGR was affected by humidity and light intensity but not by mineral nutrient addition. In conclusion, shade-tolerant tree species are adapted to the harsh abiotic environment of a degraded site if some organic amendments (e.g. vermicomposts) are provided to the rhizosphere. Our study indicated that restoration efforts using indigenous tree species, appropriate growth environments, and suitable organic amendments produced good quality and resilient saplings that are adequately acclimatised for re-introduction.

Spontaneous succession of road verges – effective approach with minimum effort

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Road verges represent new habitats established along transport corridors that can be used for the support of biodiversity in a highly fragmented and human-altered landscape. However, these sites are prevalingly planting with trees or shrub species and seeded with commercial mixture of grasses regardless of their geographical origin. We assessed the effectiveness of spontaneous succession to fulfill both requirements for desirable vegetation cover to prevent erosion damage and establishment of target vegetation composed of native higher plant species with benefits for nature conservation. We sampled 114 vegetation plots, 5 x 5 m in size, on roadsides (Czech Republic, Central Europe) which differed in age since abandonment (1-42 years). We recorded various landscape and habitat variables and analyzed data by means of ordination methods. Species richness was generally explained by successional age, mean annual precipitation, mean annual temperature, and slope. Out of 320 identified species, almost five percent were classified as endangered in national Red-List flora and only six percent were alien species that colonized newly created habitats spontaneously from the surroundings. Spontaneous succession should be used more often in the restoration of road verges because this approach can provide a cost-effective solution with rather high conservation value.
Developing a climate adjusted provenancing-plot network in Australia

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Climate change is having measurable impacts on our land, water, and biodiversity. In line with climate-driven impacts on the natural environment, there is a pressing need to understand and plan for the climate impacts on restored habitats and develop guidelines to implement and monitor climate adapted plantings and seed production areas. These areas have the potential to improve habitat resilience of native flora and fauna within the wider landscape and provide empirical data to develop effective adaptive management strategies. By including a diversity of species and seed provenances in revegetation projects, we can maximise the resilience of plantings to climate change and other environmental stressors. In Australia we plan to develop guidelines for climate adapted plantings to help restore native, biodiverse habitats under a changing climate. Some of the key questions of this project will focus on selecting a diversity of species for restoration and nursery development, seed provenance, genetic profiling and climate trajectories for different climatic regions. The establishment of climate future plots will (a) validate the ‘climate readiness’ of different provenances (identified through genetic and climate modelling), (b) act as seed production areas that provide climate ready sources of seed for future restoration projects, (c) identify how diverse ecological plantings influence faunal communities, and (d) provide demonstration sites for the public and the restoration industry. This poster will outline the development of these climate plots and guidelines and discuss how information from stakeholders, experts and practitioners nationally and internationally is being used to guide their development and implementation.

Improving grass biomass production using brush packing as restoration technology after bush clearing in the Lephalale district of the Limpopo Province, South Africa

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About 60% of South African rangelands are moderately to severely degraded with bush encroachment accounting for 25% of this. Restoration practices were used to improve soil surface properties and increase the grass biomass production for grazing animals. Two bush-encroached sites (communal area and nature reserve) were identified in the Lephalale district of the Limpopo Province in South Africa. Brush packing was used as a cost effective restoration intervention after bush clearing. Three replicates of six treatment combinations were used (1.control, 2.bush clearing, 3.bush clearing and re-seeding, 4.bush clearing and brush packing, 5.bush clearing, re-seeding, and brush packing, 6.bush clearing, soil disturbance, re-seeding, and brush packing) in each study site. The grass biomass was compared across the treatments for two seasons (2018 and 2019). There was a significant difference in biomass and season (p<0.001) at the communal area and (p<0.05) at the nature reserve across the treatments. Higher grass biomass was recorded in the treatments with brush packing. A combination of brush packing and re-seeding had lower biomass compared to treatments with brush packing and no re-seeding. The treatment with clearing only recorded the lowest biomass production. Similar trends were observed at both sites, however, the communal area had the highest biomass production for the two seasons. This can be attributed to the difference in soil type and rainfall. Careful consideration is needed before re-seeding degraded areas. The results show that degraded and bush encroached rangelands can be restored after woody (bush) clearing using brush packing interventions.
Rehabilitation of degraded silvopastures in drylands: A case study from southern Pakistan

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There are more than 3 billion people globally living in drylands that cover 40% of earth’s surface. In Pakistan, the situation is severe with 75% of the country’s area receiving less than 250 mm of annual rainfall. Drylands in southern Pakistan are home to communities living in poverty and depending on livestock rearing for their livelihood. Subsistence agriculture is losing its importance under the effects of climate change i.e. uncertain rainfall and very low productivity. To fill the livelihood gap, local communities are increasing their livestock herds. Thus pressure on silvopastures is increasing, resulting in degradation of natural resources and loss of soil fertility, adversely affecting the livelihood of communities. These climate based ecosystem challenges have remained unanswered. The Farm Forestry Support Project (FFSP) of the Intercorperation (IC) and Swiss Agency for Development & Cooperation (SDC), initiated collaboration with local communities to pilot adaptive agroforestry measures in 2014 in the extremely dry region of Karak. Major elements of these measures included the strengthening of the agro-silvopastures using hillside ditches and sand dune stabilization techniques. The objective was to harvest, conserve, and use rain water for recovering fodder vegetation and increase productivity of the area with minimum cost and hence to support livelihoods. The activity was carried out with participation of civil society organizations and farmers’ associations.

Landscape SWOT analysis of abandoned quarry sites in an urban context - a case of Pune city

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With a diverse geology, different regions in India contain rocks belonging to different geological periods. The rocks and mineral deposits are excavated for construction purposes. A quarry is a type of open-pit mine from which rock or minerals are extracted. Once quarrying is done, the open pit is left unattended and it becomes an abandoned quarry. Abandoned quarries in urban areas are regarded as a disgusting feature of the present day landscape, which are eyesores to the public at large. The quarries invariably prove a health hazard, being used as landfill sites with all types of waste dumped into them. In short, the abandoned quarries are synonymous with unattractive, obnoxious, and unpleasant surroundings. This paper undertakes the study of abandoned quarries in urban areas, with special reference to Pune city, with a view to suggest restoration of such sites with an emphasis on rehabilitation of them with various benefits. Field research, content analysis, and comparative research are the methodologies used to assess the present condition of the abandoned quarry sites in an urban context. The paper will study the strengths, weaknesses, opportunities, and threats in urban areas with respect to abandoned quarry sites, and reveal the potential for beneficial development of abandoned quarries as open spaces in and around Pune city. And lastly an attempt is made to formulate guidelines for the sustainable development, management, aesthetics enhancement, and socially and financially beneficial use of these abandoned quarry sites from the point of recreation, education, preservation, protection, and promoting environmental values.

Ground and remote assessment of the 2014-2017 drought on rehabilitation in Namaqualand

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There was a 4 year drought on the western seaboard of South Africa from 2014 to 2017. This drought coincided with rehabilitation trials in the Namaqua National Park targeted at facilitating seed establishment and plant growth. The experiment consisted of a site left intact, a site where shade nets were installed, and a third where soil was excavated to create ponds for resource accumulation. Plants were surveyed in 2015 and 2016 for composition, cover, and stature. The ground assessment was supplemented by a 250 m scale MODIS NDVI time series from 2001 to 2017, and a 30 m LANDSAT counterpart truncated to 2014-2017. Rainfall was indeed unusually sparse during the study period, although the heat was not correspondingly high. Both satellites suggest plant vigour was severely debilitated by the drought. There was a significant negative trend in NDVI according the Mann-Kendall test in the MODIS time series (t = -0.19, p << 0.001). Similarly, LANDSAT also showed a significant and negative trend via an identical MK test (t = -0.35, p << 0.001). The deterioration in plant vitality was spatially contingent, with high-lying Fynbos-like sections more likely to tolerate dry conditions. About half the plants encountered in 2015 survived to 2017, and survival was highest in the ponding treatment. Therefore, we suggest that ponding is a better strategy for rehabilitation, at least during a severe drought. Inclement weather will become more common due to global climate change, therefore this study offers a peek at how drought might impact rehabilitation efforts.

Assessment of soils naturally restoring at the surface of extensive and ageing infrastructure of Kuzbass coal mine wastes (Russia)

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Kuzbass (short for Kuznetsk Basin) is one of the largest coal mining areas in the world at about 70,000 sq. km. It was first mined for coal in 1851. The soil forming process in coal mine wastes (technogenic landscapes) undergoing a natural re-vegetation process for over 20 years was studied in comparison with undisturbed lands of the Kuzbass region. The results of the study showed that formation of new soils in the coal wastes (named embryo-soils) at each stage of a plant succession was slower than in the undisturbed lands and had incomplete soil profiles and soil horizons that were not clearly distinguished soil horizons. At the initial stage of plant succession, no new soil horizons were forming, and coal wastes were not modified (named initial embryo-soils). At the second stage of plant succession, an initial soil horizon of up to 3 cm from readily recognizable leaf litter (named organic-accumulative embryo-soil) was forming on top of the coal wastes. At the third stage, a horizon of up to 5 cm (named folic embryo-soil) was forming as the result of the introduction of grasses and formation of partially decomposed folic material (leaves and twigs). At the fourth stage, humic material from 1 cm to 4 cm (humus-accumulative embryo-soil) had begun to form under the folic embryo-soil.

A multi-agency collaboration to develop seed transfer zones for multiple native forb species in the western United States

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Native forb species are critical for the restoration of habitat after fire and other disturbances, particularly in the sagebrush steppe of the western United States, where wildlife that are dependent on healthy plant communities, such as the greater sage-grouse and native bees, are experiencing population declines. However, little is known about the adaptive genetic variation of forb species in this ecosystem. In some cases, forb species are adapted to local environmental conditions and their use in successful
restoration projects may depend on taking this information into account. Seed transfer zones, developed through common garden studies, are an excellent tool to help managers make decisions on what plant varieties or populations are the most genetically appropriate for the area being restored. This poster will describe a multi-agency project to develop seed transfer zones for multiple forb species, through a coordinated seed collection effort and the development of a common garden network to test adaptive genetic variation. The project is in its early stages. Seed collection began in the summer of 2017 with participants from the USDA Forest Service, USDOI Bureau of Land Management, USDOI Fish and Wildlife Service, and the Chicago Botanic Gardens. The first common gardens will be installed in the fall of 2019. This poster will focus on the theories behind the use and development of seed transfer zones, and the practical logistics of efficiently developing seed transfer zones for many species at a regional scale.

**Effects of deer browsing on camphor tree invasion and native vegetation on an Atlantic barrier island (USA)**

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The camphor tree (*Cinnamomum camphorus*) was introduced from Asia to the subtropical portions of the southeastern United States over 100 years ago and is naturalized in many areas. In recent decades, however, it has become increasingly abundant on Jekyll Island, an Atlantic Ocean barrier island in Georgia. Native deer populations have also increased during this period. We sought to explore whether deer herbivory is affecting native understory vegetation cover, camphor seedling abundance and growth, and abundance of native hardwood tree seedlings. We established 22 6 x 6 m plots in a 40 ha area with heavy camphor proliferation, of which 11 were fenced to exclude deer and 11 were not. Each plot was subdivided into 25 1 x 1 m quadrats. In April 2018, in each quadrat we counted, tagged, and measured height and leaf number of each camphor seedling. We also recorded total herbaceous vegetation cover, cover by species, and abundance of hardwood tree seedlings. Plots were re-measured in July 2018, September 2018, and May 2019, also tagging and measuring newly emerged camphor seedlings at each census. Deer herbivory was associated with decreased native herbaceous vegetation cover and decreased abundance of native tree seedlings, while camphor seedling abundance, growth, and turnover varied with herbivore treatment, site, and other environmental covariates. We examine the relationships between herbivory effects on camphor versus native species and discuss the implications for efforts to control camphor invasion and support native tree recruitment.

**How effective are the mangrove reforestation initiatives to restore degraded intertidal areas along the Kenyan Coast**

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Mangrove conservation and rehabilitation has a huge potential for coastal protection, fisheries enhancement, climate change mitigation, and provision of wood and non-wood products. Despite the multiple uses, mangroves are threatened, lost, and degraded. Efforts to return lost and degraded mangroves have presented mixed results globally. In Kenya, mangrove reforestation practices were initiated in Gazi Bay in the early 1990’s. Here, we evaluated the growth performance of replanted mangroves in terms of survival rates, stand biomass, and secondary succession. At least nine mangrove rehabilitation sites across the Kenyan coast were assessed. Sampling was carried out in 10 m × 10 m quadrats on a transect perpendicular to the shoreline. All trees with diameter >2.5 cm at 1.3 m above ground were measured and counted, while survival counts were done in young plantations. From these, we derived survival rates, stand density (stems/ha) and biomass (t/ha). To compliment the study, purposive sampling was used for community interviews. From the results, survival rates ranged from 0-90%. Stand density ranged from 7500 to 3766 stems/ha while stand biomass ranged from 14 t/ha to 375.9 t/ha for 7 to 24 year-old
plantations. Motivation to plant mangroves included the need for; environmental protection (70.9%), fisheries enhancement (49.1%), and wood products (34.5%), while 34.5% were driven by incentives. Good and/or poor performance of replanted mangroves could be attributed to species match, planting techniques, community participation, and monitoring. To enhance successful mangrove restoration, understanding the ecological settings of prospective mangrove reforestation sites and community participation should be emphasized.

**Successful approaches to restore forestry ecosystems and biodiversity: Lessons learned during four decades to continue achievement in Nepal**

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Ecosystem and ecological restoration is a complex process. Nepal with its fragile landscape is facing degradation. From 1978/79 to 1994, Nepal's forest area decreased at an annual rate of 1.7%. Megafauna (Great One-horned Rhinoceros [Rhinoceros unicornis], Royal Bengal Tiger [Panthera tigris] and Wild Buffalo) were under increasing threat. This presentation reviews achievements in ecological restoration in Nepal to address these challenges. Protected areas have increased from 1% (932,000 ha) in 1973 to 23.39% (3.42 million ha) currently. This represents significant progress toward achieving relevant Aichi biodiversity targets. Forest cover increased from 39.6% to 44.74% between 1994 and 2010. The rhinoceros population, below 100 in the 1950s, has increased to an estimated 650 with zero poaching observed in 2013, 2015 or 2016. The tiger population increased from 121 in 2009 to 235 in 2018, and the wild buffalo population from 63 in 1973 to 432 in 2017. A policy paradigm shift from government managed systems to community-based forest management is an important factor for change, codified through such instruments as the National Forestry Plan (1976), Master Plan (1989) and Terai-Arch Landscape Strategy (2004). This shift has fostered connections among communities and conservationists for co-benefit (communities and nature) of ecosystem and biodiversity restoration. Climate adaptive management is also a focus at the national and sub-national level, with emphasis on corridors and connectivity of ecosystem fragments for sustainable ecological restoration. Notwithstanding these achievements, human-wildlife conflicts, infrastructure, poaching, and invasive species remain challenges that must be addressed within Nepal's broader ecological and social context.

**Costs associated with Payment for Environmental Services in ecological restoration programs: A literature review**

**Raquel Lacerda**
Ibama, Brasilia, Brazil

Several costs can be associated with ecological restoration or recovery of degraded areas, among them the use of Payment for Environmental Services (PES) as an economic incentive instrument. Here I review the literature associated with the costs that affect the efficiency of ecological restoration programs to build PES schemes properly in all their phases. During the conceptual phase, the main focus is the restoration and opportunity costs, which directly impact project and PES design. They represent the costs ($ per hectare) involved in estimating the amounts to be spent to obtain resources or as part of their accountability to funders, beneficiaries, or users of restored environmental services. However, many authors show that other provisioning costs are also relevant, i.e., costs associated with transaction, administration, compliance, or monitoring, which can significantly affect the efficiency of reaching the goals of PES schemes. Based on the experience of programs or large-scale projects built around the world, the most relevant costs are opportunity, restoration, monitoring, and transaction costs. These costs can occur at all phases of programs or projects that use PES, from planning to final evaluation. The three most common phases of an ecological restoration program using PES are
conception/planning, development/implementation and monitoring/evaluation when payments are made to the restored environmental services provider. However, the incidence of costs can vary enormously, so the program must be reassessed constantly. Finally, raising the awareness of stakeholders is critical to reducing all costs and achieve the objectives of the Program in an efficient way.

Seed sourcing to reduce weed species introductions in restoration plantings
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Habitat restorations that use plant species translocations are an increasingly critical component to preserving at-risk species and connecting fragmented landscapes. The academic literature surrounding plant translocations is highly focused on the genetic provenance of a plant species as a key determinant of the risks and benefits associated with using plant translocations. However, moving plant species, typically as commercially produced seed, can introduce “weed seeds” (undesirable, exotic or invasive species) along with the native species. We purpose that, for commercially produced seed, the distance between the production location of the native plant seed (not the genetic provenance) and the restoration site substantially affects the nature and degree of risk associated with moving native plant species. That distance also impacts the logistical constraints faced by restoration practitioners attempting to obtain enough genetically appropriate seed. Using georeferenced databases of weedy plant species distributions and native plant seed producers, we created a spatially explicit framework for balancing the risk of introducing weed species with the benefit of increased native seed availability that come with increasing the distance between native seed production locations and restoration sites for the upper Midwest, USA. This framework will provide evidence-based, practical guidance incorporating more than genetic concerns. For example, by determining which weed species are most likely to enter the upper Midwest with climate change, our framework can determine if the balance between weed risk and seed availability changes should practitioners adopt seed provenancing strategies that attempt to anticipate future climatic changes.

Partiality among passerines: A savanna land-use gradient example
Rion Lerm, A.M. Swemmer
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Habitat modification is generally regarded as having a negative impact on biodiversity, but this is not always the case, particularly when it leads to the creation of novel ecosystems. The Savanna Biome in South Africa is host to a diverse bird community (ca. half of the country’s species) but its passerine communities generally contain neither Red Data (IUCN) species nor endemics and, as a result, draws less attention than some of the more threatened Biomes such as the Grassland or Fynbos. Here, we demonstrate how a land-use gradient (including "restored" mining areas) shaped passerine bird communities located in the northeastern part of the Savanna Biome using a fixed-radius point count technique. Species richness, relative abundance, and a diversity index, all showed similar trends where one of two rehabilitated mining areas and the rural rangelands produced the largest values compared to more natural and protected areas. The passerine community composition of the rural rangelands was also most distinct from the other areas and contained many significant indicator species. Unexpectedly, the two rehabilitated mining areas contained species that were significantly related to those areas only. Areas that experienced most human influences (rural rangelands and rehabilitated), clustered closest together when Beta diversity (species turnover) was compared. Here we demonstrated the more significant roles rehabilitated and disturbed/modified areas played in shaping passerine communities, compared to the lesser significance of the more undisturbed/protected part of the northeastern Savanna Biome.
Ecological restoration through effective partnerships between communities and business in Lesotho

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Water production from the mountain catchments in Lesotho is one example of the many benefits from ecological infrastructure. However the extent and consequences (ecological and socio-economic) of catchment degradation in Lesotho are widely recognised. This degradation and loss of associated ecosystem services raises risks to local livelihoods and to the business sector, particularly in the context of climate change. The Khokhoba Catchment Resilience (CaRe) Fund was developed in recognition of the need for incentivising ecological restoration within the mountain catchments in a way that builds the resilience of local communities and businesses in the long-term. The CaRe Fund is a partnership between the Khokhoba Community and a business partner, SanLei. SanLei is an aquaculture business that produces high quality trout in Katse Dam and is dependent on good water quality to sustain its operations and product quality. Degradation of ecological infrastructure in the catchment poses a risk to the sustainability of SanLei’s operations. The CaRe Fund partners SanLei (providing sustainable incentives) with the Khokhoba Community (undertaking ecological restoration and improved catchment management in the long-term) to generate socio-economic benefits that address the Community’s development priorities as well as a more resilient operating environment for the aquaculture business. This presentation demonstrates the design and development of a performance based investment mechanism for ecological restoration. It highlights the power of partnerships between stakeholders in bringing about ecological restoration while simultaneously generating socio-economic benefits and a resilient environment supporting businesses.

Dynamics of soil nitrogen cycling during post-agricultural succession in a subtropical karst region

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Soil nitrogen (N) dynamics are crucial for ecosystem development and carbon sequestration. Nevertheless, how soil N cycling changes during post-agricultural succession in karst regions has not been well assessed. Here, N cycling during post-agricultural succession in the karst region of southwest China was evaluated. Bulk N content increased rapidly along a post-agricultural succession sequence including cropland, grassland, shrubland, secondary forest, and primary forest. Across the sequence, soil N accumulated with an average rate of 12.4 g N/m²/yr. Soil N stock recovered to the primary forest level in about 70 years following agricultural abandonment. Nitrate concentrations increased while ammonium concentrations decreased with years following agricultural abandonment. N release from bedrock weathering was likely a potential N source in addition to atmospheric N deposition and biological N fixation. Both gross N mineralization and nitrification rates decreased initially and then increased greatly following agricultural abandonment. Gross N mineralization rate correlated significantly with protease activity, implying that the depolymerization of N-containing polymers was likely the rate-limiting step of gross N mineralization and benefited N accumulation following agricultural abandonment. Net nitrate production rate and N saturation index increased significantly from the grassland to the forest, supporting that soil N cycling likely became more open during post-agricultural succession in the karst region of southwest China. Multiple lines of evidence showed that N cycling in the karst forest was leaky, but N cycling the neighboring non-karst forest was very conservative.
Time and space dynamic management of urban abandoned land to a green network through the ecological restoration of Jingzhang railway

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With the rapid development of urban construction and the renewal of railway technology, some railway sections in cities have been abandoned. Abandoned railways divide cities, occupy important urban public spaces, waste land resources, and demolition of railway wastes damages the ecological environment and contributes to loss of historical memory. We hope to change the city’s abandoned railway by establishing a model that adapts to the dynamics of time and space. The Beijing-Zhangjiakou Railway is the first self-built railway of the Chinese. With development of the city, the terminal section of the Beijing-Zhangjiakou Railway was abandoned, which affected the urban traffic, the environment, the safety of the residents, and became the urban gray space. From the perspective of landscape planning, the goal was the establishment of a green renewal model to adapt to urban development. The first phase was urban transport improvement to create open space. The second phase was construction of the linear pergola railway. This improved the surrounding ecological environment. The third stage was the greenway extension, which links the surrounding mountains and the urban green network. Through the ecological strategy of dynamic protection, the ecological environment of the abandoned railway and its surrounding areas will be restored, and the utilization of abandoned land will be strengthened.

Organic carbon density of degraded and restored desert grassland in the southeastern fringe of the Tengger Desert, China

Xin Rong Li, Haoatian Yang
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Desert grassland is an important component of the terrestrial ecosystem. The study of carbon density in degraded and restored desert grassland ecosystems is important to evaluate the role of desert grassland in global climate change. Field investigation, sampling, and laboratory analysis were carried out for natural, heavily degraded, and restored desert grassland in the southeastern fringe of the Tengger Desert, China. Differences in the total organic carbon density, soil organic carbon density (SOCD), and shrub biomass carbon density (BCD) among three ecosystems were examined. The results showed that shrub (leaves, new branches, aging branches, standing-dead and roots) BCD and SOCD of 0-100 cm soil profile of typical desert grassland were 213.234 g m⁻² (17.688 g·m⁻², 8.035 g·m⁻², 59.163 g·m⁻², 21.732 g·m⁻² and 106.617 g·m⁻²) and 2.517 kg·m⁻², respectively. The carbon loss of degraded desert grassland was serious, shrub BCD, and SOCD only accounteded for 14.901%, and 26.852% of natural desert grassland. Degraded desert grassland had strong carbon sequestration potential, shrub BCD, and SOCD of the 0-100 cm soil profile of restored desert grassland increased significantly, they were 2.463 times, and 2.392 times as much as that of degraded desert grassland, respectively. Our study suggests that the desert and desertification area in China has great carbon sequestration potential. Reasonable restoration measures are important strategies to increase carbon storage of desert grasslands, alleviate the increase of CO₂ concentration, and mitigate global climate change.

Biological integrity of grassland topsoils subjected to long-term stockpiling

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Surface mining and energy exploration often require topsoil storage for long periods of time (1-30 years). Such soil handling and storage results in physical and biogeochemical changes and may alter the soil biological integrity. Microbial activity regulates nutrient cycling and soil quality, and post-mining revegetation of most native forb species in grasslands rely on a viable seedbank. Soil condition and biological viability influence the establishment and success of the aboveground plant community, and therefore should be considered in facilitating successful reclamation. In this study, we characterized soil biological integrity via the seed bank and microbial community structure in a topsoil stockpile (depths of 15cm-750 cm). We hypothesized with increasing depth, soil biota and the viable seedbank would decrease in abundance and exhibit a shift in community structure, and stockpiled soils would display different communities than an undisturbed reference site. We found shifts in microbial communities structure and declines in overall abundance of organisms with increased depth using principal component analysis. Furthermore, overall microbe abundance within the top 15 cm of stockpiled soil was nearly one third less than in our native undisturbed reference site, and soil at depth was increasingly depleted. Total seedling emergence from soil collected at all depths of the stockpile was lower (20 viable seeds) compared to the reference soil emergence (36 viable seeds). Our results demonstrate that stockpiling greatly affects soil microbial communities and that stockpiled topsoil is not a dependable source for forb seeds. Reclamation may require forb seeding and soil amendments to facilitate whole-system restoration.

Driving targeted habitat restoration within a protected area: Using a highly sensitive and threatened amphibian as a proxy for change

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Amphibians are heavily affected by human activities, and habitat transformation is causing declines in round 40% of species globally. In South Africa, the proportion of amphibian species of conservation concern has increased by over 12% in the last decade, largely due to habitat transformation and degradation. The Table Mountain Ghost Frog (Heleophryne rosei) is Critically Endangered and restricted to just six perennial streams on Table Mountain (Cape Town, South Africa). The species has a naturally small distribution (7.87 km\textsuperscript{2}), and is entirely within Table Mountain National Park and the Kirstenbosch National Botanical Gardens. Despite its distribution fully occurring within Protected Areas, the recent National Biodiversity Assessment classifies the species as “Not Protected”. It has disappeared from two streams directly impacted by alien vegetation encroachment and habitat degradation due to heavy foot traffic on popular hiking paths. Ghost frogs are uniquely adapted to the freshwater ecosystems found in the Afromontane forested gorges and valleys of Table Mountain, and act as early indicators of environmental change within the ecosystem. Their disappearance from several streams emphasises the impact that human activity has had on ecosystem function and integrity. Through this project, we make use of Visible Implant Elastomer (VIE) markers and detailed presence/absence monitoring data within an occupancy modelling framework to understand the species habitat requirements, as well as acoustic data to estimate population size. Understanding the species habitat requirements is crucial to accurately address the impacts they face and rehabilitate their habitat, safeguarding not only the species, but the broader freshwater ecosystem.

The impact of protection from grazing on vegetation cover of Fescue-forb rangeland in Mongolia

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Degradation is the main problem in the rangeland ecosystem of Mongolia. It results from grazing pressure and climate change. In this research, we wanted to elucidate the influence of protection on vegetation cover of rangeland at different degradation levels. The study was done in areas protected from animal grazing on fescue-forb rangelands in the mountain steppe of Mongolia from 2004 to 2009. Resting is one of the possible and cheapest ways to recover degraded rangeland in the harsh climatic conditions of Mongolia. At the beginning of our study, Agropyron cristatum and Koeleria macrantha grasses were dominant at the slightly degraded site; Artemisia frigida and A. commutata forbs were dominant at the moderately degraded site; and Carex duriuscula and other sedge species were the main dominants at the heavily degraded site. The weather conditions fluctuated during the study period and that affected plant growth and vegetation cover. The total vegetation cover at the un-grazed site was 18-22% higher than at the slightly degraded site; 8-10% higher than at the moderately degraded site; and 39-58% higher than at the heavily degraded site in 2005 to 2006. In most years total vegetation cover was higher (P<0.05) at un-grazed compare to grazed sites. Due to drought and accumulation of litter cover, vegetation cover was lower at all areas in 2007 and 2009. Grasses and forbs increased at the un-grazed area relative to the slightly and heavily degraded sites. This study shows that recovery of rangeland can be slow when weather conditions are unfavorable.

Current state of Ammophila arenaria (marram grass) distribution in the Eastern Cape, South Africa and the possible effect of the grass on dune system dynamics

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The principal aim of this paper in is to show that marram grass, introduced to the Cape dunes in the 19th century, is not an invasive alien in South Africa although it does invade dunes in other countries, e.g. USA. In an EU-funded project in the 1990s we showed that marram was non-invasive. Nevertheless, SA environmental authorities prohibited the use of marram as a dune stabiliser. This prompted the repeat survey of the current distribution of marram on dune sites stabilised in the 1970s in the Eastern Cape. Abundance of 66 dune species was recorded in 69 releves from Gonubie west to Oyster Bay. These data were analysed to show the relationships of the samples and species in 2-dimensonal DCA scatter diagrams. In four dune sites marram grass was no longer present, due to either marram being out of its climate range, the complete erosion of the dune habitat or marram simply disappeared. Marram was recorded in some pioneer sites where 3-5 pioneer species were recorded. Marram was the most abundant dune pioneer on some dunes but it never dominates the dune system. The 8 pioneer species of the Eastern Cape dunes are widely dispersed on the DCA scatter diagrams showing a similar behaviour of pioneer dune communities in the dune successional series. Thus marram grass often does not persist in these dune systems, and if present, it does not compete and become invasive, but behaves identically to the other pioneers and can be used in dune stabilisation projects.

Below ground diversity as an indicator of relative restoration success in invaded mountain fynbos stands and along riparian zones in the Western Cape Province

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Globally, invasive species threaten indigenous ecosystems through competition for resources, habitat alteration, and changes to ecosystem services (Van Wilgen et al. 2004). The Fynbos biome of the Western Cape Province, South Africa, is home to some of the rarest plant species globally (Simmons andCowling 1996; Moran and Hoffmann 2012), but
this region is prone to invasion by several weed species, including Acacias, pines, Hakea spp., and others. Controlling these IAPs can be accomplished through mechanical means, biological control, or spraying. Often, however, follow-up operations in terms of restoring or rehabilitating sites are not conducted, paving the way for secondary invasions (Marchante et al. 2011). Also, restoration efforts are often concerned with above-ground changes to the landscape, but not with the restoration of ecosystem function. Several invertebrate taxa have been used successfully as indicators of restoration efforts (e.g. Andersen and Majer 2004; Longcore 2003; Lyons 2009), but little work has been conducted in the context of the fynbos biome and the below-ground soil fauna, with most studies to date concentrating on aboveground, epigaeic species (e.g. Pryke and Samways 2010; Uys 2012). Because the belowground faunal groups are considered pivotal in ecosystem functioning and could be good indicators of ecosystem health, this study aims to determine how this faunal group changes in response to the level of invasion/restoration, in an effort to better inform management going forward and to improve the long-term sustainability of restoration efforts following clearing operations.

Assessment of ecological infrastructure presence, current state, and prioritisation for rehabilitation and drought mitigation in the Tsitsa River Catchment

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The benefits of ecological infrastructure (EI) have been recognised by the South African government, hence they are developing the health of ecological infrastructure as a method for identifying degraded lands for rehabilitation (Sigwela et al., 2017). The rehabilitation and maintenance of ecological infrastructure sustains livelihoods for rural communities, through direct and indirect benefits, and provides regulating and provisioning ecosystem services. Therefore, this project aims to identify the current state and determine the changes in the essential ecological infrastructures in the Tsitsa River catchment for protection and rehabilitation for drought mitigation. This study will use satellite imagery to document the historical changes (2000-2019) in three targeted EI land cover categories (grasslands, wetlands, and cultivated lands) in the Tsitsa catchment. Grasslands and wetlands are considered to be critically important as they provide benefits such as flow regulation, trap sediments, improve water quality, and reduce the impacts of floods. Abandoned cultivation areas promote the spread of invasive alien vegetation, and thus they need to be targeted for rehabilitation. Remote sensing data (NDVI trend and anomaly analyses of MODIS and Landsat imagery) will be used to quantify changes and degradation status of the targeted EI. By mapping out and identifying changes in the Tsitsa catchment, this study will hopefully contribute to the prioritisation of EI for ecological rehabilitation planning. Moreover, assessing the health of the Tsitsa catchment EI will contribute to the field of climate change adaptation for local communities, especially in times of drought.

2013 Colorado flood recovery: A case study in natural stabilization techniques for riverine/fluvial applications

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The 2013 Front Range Floods were catastrophic for Colorado. To assist with flood recovery, Randy Mandel co-authored a Fluvial Bioengineering Guide for the Colorado Department of Natural Resources (DNR), Colorado Water Conservation Board (CWCB) to use as a guide in the implementation of the Emergency Watershed Protection (EWP) Program. The primary purpose of the Stream Bioengineering Guide is to: (1) Provide practitioners with natural stabilization design guidelines; (2) better incorporate specific design elements that determine a bioengineering project's stability; (3) include recommendations on design decisions that minimize project risk during the periods of greatest susceptibility to failure;
(4) provide an understanding of how to apply the bioengineering techniques; (5) provide the means to calibrate the strength of outlined techniques to the anticipated forces of flowing water and gravity; and (6) include a searchable restoration matrix that incorporates natural and nature-based restoration design parameters for approximately 270 of Colorado’s native riverine and wetland plant species. The database includes 51 different design parameters, including nomenclature, county, hydrology, physiographic preference, morphology, seed weight, seed storability, propagule type, root parameters, and germination protocol. The searchable database was provided as an electronic supplement with the Stream Bioengineering Manual. Using the Manual and Matrix as a reference, R. Mandel served as the ecological restoration lead for the design, implementation, and monitoring of all 74 Colorado EWP Restoration projects. This presentation will provide a brief overview of the Stream Bioengineering Guide and the restoration matrix as applied to the Colorado EWP projects.

A review of methods for economic valuation of seagrass (Zostera capensis)

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Marine seagrass (Zostera capensis) ecosystems are among the most diverse and widespread ecosystems in South Africa that provide ecological, socio-cultural and economic ecosystem services. Despite their formal protection status, Z. capensis meadows are regressing, often due to anthropogenic influences. Globally, multiple studies have documented the ecological importance of seagrass services, but economic valuations of these services have not been as extensive. The economics of ecosystem services are important to place a monetary value on non-market goods and services, such as the services Z. capensis provide. To mitigate the effects of the decline of Z. capensis meadows, restoration efforts have been suggested. In this research project I review the ecosystem services Z. capensis provides and evaluate numerous ecosystem service valuation models to develop a model to determine the value of the ecosystem services of Z. capensis in the Knysna estuary, South Africa. The developed model will assist in determining restoration efforts for Z. capensis in the Knysna estuary.

Restoration of Malahlapanga complex spring mire

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The Malahlapanga spring mire (22° 53’ 16.38” S, 31° 02’ 23.92” E) is situated near the western boundary of Kruger National Park on a small tributary stream, close to the confluence with the Mphongolo River. The spring mire complexes in the Kruger National Park (South Africa) are fed by thermal water with a temperature of 37 to 42°C. The mires lie in an almost straight line, supporting the hypothesis that the water originates from deep aquifers which discharge at geological faults. Thermal springs originate from rainwater that percolates into permeable rocks or joints and becomes heated underground. In recent times, managers of KNP drew attention to the thermal mires because some of them had been heavily impacted by wild animals and excessive erosion due to man-man infrastructure (roads). Some of the domes have dried out severely and show signs of erosion due to water flow and trampling by large animals (loss of peat formation). A management road is aligned next to the spring deposits sediments with rain water that flows in the direction of the road. Rehabilitation intervention (earth berms, diversion of roads, and erosion reduction measures) have been put in place since 2016. This paper will outline the objectives of the various interventions, their success and effectiveness, and the resulting outcomes in halting erosion and restoring the ecological processes within the Malahlapanga spring mire complex after 4 years of rehabilitation.
Seed rain as a strategy for passive restoration of Southeast Atlantic Forest remnants, Brazil

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Brazil has large degraded areas and many fragmented habitats. The Atlantic Forest, in particular, has only 12% of its original area. Although, in the last few years the southeast part of the biome, in the Paraiba Paulista Valley, has been experiencing an expansion of tropical forest cover, mainly attributed to pasture abandonment and natural regeneration. For that restoration to happen, it is necessary that seed dispersal occurs and that seeds are able to arrive in safe environments. Thus, we aimed in this study to characterize species of the seed rain and evaluate how far seeds can travel from tropical vegetation remnants. We selected two sites based on forest remnant size (large and small) and, in each of them, seed collectors were installed at three different distances from the border (1, 5 and 10 m), totaling 12 collectors per site. Seed collections were carried out monthly and seeds were counted, measured, weighed and identified, when possible. Both forest remnant sizes had similar species richness in the seed rain. The large remnant had more tree species in the seed rain and the small remnant had more shrub species seeds. In both areas the number of seeds in the 1 m-collectors was higher in relation to other distances. Passive restoration may be an effective restoration mechanism, especially in areas that are close to large remnants of native vegetation.

Native soil inoculation as a means of enhancing re-vegetation in arid areas

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Revegetation of degraded areas, particularly in arid regions, is extremely challenging. A possible mechanism that may contribute to revegetation success is the restoration of the soil microbial matrix in affected areas. This study was conducted with the objective of evaluating the inoculation of revegetation areas with soil from sites supporting native soil microbial communities as a means to increase revegetation success. This study was conducted in the southern Great Basin region of the USA. Seeds of four species of shrubs and two species of grasses was planted by hand in the field plots. Inoculation was achieved by spreading soil from the native plant community and incorporating the soil into the surface soil of the plot by hand. Some plots were irrigated by drip irrigation, applying the equivalent of 2 cm of water per week to each plot receiving the irrigation treatment. The plots were visually checked every 1-2 weeks to monitor the emergence of the seeded species. The vegetation in the plots was sampled during two years after the experiment was established. Two metrics were recorded by plot: number of plants and canopy cover of plants, both by species. Results indicate that soil inoculation potentially provides a method of increasing the effectiveness of revegetation in the Owens Valley. At the end of the second growing season, inoculation increased the survival of seedlings by 37%. Native soil inoculation is recommended in revegetation efforts in arid areas. This inexpensive technique can be applied in any system where native intact soil resources exist.

Restoring soil quality for improved household agricultural productivity in Malawi

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Soil degradation is a major environmental challenge in Malawi that greatly reduces productivity of agricultural land. Land holding size for the poor, who make up the majority of smallholder farmers, has declined and is currently at 0.2 ha/capita. Consequently, land
Restoration should aim at improving soil quality, which maintains the livelihoods of the smallholder farmers. This initiative should provide practical solutions that allow farmers to get immediate benefits. Restoring ecological processes takes several years; hence NRC Campus is implementing projects that restore soil quality and contribute to improved agricultural productivity for farmers. Our projects encourage sustainable land management such as agroforestry, conservation agriculture, and organic farming. We designed demonstration plots on conservation agriculture, agroforestry, and organic farming. These act as learning centres for students and farmers. Field days and agriculture fairs are organized to demonstrate the technologies to farmers to combat soil erosion and increase production. Field days and agriculture fairs provide a platform for a mutualistic information exchange between us and our stakeholders. Preliminary results indicated improved crop stand in demonstration plots compared to conventional farming during prolonged droughts. To address the drivers of degradation, we train farmers on alternative livelihood activities such as mushroom production, beekeeping, and drip irrigation. Our work has demonstrated that ecosystems that are able to support agricultural production can be restored. Ancillary benefits (e.g., flood control, wildlife habitat, and power generation) will follow. We will achieve these goals with a directed focus on smallholder farmers who are most vulnerable to land degradation.

**Land-holder perceptions of wetland restoration: A case study from a drier Northern Cape, Working for Wetlands Programme, South Africa**

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A key aspect of wetland restoration is consultation with the land-holders, i.e. whoever is directly responsible for management of the land, including private, communal, and government landowners. Progression towards desired outcomes of wetland restoration and sustainability may be strongly dependent on how these land-holders perceive the restoration. Therefore, as part of project monitoring and evaluation it is important to collect a narrative of how the land-holders perceive the following elements: (1) his/her engagement or consultation during the restoration process, (2) the wetland and the wetland restoration project, and (3) his/her perceptions in relation to monitoring, aftercare, and maintenance of the interventions. Guidelines for interviewing land-holders in relation to these elements were developed, and applied at six different wetland sites where wetland restoration was undertaken by Working for Wetlands (WfWet), South Africa. The sites encompass a diversity of contexts, including: (1) the land-holders are actively involved in monitoring and the identification of maintenance requirements to ensure that the interventions continue to achieve their restoration functions, (2) land-holders are indifferent to the interventions and take no interest or responsibility for monitoring and maintenance, and (3) land-holders have actively pursued their own modifications of the interventions in order to meet their water needs, and, therefore could be undermining the intended restoration functions of the interventions. The presentation outlines the guidelines and key findings from their application at the seven sites. The findings will inform the potential future improvements that WfWet can make on how they consult with land-holders about restoration, monitoring, and maintenance.

**Awareness and consideration of ecosystem services in quarry restoration in western Europe**

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In urbanized or intensive agricultural landscapes of western Europe extractive activities may play a role in biodiversity restoration by developing important patches of valuable habitats and unique landscape features. Biodiversity restoration may be enhanced by the consideration of ecosystem services. We explore the link between restoration and ecosystem services in active quarries of western Europe based on a set of recent works including large face to face survey of quarry and non-quarry people. Before the restoration process, ecosystem services are assessed to guide restoration choices. Provisioning, regulating, and cultural ecosystem services are taken into account through an integrated assessment, including biophysical, monetary, and social valuation. We found a great awareness among quarry and non-quarry people about the ecosystem services that may be delivered in active quarries, with the three categories of ecosystem services cited and a clear focus on cultural services that are directly linked to biodiversity, people, and their wellbeing. This awareness is a foundation for training programs that allow quarry people to be actors of their own biodiversity, and for open days to allow non-quarry people to enjoy the quarry site. A wide variety of ecosystem services are provided in quarries, the consideration of different ecosystem services during the decision-making process of restoration depends on the stakeholders’ awareness. There are great opportunities for improving the wellbeing of extractive business ecosystem, its people, and non-quarry stakeholders by restoring quarries as ecosystem services provisioning landscapes.

Global climate impact of peatland restoration

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Globally, over 330 000 km² of peatlands are drained for agriculture and forestry. These peatlands emit greenhouse gases 1-2 Gt of CO₂ eq. annually. This is 25 to 50% of the emissions from the whole LULUCF sector, even though peatlands cover only 2% of the Earth's land area. Restoration has been offered as a tool to stop emissions and mitigate climate change. However, although restoration can successfully stop CO₂ and N₂O emissions, CH₄ emissions are typically increased. In forestry, the fate of the growing tree stand and wood products complicates the comparison between restored and drained peatlands. We estimated, based on IPCC emission factors, the impact of global rewetting of drained peatlands on radiative forcing (RF). We did this separately for boreal, temperate, and tropical peatlands. We also estimated, as a case study for Finland, the change in tree stand and wood products C pools and resultant RF following rewetting, with four options concerning stand management. Rewetting instantly and effectively reduced RF in tropical and temperate agricultural peatlands. In forested peatlands RF increased at first, due to increased CH₄ emissions, but decreased below starting levels in 10 to >100 years after rewetting. Mere abandonment from forestry was a better way of mitigation than rewetting. As a whole, the rewetting of forested peatlands had a negligible effect on RF, whereas rewetting tropical and temperate agricultural peatlands reduced RF by 70 mW m⁻² in one hundred years, which is 15% of the RF of global anthropogenic methane emissions.

Effects of restoration of Prosopis-impacted ecosystems on soil respiration: Potential trade-offs in restoration decisions

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Prosopis juliflora, and associated species and hybrids, has been called one of the worst invasive species in the world; its spread in Australia, India, Sri Lanka, Ethiopia, South Africa, and East Africa has had disastrous effects on ecosystems and human communities. In Tanzania the distribution and dominance of P. juliflora is not yet widespread. Most efforts to combat this invasive species in East Africa thus far have involved mapping its extent along with some removal trials. Active revegetation of damaged rangeland and savanna ecosystems is often required following invasive species removal in order to more quickly
establish a plant community that is resistant to reinvasion. The primary objectives of the proposed research are threefold: 1) to test locally appropriate methods to establish a competitive plant community that prevents reinvasion, 2) to determine tradeoffs regarding carbon flux to the atmosphere from soils as a consequence of vegetation modification, and 3) to test the utility of using drone-based very high-resolution remote sensing to facilitate scaling between plot-level measurements and satellite based remote sensing. Thus, we will be determining methods to avoid the “Dandelion Effect” (invasive species control is often only temporary) by employing active restoration such as planting grasses or native trees and employing soil stabilization techniques (e.g. small fences or brush piles). Further, we will assess potential implications for climate change on the choice of functional groups used in revegetation and address scaling issues that have made it difficult to translate plot-level measurements to landscape and larger scales, and vice versa.

Eradication of the emerging alien cactus species Cylindropuntia pallida F.M. Knuth and active restoration in arid areas of South Africa

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The emerging cactus species Cylindropuntia pallida (Thistle cholla), native of northern Mexico has been recorded in arid areas of South Africa. The detected multiple populations of C. pallida display high invasion potential with propagule dispersal mediated by the predominant ungulates exploiting the invaded grazing land. For containment of invasion problems, eradication by chemical spraying (GARLON* 480 EC HERBICIDE) has been applied across 16 populations located in different areas. The aim of the study is to determine the efficacy of the chemical method in suppressing the population growth of C. pallida, and demonstrate the subsequent need for active ecological restoration of native species in 16 locations under treatment. The chemical spraying method substantially (95%) reduced the populations. The spayed adult plants take 1-2 months to completely die. However, post-eradication monitoring after a two-year interval showed that follow-up control is needed to eradicate the remaining 5% of plants that might have been missed, the resprouters, as well as seedlings that had not emerged during the spraying operations. After three years of spraying, no native plant species have recolonised the C. pallida canopy area (i.e. empty niche) covered with dry biomass. Soil samples from both within and away from individual plant canopy across the populations are being analysed to determine any possible chemical contamination during eradication of the plants, and recommendations for active rehabilitation of the affected areas are discussed.

The importance of raising awareness of land degradation and restoration in Lesotho

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Lesotho has suffered severe degradation of both cultivated and grazing lands, this can be seen in the severe soil loss in the form of gully formation. Fertile fields have been reduced to unproductive wastelands caused by poor land management over the years. Lesotho is mostly dominated by grassland as the natural vegetation and its steep slopes render it prone to land degradation and erosion by water. Supplementary to this, overutilization of the cultivated land, overgrazing, and over-exploitation of resources also contribute to the degradation of natural resources. Environmental problems are multi-scale and affect many actors and agencies, necessitating public awareness. Public awareness provides acknowledgement of values and environmental benefits, thus helping communities to manage social and environmental issues that concern their land to facilitate sustainable use. Knowledge improves understanding of land degradation and restoration, and hence easy adoption of remedial practices. A knowledgeable nation can innovate relevant restoration technologies that could be exerted to regain productive ecosystems to regain
restoration of lost biodiversity. The knowledge imparted by public awareness is also a prerequisite for improved agricultural production for the alleviation of poverty and hunger. Public awareness encourages alternative livelihoods to decrease the dependence of citizens of Lesotho on natural resources. It is recommended that public awareness be increased by training resource managers to educate resource users through campaigns, radio, television, press, and internet on land degradation and restoration.

The application of Tree Popper® mechanical control of woody plant encroachment in savanna rangelands

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This study tested the hypothesis that a Tree Popper® mechanical tool may be an effective way to mechanically uproot seedlings of woody plants in savannas. To conduct this study, seedlings of eight woody plant species were selected (i.e. Vachellia (Acacia) karroo, V. nilotica, V. tortilis, Dichrostachys cinerea, Ziziphus mucronata, Euclea crispa, Ehretia rigida and Gymnosporia buxifolia) and grouped into three height classes (i.e. between 0-49 cm, 50-99 cm and 100-150 cm) of 10 seedlings per species per height class. For each seedling, we measured plant height, canopy diameter in two perpendicular directions, and stem basal diameter. We also recorded whether the seedling was single- or multi-stemmed. The Tree Popper® successfully uprooted 64.7% of the seedlings. The Tree Popper® uprooted 100% of G. buxifolia, 97% of Z. mucronata, 97% of E. crispa, 93% of E. rigida, 81% of D. cinerea, 16% of V. karroo, 15% of V. nilotica and 3% of V. tortilis seedlings, respectively. The effectiveness of the Tree Popper® depends largely on plant species and not only on soil wetness. The Tree Popper® was more effective on broad-leaved trees such as Z. mucronata, E. rigida, E. crispa and G. buxifolia. The effectiveness of this instrument may be due to the differences in plant morphological structure, particularly the root system, among fine-leaved trees and broad-leaved trees. Unfortunately, the Tree Popper® is not an effective tool for controlling the encroachment of most species causing woody plant encroachment in savannas.

Flowering and fruiting patterns in a 20-year-old restoration site in the Brazilian Atlantic Forest

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A phenological study was carried out to support local forest restoration in an Atlantic Forest remnant in Southeastern Brazil, a reference site and a source of seeds for seedling production as well. Two decades later, a new study assessed flowering and fruiting phenology of 14 native tree species, shared between the 20-year-old restoration sites and the reference forest remnant. Phenological data were recorded monthly from August 2014 to July 2015 for a total of 178 individuals of the 14 species. That period recorded an unusually low annual rainfall (less than 25% of mean rainfall for data from 20 years ago). Recent data (2014-2015) showed a positive correlation between flowering and rainfall; there were more species flowering in the former phenology, under high rainfall values. Both low rainfall and high temperatures also affected fruit production in the 20-year-old restoration sites. The lowest precipitation recorded in 2014-2015 may have contributed to reduced flower and fruit production within the tree species in the restoration sites, which suggests a protection against water scarcity. Despite reduced production, the ripening process made fleshy fruits available over most of the phenology study. Additionally, other species produced fruits in different periods of the year, filling monthly gaps in fruit production. Restoration can fail in attracting pollinators and fruit dispersers if there is low availability of flowers and fruits due to climate. In our study, phenological data suggest redundancy and
complementarities of fruit production may enhance the resistance of restoration sites to disturbances caused by climate change.

**Uprooting but not mowing could control invasion by Salvia coccinea**

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Effective management, control, and possible eradication of alien and invasive species depend on early detection and rapid response. Most invasive species largely go unnoticed until they cause significant and noticeable biodiversity impacts and at that stage, eradication is often not feasible or will potentially be costly. Salvia coccinea was recently found in Limpopo province, South Africa. The purpose of this study was to ascertain the extent of the plant's population in the Limpopo province and assess eradication methods. We used active search, spotters records, and line transects to locate and quantify the population size of Salvia coccinea. Over 14 naturalised populations were detected and sampled, yielding over 7,834 plants. Our results show that the Salvia coccinea population is rapidly expanding. Our research found that Salvia coccinea is flowering throughout the year. The study highlighted that Effective Rapid Response (ERR) needs to be considered to limit the Salvia coccinea population, especially in the early stages of invasion to reduce its potential impact on native biodiversity. In the absence of a coherent ERR, Salvia coccinea could become an aggressive invader by colonizing warm areas in South Africa.

**The “oak regeneration problem” in maritime live oak forests: The effect of herbivory, drought, and land use legacies on live oak seedlings in coastal Georgia**

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The “oak regeneration” problem has been studied worldwide and is often linked to herbivory and drought. Maritime live oak forests on the southeastern United States coastal barrier islands feature long-lived southern live oak (Quercus virginiana) and sand live oak (Q. geminata), which are currently displaying limited recruitment and face a number of stressors. Deer and feral hog herbivory, changes in water availability on the coast, and legacy effects from the history of agriculture may be contributing to limited oak seedling survival and sapling recruitment. We conducted an exclosure experiment across 4 islands to determine the effect of these potential stressors on oak seedlings. Oak seedlings were planted within fenced and unfenced plots. We evaluated the effect of type of fencing, forest type/land use history, and water stress on planted seedling growth and survival. Our results indicate that fencing is an effective conservation strategy to increase the abundance of natural seedlings and the survival and growth of planted seedlings, and that herbivory and water stress may be stronger proximate factors for oak seedling survival than legacy effects from historic agriculture. Sand live oak seedlings showed increased growth and survival compared to live oak seedlings after a summer drought period. Sand live oaks may be a more appropriate species for planting, particularly in light of projected future climate conditions. We also discuss lessons learned from our collaboration with land managers and stakeholders, which included two workshops. Their local knowledge has significantly contributed to our theories of forest dynamics within this little-studied ecosystem.

**Restoring biodiversity of disturbed peatlands as a basis for restoration of their future ecosystem functions**

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Central European peatlands are unique isolated ecosystems, most of them having persisted continuously at the same sites and to similar extents since the early Holocene. Human-made disturbances have detrimental effects on them, but their restoration seems to be possible to a certain degree. The most destructive disturbance is large-scale industrial peat harvesting, accompanied by profound changes in the water regime. The relatively simple community structure is an advantage for studying relationships among different trophic groups of organisms. Such studies are, however, rare. In our project we concentrate on plants, fungi, and selected groups of insects and their mutual interactions in spontaneous and assisted colonization of disturbed bogs. The role of underground water level, pH, and peat thickness were recognized to most influence recolonization of peatbogs. Many plant species established spontaneously during two decades since harvesting ceased. Some important target species were re-introduced (Andromeda polifolia and Vaccinium oxycoccos). Their survival was mainly affected by water level, with A. polifolia as the more successful species due to its ability to deal with water stress. Water level and thickness of peat were found to also influence fungal species composition (103 species in total). Some insect species typical of peatbogs (tyrphobionts) have already appeared. However, the overall rate of spontaneous restoration was slower than expected. A combination of spontaneous and assisted restoration seems to be the best approach to restore the peatbogs.

**Spatial-temporal patterns of land use/cover change in a restored floodplain wetland ecosystem**

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Ecological restoration provides new ideas and opportunities for conservation of biodiversity and management of wetland ecosystems. Restoration projects done in the past elsewhere have been considered less successful due to a combination of factors, including lack of quantified evaluation methods among others. Evaluating restoration efforts through analysis of land use/cover changes in freshwater wetland systems is critical for policy development and monitoring procedures. This study evaluated ecological restoration efforts through assessing natural vegetation development and patterns of change within a Nature Reserve. The reserve was established to provide protection to flood plain wetlands and its unique vegetation, birdlife sites, and for breeding Roan and Tsessebe. The study was conducted in Nylosvley Nature Reserve, a RAMSER site of international importance in Limpopo Province of South Africa. Landcover maps of the Reserve were generated from the classified images using maximum likelihood classification algorithm in ArcGIS 10.5. Land use/cover classification system was designed consisting of areas of fields, sparse vegetation, dense vegetation, and bare ground. The results show that densely vegetated areas covered about 45.5% of the site in 1984 and were reduced to about 40% by 2005. Sparsely vegetated areas showed a negative change of about -12.9% from 34.6% in 1984 to 21.7% in 2005. Bare ground also showed a negative increase in size by 18.7%. Fields remained static with 0.1% increase from 1984 to 2005. Vegetation in the Nature Reserve has not significantly increased despite the restoration efforts in place. Other factors affecting vegetation changes in this floodplain require further investigation.

**Will exotic tree species support local fauna in reclaimed sites? A case study of insect biodiversity in reclaimed sites of the Guinea savanna zone of Ghana**

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Exotic tree species have been used extensively in the reclamation of degraded lands in Ghana, but the ability of these species to support local fauna has rarely been studied. The
The present study compared insect biodiversity in natural savanna woodland with sites reclaims with exotic tree species (Azadirachta indica and Anacardium occidentale). Insects were sampled with flight interception traps, pitfall traps, pan traps, and sweep nets in a 100 x 100 m land area in each site. Insect samples were collected for 24 sampling days across wet (August – October) and dry (January - March) seasons. A total of 1,492 insects belonging to the orders Lepidoptera, Hymenoptera, Coleoptera, Orthoptera, Mantopedia and Odonata were classified. Tree species used in reclamation had a significant effect on the abundance of insects (P > 0.05) with the natural savanna woodland recording the highest (38.1%) insect abundance whilst the Azadirachta indica reclaimed site recorded the lowest (28.8%) abundance. Similarly, insect order distribution also varied across the different reclaimed sites with the natural savanna woodland recording a higher number of insect orders. The use of exotic tree species in reclamation tends to have negative effects on the diversity and abundance of insects.

Field surveys and revegetation experiments show that simulation of topographical habitat features could improve the chances of successful restoration for the threatened succulent Juttadinteria albata

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Species with highly restricted ranges are disproportionately at risk of extinction, particularly where habitat loss occurs as a result of mining. Postmining restoration of rare species populations is considered an appropriate response to counter such threats, but requires a careful, evidence-based and information-driven approach. The economically important diamond mining at Sendelingsdrif in the southern Namib Desert occurs in the highly diverse Succulent Karoo Biome and threatens a significant part of the population of the narrow endemic succulent plant species Juttadinteria albata. To decrease the inherent risks of restoring such a rare species, we studied the habitat features of premining J. albata populations and experimentally tested whether some features could assist future reintroductions in postmining substrates. Plots where J. albata occurred were mostly south- to west-facing and had among others conditions, higher rock cover and steeper slopes than plots where J. albata plants were absent. A revegetation experiment, with J. albata cuttings that were established on postmining substrate mounds, revealed that plants on steeper slopes, facing south to west, grew faster than plants on other slopes and aspects. Slope and aspect are therefore important habitat properties to recreate when restoring J. albata populations. These, and other preferred habitat properties such as higher levels of organic C, should now be tested in larger-scale field trials. Validation of habitat requirements of J. albata through the revegetation experiment has decreased the risks, at least partially, and provides additional empirical evidence of the importance of establishing reference conditions to enhance ecological restoration.

How to scale up ecological restoration: Circumventing fire in Cape Fynbos restoration as a case study

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There is an urgent need for ecological restoration interventions to take place on a much bigger scale if sustainable development and environmental goals are to be met. The emphasis and urgency on scaling up follows the United Nation’s declaration for 2021-2030 to be the Decade on Ecosystem Restoration. Scaling up requires provision of best practice restoration guidelines on execution, costing, standards, and legislation to mention a few. It is imperative to identify key ecological drivers that may hinder ecological recovery
processes at larger scales. In this way, active interventions can take advantage of or manipulate such factors and use them as leverage points during restoration, making active restoration more feasible and applicable for large scale purposes. Using a systematic literature review approach (ROSES for Systematic Review Protocols version 1.0), this study sought to identify pragmatic ways and adaptive shortcuts that can be implemented during restoration to enforce and speed up ecological recovery. The meta-analysis indicates a diverse array of generic methods that are refined to suit the scale and specific needs of the projects. In this context, a case study seeking to explore the efficacy and cost efficiency of circumventing fire as a natural process in the restoration of lowland fynbos at the Cape of Africa is described.

**Modifying the current planting protocol to improve establishment of Portulacaria afra in the Albany Thicket Biome (ATB) of the Baviaanskloof, Eastern Cape**

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The Albany Thicket Biome (ATB) lies on South Africa's western reaches of the Maputaland-Pondoland-Albany hotspot, which supports high levels of diversity and endemism. However, decades of overstocking with domestic herbivores have led to the degradation of this ancient biome. To combat degradation, Portulacaria afra (spekboom) has been used as a target restoration species across degraded ATB. However, the current planting protocol has seen little success in spekboom establishment. Using a communally owned property in the western Baviaanskloof, South Africa, the study sets out to determine the influence of different plant and soil manipulation techniques on the establishment and growth of spekboom. Three major modifications to the current protocol were explored: 1) nurse planting 2) companion planting and 3) post-planting irrigation frequencies. The spekboom planted under the nurse plant performed the best in terms of survivorship and vigor, the canopy providing favorable conditions. The companion plants aided in the successful establishment of spekboom via facilitation. The spekboom watered once a month outperformed the semimonthly (twice a month) and weekly-watered plants. In conclusion, the study shows the benefits of planting underneath an existing canopy. However, the watering of rooted cuttings brought diminishing returns with increasing watering frequency and the companion plants failed to establish. The implications for these findings entail future innovation on the existing planting protocol for fast-tracking ATB rehabilitation and the return of ecosystem goods and services. It can also substantiate the notion that solving socio-ecological issues is context-specific and therefore solutions must be conceived, discussed, and implemented accordingly.

**Restoration of kimberlite tailings with native grassland vegetation in the Afro-alpine zone, Lesotho**

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Mining is an anthropogenic activity that creates vast amounts of mine waste that threaten the natural integrity of the environment. This type of disturbance becomes even direr in sensitive Afro-alpine ecosystems, such as the diamond-rich kimberlites of the Mokhotlong district, Lesotho, at altitude of 3100 m. Diamond mines produce kimberlite tailings with a high sand fraction and low organic matter content that are, in combination with a harsh climate, not effectively rehabilitated with conventional methods. The aim of the study was to determine an effective restoration approach using better adapted native species and by manipulating the depth and mixes of topsoil and kimberlite tailings. Trials using seeds of native pioneer species were used to identify species with rapid germination ability. Best performing species were then tested for ability to establish on different kimberlite tailings...
treatments and in combination with other species. Results showed substantial germination of Tenaxia disticha (Poaceae) out of nine plant species on various kimberlite treatments. Additionally, three species of two families germinated copiously in the presence of T. disticha seeds. High seedling establishment and growth performance were associated with 150 mm topsoil on kimberlite tailing treatments. The additional emergence of 18 unsown plant species in trial treatments confirmed that T. disticha also acts as a suitable ‘mother’ crop to facilitate germination from the seed bank. We revealed that addition of topsoil and a pioneer species with rapid germination and establishment is essential for restoring native plant diversity on the kimberlite tailings in the Afro-alpine zone of Lesotho.

**Mycoremediation potentials of Pleurotus ostreatus (Jacaum ex. Fr. Kummer) on crude oil polluted soil of Michael Okpara University of Agriculture, Umudike**

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We examined the mycoremediation potentials of Pleurotus ostreatus (Jacaum ex. Fr. Kummer) on crude oil polluted soil, including assessment of its morphological characters, mycoaccumulation potentials, proximate analysis, quantification of extracellular enzymes and their degradation effects, and mycoremediation activities on PAHs. The experimental was conducted in-situ at the University of Agriculture, Umudike, Nigeria, screen house. Pure mycelia were obtained from FIIRO, Lagos State, Nigeria. The substrate consisted of Andropogon gayanus straw of 150 g/kg (4 cm) and 300 g/kg (8 cm) placed on 2500 g/kg loamy soil polluted at 2, 4 and 6% crude oil in 5-litre transparent buckets. A Completely Randomized Design (CRD) with five replications was employed and parameters determined. Data was analyzed using ANOVA, with mean separation with DMRT at 5% probability. There was significant reduction in morphological characteristics; There was significant (P ≤ 0.05) reduction in moisture, total ash, lipids, crude protein, and fibre and a significant (P ≤ 0.05) increase in total carbohydrate content with increasing concentration of pollutants and substrate quantities. This species showed significant (P ≤ 0.05) increase in minerals of harvested fruit bodies whereas, vitamin concentrations were not significantly (P ≥ 0.05) affected. Higher levels of phenols and flavonoids were obtained, followed by alkaloids, steroids, terpenoids and glycosids. Heavy metals concentrations were significantly higher with 4% and 6% crude oil pollution. Activity of enzymes such as cellulase, peroxidase and lipase clearly demonstrated the capability of P. ostreatus to degrade PAHs. Improvement on more strains of macro-fungi through biotechnology and nanotechnology is recommended for effective remediation and restoration of oil spilled-polluted environments.

**Massive open online courses on business-driven landscape restoration**

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Ecosystem degradation is a serious environmental, social and economic problem. It must be addressed with other major contemporary issues, including climate change and, food and water security. These challenges are directly linked to human well-being, security, poverty, migration, and many of the Sustainable Development Goals. This makes restoring landscapes one of the most important tasks of our time. To scale up landscape restoration we need to involve the private sector and engage the business community in catalyzing sustainable land use and management. The ENABLE consortium, an Erasmus+ co-funded programme, was established to develop high-quality education targeted at business students and -professionals to create awareness about the functioning of ecosystems and
the benefits of restoration based on sustainable business models. We have created two massive open online courses (MOOCs) on how restoration of degraded land and sustainable land management provides a return of financial-, natural- and social capital and a return of inspiration (the 4 returns approach). Our first MOOC “A Business Approach to Sustainable Landscape Restoration” offers comprehensive knowledge of landscape degradation and restoration from both the perspective of natural science and from an economics and business perspective. Our second MOOC “Business Model Innovation for Sustainable Landscape Restoration” moves the participants from ideas towards the successful implementation of a new business model for sustainable landscape restoration, which delivers four returns. Each step is illustrated with three real cases of landscape restoration in Spain, Iceland, and Portugal. Both MOOCs are open for all and free of charge on coursera.org*

*https://www.coursera.org/learn/landscape-restoration-sustainable-development
https://www.coursera.org/learn/bmi-sustainable-landscape-restoration?

Litter contribution, abiotic factors, and species composition: A case study of restoration in a seasonal forest region in Brazil
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Litter is an important component of the forest and is deposited differently in different ecosystems, whether natural or restored. However, its relationship to the composition of species in seasonal forests is not well understood. In this study, the objective was to evaluate and identify the relationships between biotic factors (diversity and species composition) and abiotic factors (climate) and the contribution of litter in restoration areas in the Seasonal Forest. The research was developed in a 2.7 hectare forest restoration area, located in the city of Sorocaba, Brazil. For the sampling of litter produced in the area, a total of 15 plots of size 5 x 5 m were selected in which three conical collectors were installed, totaling 45 collectors. The litter was collected monthly, obtaining data of the abiotic variables of temperature, wind speed, and precipitation and data on the biotic variables by calculation of diversity indexes. Nonmetric Multidimensional Scaling (NMDS) was used to represent the species composition in the restored area. The stepwise regression analysis was used to select variables that affected the contribution of litter over 24 months. A significant effect of all climatic variables analyzed was detected. However, together the richness and the equitability, besides the composition of species, positively altered the contribution of litter. The results emphasize the need to select key species for the contribution of litter and maintain high diversity in the restoration projects so that the ecological process of nutrient cycling is not affected.

Effects of road width on roadside vegetation and soil: Interpreting the changed perception of forest road management
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The majority of ecological studies of roads have focused on their deleterious effects, and these emphases have hampered a full evaluation of the ecological functions of roads. As an integrated indicator, road width represents combined effects, including anthropogenic and natural disturbances. We explored the different effects produced by various road widths by examining changes in forest vegetation and soil. We selected six samples distributed from southern to northern China, including Kunyushan (KYS) Nature Reserve, Hengshan (HS) Nature Reserve, Danxiashan (DXS) Nature Reserve, Dinghushan (DHS) Nature Reserve, Heishiding (HSD) Nature Reserve, and Baiyunshan (BYS). We assessed the influences of wide and narrow roads on plant species diversity, biomass, and soil properties along transects running from the forest edges and adjacent forest interior. We used a “shape-dependent model” to explain the factors that determine the magnitude of road effects on forests. Some parameters measured in this study changed significantly with
increasing distance from the road to the forest interior along wide roads, including biomass (trees and herbaceous plants) and soil pH. However, there were no measurable effects on biological-environmental aspects along narrow roads; thus, they are compatible with forest conservation. The differences between wide roads and narrow roads are caused by road width, and road width is determined by a shape-dependent extrinsic disturbance. Specifically, the perception of forest road management should be changed in the future.

A standardized UAV coastal inventory protocol for consistent restoration project planning

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Rising water levels and increased frequency of extreme weather events are rapidly eroding coastlines around the world. Despite the challenges posed by ongoing climate change, restoration projects have the potential to mitigate the negative consequences of climate change in coastal communities. Using unmanned aerial vehicles (UAVs) as the method for documenting coastal restoration projects and natural disasters is becoming more popular as UAV technology is becoming cheaper and more user friendly. Global efforts are underway to restore coastal ecosystem services that lessen the impact of natural disasters and promote native biodiversity, but the integration of UAV acquired coastal inventory data is lacking consistency. I examined case studies from a diverse group of restoration projects using UAV derived data for best practices to create a standardized UAV coastal inventory protocol. I tested the proposed UAV coastal inventory protocol on a green infrastructure project on the southern coast of Lake Superior in Marquette, Michigan, United States. Lake Superior is experiencing record wave heights and water levels, intensifying coastal erosion and the need for restoration project monitoring. I propose standardizing coastal inventory data collection to allow for consistency in the comparison of future coastal restoration project results. The implications of comparative photographic analysis derived from the standardized UAV coastal inventory protocol will allow project funders to compare past project results with increased transparency. This standardized protocol will also help coastal resiliency planners compare strategies during the planning process of projects to inform decision making and local policy change.

An ecophysiological approach to mined site reclamation using tropical native grasses

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The rehabilitation of degraded iron-ore mining sites is a complex task due to irreversible environmental changes. Here we propose an ecophysiological approach for tropical iron-ore-impacted environments in Brazil using native grasses selected from reference grasslands. After characterizing the target site by analyzing microclimate conditions and substrate properties (e.g. pH, organic matter, nutrients), we focused on selection of tropical native grasses. Two species (Paspalum densum and Setaria parviflora) showed higher resistance to excess iron toxicity in nutrient solution. These grasses sustained high photosynthesis rates with uptake of potentially toxic iron concentrations through tolerance mechanisms. In rehabilitation initiatives, the grasses must establish in the sterile waste. Seeds from both species could successfully germinate in this substrate. The procedures for seed collection and storage were standardized. Germination maintained its initial values (50-60%) even after 11 months of storage. The abiotic stress effects were investigated in laboratory and field conditions. The grasses presented efficient drought-response mechanisms through effective stomatal control, energy dissipation, and reactive oxygen species scavenging, which contributed to its resilience in the sterile waste in dry seasons. The macronutrient limitation (mainly N and P) challenged the growth of grass species in
field conditions, but it was solved by adding controlled amounts of organic amendments (mainly poultry manure) and inoculation of seeds with mycorrhizae from a reference site. The species selection in laboratory conditions and the ecophysiological characterization of stress-responsive mechanisms appeared to be an efficient approach to promote the rehabilitation of degraded mining sites. Acknowledgements: CNPq, FAPEMIG and VALE S.A.

PACTO and ECOSIA: Joining forces to finance ecological restoration of the Atlantic Forest in Brazil

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Finding financial resources for ecological restoration has always been a challenge for environmentalists. This challenge has been getting harder through time, due to economic and political aspects that come into play. In Brazil, the Atlantic Forest (AF), one of the biodiversity hotspots in the world, needs urgent restoration interventions and deals with the conflict of being in the most densely populated portion of the country. Many institutions are working on conservation and restoration of AF, and they always run into the problem of lack of funding. One way out was the creation, 10 years ago, of the Atlantic Forest Restoration Pact (PACTO), a movement of Brazilian Society to integrate stakeholders (about 300 institutions) and strengthen their actions and results to achieve the goal of recovering 15 million hectares by 2050. PACTO has been able to gather up resources and recently had a partnership, captained by its current Executive Secretary on the Northeast Center of Environmental Research (CEPAN), with ECOSIA, a German Social Business that converts part of the profits of its search website into planting trees around the world. In this program, the financial resources from ECOSIA were used to support tree planting by Pact members in Brazilian AF between 2017 and 2018, resulting in 2.2 million native trees planted and 12 institutions supported in the Brazilian Northeast, Southeast and South regions. These results show the importance of those kinds of international partnerships and how coalitions can amplify the effects of restoration actions in challenging scenarios.

Does wildfire restore landscapes heavily fragmented by oil and gas exploration in the boreal forest of western Canada?

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Given the nature of exploration practices for oil sands development in the boreal forest of Canada, in-situ oil extraction has fragmented and affected large extensions of land by the creation of a network of thousands of kilometers of seismic lines. Moderate to high intensity wildfires are important drivers of environmental change, succession and stand development, and are known to ‘reset’ stand conditions to early successional stages. Consequently, it may be reasonable to assume that wildfire may have an ‘erasing’ effect on the industrial footprint; however, it is largely unknown to what extent this is true. This study evaluates the interaction of linear features and wildfire on different ecological properties with respect to burned and undisturbed natural habitats in peatlands by assessing biodiversity responses and changes in site conditions one year post-fire. Ground moisture on lines was significantly higher than that in the adjacent forest, which explains the little evidence of fire on the lines in relation to the burned adjacent forest. Species composition on seismic lines within and outside the burned area was similar, but different from that in the burned and unburned adjacent forest. These results suggest that fire did not erase the linear footprint at the studied sites and may exacerbate the influence of these lines on the recovering adjacent forest. These observations, however, are based on early post-fire responses and as such, longer term monitoring would provide further knowledge on how
these sites recover and regenerate from the cumulative effect of both wildfire and linear disturbance.

**Preservation and restoration of critically endangered Elim Ferricrete Fynbos on the Agulhas Plain through habitat restoration and preservation**

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The Grootbos Foundation, established in 2003, is dedicated to the conservation of the Cape Floral Kingdom and the uplift of communities therein. Through programs for skills development, social enterprise development, and sports, the Foundation reaches over 12,000 individuals a year. Grootbos is located on the edge of the Agulhas Plain, and has been described as one of the hottest biodiversity hotspots, with a species list totalling 2500 plant species, equating to 25% of all fynbos species. Ground truthing and GIS mapping has revealed that less than 5% of the critically endangered Elim Ferricrete Fynbos remains within the surrounding area. Because the soils are fertile and easy to plow, this vegetation type is under threat from agriculture. In addition, the rampant spread of invasive alien vegetation is threatening biodiversity and requires specialist clearing, an exercise that often has to be repeated multiple times in order to have any effect - a cost which very few landowners can afford. Once sites have been cleared, endemic and endangered conebush species (Leucadendron elimense, L. laxum, L. modestum, and L. stelligerum) can be established by collecting seed and propagating seedlings at the Green Futures Nursery.

Conservation cannot happen in isolation and because of this, it is critical to involve local communities in our conservation efforts through job creation, which can lead to habitat restoration, ensuring the integrity of the landscape for both human and animal inhabitants.

**The effect of season and fire on Seriphium plumosum L. forage quality in grassland communities**

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Woody plant encroachment is regarded as a form of rangeland degradation worldwide because it reduces the grasslands and subsequently livestock production. Although woody plants deter herbivory by chemical and structural defences, there is a need to enhance woody plant use by livestock to restore grassland since conventional control methods are slow, expensive, and sometimes impossible. The interaction effect of season and fire on Seriphium plumosum L crude protein (CP), neutral detergent fibre (NDF), total phenolics (TP), and condensed tannins (CT) concentrations was explored to test the resource availability and the growth rate hypothesis. We hypothesized that S. plumosum crude protein concentrations will be higher during the wet season because the plant is actively growing and resources are relatively available than during the dry season when the plant is dormant and resources such as water and light are inadequate for plant growth. Consistent with our hypothesis, S. plumosum CP content was significantly higher during the wet season in burned areas than in unburned areas, which were also significantly higher than similar CP concentrations during dry season at unburned and burned areas. Contrary, S. plumosum NDF concentrations were similar during the dry season in burned and un-burned areas and significantly higher than NDF concentrations during the wet seasons, which were similar in burned and unburned areas. This study suggests opportunity to use browsers in the restoration of S. plumosum encroached grasslands, especially during the wet season when S. plumosum CP concentrations are high and the fibres are minimal.
Madagascar Forest Landscape Restoration sites for better impact

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Madagascar is committed to restore 4 million ha of degraded land and forests by 2030 within the AFR100 initiative. An intersectoral dynamic was initiated, then formalized in April 2016, by the creation of a national committee on Forest Landscape Restoration and this by combining the promotion of actor consultation and a systematic analysis of data of different landscape categories. For the enhancing exchanges between African countries for the achievement of 100 million ha of Forest Landscape Restoration, the systematic approach based on ecological functions for the classification of priority landscapes deserves to be shared. This will emphasize the need of ecosystem services to guide the policy decisions to honor the countries commitment to the Forest Landscape Restoration target. This is for the benefit of the local population to move toward sustainable development. On the basis of the MEOR results on restoration opportunities, an approach reconciling three groups of ecosystem functions relative to the water resources management, biodiversity sustainable management, and the maintenance of the soil fertility has therefore characterised the methodology to guide the conduct of the Madagascar Forest Landscape Restoration commitment.

Integrated catchment management: A sustainable and equitable management of Lesotho's rangeland resources through grazing associations

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The Kingdom of Lesotho has a total land surface area of 30 355 square kilometers of which over 70% is estimated to be rangelands. Rangelands play a pivotal role for Lesotho as a country and for Basotho as a nation. Lesotho's rangelands are very important regionally and globally as major sources of high quality, abundant water, bio-resources and are also provide life support for plants, animals and humans. The excess water is exported to South Africa, which contributes significantly to the country's GDP in the form of royalties. However, Lesotho's rangelands are under severe and rapid loss of productive and very fertile soils due to a myriad of factors including excessive livestock grazing, causing extensive land and vegetation degradation characterized by severe erosion, thereby threatening people's livelihoods. To address the prevailing injudicious and unsustainable rangeland management practices, a study on sustainable and equitable management of Lesotho's rangeland resources through grazing associations was carried out. The main objective of the study was to assess the impacts of integrated approaches through grazing associations on Lesotho's rangelands. The study revealed that such integrated approaches use land resources holistically for sustainable production of goods and services to meet changing human needs and ensuring long term maintenance of productivity. The integrated approach to planning and management of rangeland resources used for this initiative has brought about positive changes in the community livelihoods through provision of social-economic, cultural as well as ecological demands. Improved rangeland has enhanced biodiversity maintenance, healthy ecosystems as well as ecological functioning.

Community engagement for socio-ecological resilience of coastal restoration projects: The Salish Sea Nearshore Habitat Recovery Program

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Community engagement builds both social and ecological resilience of restoration projects. This is particularly true in coastal areas, which are complex both ecologically and socially. The Salish Sea Nearshore Habitat Recovery Program builds on 20 years of community building towards coastal ecosystem restoration on the south coast of British Columbia, Canada. Funding was obtained by a small non-profit organization for seagrass and marine riparian restoration, and marine debris removal to support forage fish and juvenile salmon habitat recovery. The engagement and involvement of a broad community including Indigenous groups, coastal residents, all levels of government, academics, and industry has resulted in the equivalent of tens of thousands of dollars of additional support for restoration works within this program. The broader community is engaged in multiple steps of restoration including site selection, planning, and implementation. Recognition of the value of traditional and local knowledge, an investment in bringing people together, and ongoing communication have built collective enthusiasm and ownership for the project. Marrying restoration activities with cultural events is increasing ecological literacy and building the resilience of the work. Restoring or establishing connections between parties that do not otherwise work together is a fundamental step towards restoring ecosystems.

Villager's awareness of wetland restoration and its importance: The fight against climate change, Gujarat, India

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Wetlands provide globally significant social, economic and environmental benefits. Important functions of wetlands include water storage, groundwater recharge, storm protection, flood mitigation, shoreline stabilization, erosion control, and retention of carbon, nutrients, sediments, and pollutants. Indian wetlands are mostly connected with rivers and the water retention capacity is based on soil type and the availability of wells, canals, etc. Management of wetland ecosystems requires intense monitoring and increased interaction and cooperation among the various agencies (state departments concerned with environment, public interest groups, citizen groups, agriculture, forestry, urban planning and development, research institutions, government, policy makers, etc.) of Vadodara city lying in the semi-arid region of Gujarat. We have more than 50 wetlands and among these, 70% are in degraded condition due to anthropological pressure. Therefore, the main objective of this work is to make the local community aware of the environment, climate change and its effects, and wetlands and their importance. Moreover, involved local governments are the policy makers for sustainable development. We have already given awareness programs in more than 1,000 villages and to more than 1,000 school students. Now we want to create awareness and restoration of wetlands as this will also help villagers to generate their own revenue.

Potential for carbon sequestration in soil and plant biomass from an amended and reforested tailings impoundment

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Larges amount of mine residues are accumulated in tailings impoundments. The guidelines for preparing mine closure plans in Québec’s Mining Act, include minimal revegetation requirements using herbaceous plants or shrubs. However, these minimal requirements maintain the initial land-use change, when naturally occurring forest stands surrounded the mine sites. A factorial split-split-plot experimental design was established in 2015 on the non-acidic tailings impoundments of ArcelorMittal’s mine site located at Mount Wright, within the boreal forest in Quebec, Canada (52°46’ N, 67°20’ O). The design combined two different Norco treatments (mixtures of sown grasses and chicken manure) with three types of soil amendments (topsoil, paper mill biosolids, and a no amendment control), and two planted woody species (Pinus banksiana or Alnus alnobetula subsp.)
The objectives of the study were (1) to evaluate the amount of soil organic and inorganic carbon (SOC and SIC) and dissolved organic carbon (DOC) at different soil depths, and (2) to determine the survival and growth rate of the planted woody species after 3 years of growth. The preliminary results obtained indicate that the use of paper mill biosolids as a soil amendment allows better establishment of the two woody species, which results in higher survival rates. Tree survival rates are also significantly increased when reclamation treatments include the meadow (Norco) treatments. The use of topsoil as a soil amendment treatment induced significantly distinct soil organic carbon profiles, down to 1 m of depth beneath planted woody plants.

The Remanguezar Project – Restoring degraded mangroves in the Municipality of Vitória, Espírito Santo, Brazil: First steps toward the future

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The mangrove is one of the most extensive protected areas of the municipality of Vitória, with an area of 955.21 ha. In the 1980s the northwestern portion of the island was subject to a process of irregular occupation between the lowlands and the slopes, causing socio-environmental conflicts. In 2010 a multidisciplinary team of technicians from the Municipal Environment Secretaria - SEMMAM developed the Mangrove Ecological Restoration Project, called REMANGUEZAR, and aimed to restore areas whose anthropogenic pressure was impeding natural restoration. The project was based on two lines of action, the development of technologies adapted to local factors, and socio-educational and participatory processes of the local community. Technologies utilized were adapted from the literature, methodologies, and specific techniques for the Municipality, allowing the identification of areas, the production of seedlings, and techniques of planting and replanting. Remanguezar was the first project in the state to restore mangroves with community participation, and its main contribution was the establishment of new paradigms, breaking with the current common sense that once degraded, the mangrove could not be restored. The actions involved theoretical and practical classes for 50 students and teachers of the EEEFM Almirante Barroso, aiming not only to raise awareness and training to carry out the restoration, but also to share experiences as agents of this process. The target areas of the restoration totaled 5000 m², in the Lameirão Island Municipal Ecological Station, and received approximately 5,500 seedlings of the typical species.

Aboveground biomass recovery of restoration plantings in the Brazilian tropical forest

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Tropical forests are biodiverse ecosystems that contribute to numerous ecosystem services, being a crucial component of the global carbon cycle. Large areas of tropical forests have been converted to various land uses, thus altering carbon and water cycles locally and regionally. The restoration of some of the converted areas has been highlighted as an important mechanism for mitigating climate change, using the carbon sequestration and carbon storage capacity of trees in their biomass. However, it is yet poorly understood to what extent restoration plantings can provide equivalent levels of ecosystem services to those provided by old-growth forests. In our study we compared above-ground biomass (AGB) recovery over time in 87 restoration plantings with the biomass of old-growth forests in Sao Paulo state, Brazil. Our goal was to determine the time it took for restoration plantings to reach 50% of AGB of old-growth forests. AGB was calculated by using an
allometric equation; adjustment and model selection for AGB was performed in relation to the age of planting. The resulting model followed a non-linear sigmoid trend and suggested that plantings recovered 50% of the AGB of reference ecosystems at ca. 7 years after planting. Our results highlight the rapid biomass recovery potential of restoration plantings with significant carbon mitigation potential, especially important for highly degraded landscapes. However, we emphasize the need for protecting natural vegetation, due to its irreplaceable value for biodiversity conservation and numerous ecosystem services.

**Evaluation of the early performance of plants for the artificial enrichment of tropical forests in Brazil**

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Knowledge of the early performance of plant species for forest enrichment can improve the success of this restoration strategy. Considering the variation in survival in response to microhabitat and interspecific interactions, we evaluated variables (basal area, direct light under the canopy) of two distinct forest conditions (degraded forest and forest undergoing restoration) in the Brazilian Northeast Atlantic Forest and their effect on early performance of four tree species (early and late secondary) and one threatened palm. We considered the functional attributes: shade tolerance, faunal pollinators, and dispersion. We installed 60 plots, each 90 m² with 12 replications for each of the five species. We planted 30 seedlings/plot and evaluated them four times in 12 months. Our results showed that the forest structures differ (basal area: p<0.001; direct light: p=0.037; df=58), and both direct light and basal area are higher in forest undergoing restoration. However, there was no significant correlation between these variables and species' survival. Nevertheless, the survival was higher in the forest undergoing restoration for all species (p<0.01) with overall survival 93% (sd=2.14). In the degraded forest, there was 43% total plant survival (sd=12.8), and the positive effect was only for two species (early and later secondary) (p<0.001) with higher than 90% survival (sd=1.53). We conclude that forest condition has an effect on the early performance of species and is notably heterogeneous in degraded tropical forests. It is necessary to consider the condition of this microhabitat to increase the success in degraded tropical forests.

**Socio Economic and ecological effects of chemical control method on aquatic weeds on South African dams and rivers**

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Eichhornia crassipes (Water hyacinth), an aquatic plant originally from South America, is a free-floating vascular plant known to cause major ecological impacts on river systems. Water hyacinth was first recorded on the Cape flats in the early 1900’s and since then has spread through the country. It is listed as a category 1b alien invasive species. The resilience of the weed is attributed to the highly eutrophic or nutrient enriched state of South African rivers. The Duzi-uMgeni Conservation Trust (DUCT) is a non-profit organisation dedicated to improving the river health of the uMsunduzi and uMngeni Rivers in Kwa-Zulu Natal. One of their key strategic objectives is the removal of alien invasive plant species in the water courses of the riparian zones. Water hyacinth has been a significant problem, choking sections of the river and dams. In 2012 - 2013 weevils were released as a biological control agent in Pietermaritzburg on the Duzi river but with limited success. As a result, since 2013 DUCT has been actively managing the known populations of the weed species, utilising chemical and manual removal control with different types of equipment and labour intensive practices. In 2019 the Duzi Canoe Marathon race survey attested to extreme low E. crassipes volumes during the race for the first time in decades. This major success is a
testament to the management efforts undertaken in the past years, and lessons learnt could be applied in other river courses across South Africa.

**Plant-canopy effects on natural regeneration in sites under restoration: Do tree species matter?**

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How does species choice influence ecological restoration outcomes? In order to answer this question, the goal of this study was to assess the community structure and species richness of natural regeneration beneath the canopy of four native species from the Atlantic Forest (Guarea guidonia (L.) Sleumer, Inga edulis Mart, Nectandra membranacea (SW) Griseb, and Piptadenia gonoacantha (Mart.) J.F. Macbr). Our study was conducted at a 13-year-old restoration project (native tree species plantation) at the Guapiaçu Ecological Reserve (22°25'10" S and 42°46'13" W) in Rio de Janeiro State, Brazil. We randomly selected 14–16 focal individuals of each tree species with a canopy diameter of at least 2 m and without canopy overlap with other species. Our results pointed out that abundance, basal area, and species richness were significantly higher beneath Inga compared to Nectandra and Guarea. Whereas the lowest values observed in Guarea may suggest its negative effects under natural regeneration. Therefore, the use of Inga edulis in restoration program projects is highly recommended. Thus, we believe that this essay can offer a significant contribution to restorationists engaged in meeting the ambitious restoration targets. Finally, we also intend to emphasize the relevance of regarding tree species effects, positive (e.g. facilitation) or negative (e.g. inhibition), instead of their simple response (mortality and initial growth) in drawing up a list of potential species to be utilized in ecological restoration initiatives.

**Applied nucleation in silvopastoral systems: Restoration, livelihood and provision of multiple ecosystem services in rural landscapes**

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High Biodiversity Silvopastoral System (SPS nuclei) was designed in a participatory framework to embrace ecological restoration, agroeconomy, and livelihoods in Southern Brazil. Our goal was to restore and rehabilitate the ecosystem while synergistically increasing food security from non-timber forest products (NTFP), provide shade for livestock, enhance tree biodiversity per hectare (50 native species), improve connectivity, and change the pasture matrix to a scattered forest-like landscape. In each hectare, 40 nuclei (5 m x 5 m) were fenced off (10% of pasture area). Inside each nucleus, agroforestry was planted with 20 native trees (8 spp from 4 functional groups), 4 shrubs, and 4 bananas. After five years we measured soil attributes, carbon flow, microclimate and ambiance, bird assemblages and ant fauna, forage characteristics, and economic feasibility. SPS nuclei and primary forest (F1) had higher total soil organic carbon and nitrogen than treeless pasture (TLP) and secondary forest (F2). The average temperature of SPS nuclei was 3-4 °C less than TLP with the lowest means of air temperature, illuminance, wind speed, and soil surface temperature. We recorded 108 species of birds. SPS nuclei adds structure to the landscape, acting as stepping stones and facilitating movement between fragments. SPS nuclei produces 111.231 kg of tree biomass accounting for 22.740 kg of carbon sequestered per hectare over the five years. The system provided shade, banana, and rose pepper in the 2-4th year and açai in the 7th year. Farmers recover restoration costs in the 7-8th year. As a broad public policy, SPS nuclei could restore while enhancing livelihood.
Multi-dimensional training among Latin America's restoration professionals

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The ambitious restoration commitments made by Latin American countries have increased the demand for professionals having multi-dimensional training in ecological restoration; however, little is known about the kind of training that professionals are currently receiving. Through an online survey, we explored whether restoration professionals in Latin America have been trained on the ecological, socioeconomic, and management dimensions of ecological restoration, and their perceptions of training constraints and curricula needs. Half of the 411 respondents simultaneously work in academia, governments, and non-governmental organizations, lessening the typical division between the science and practice of restoration, and suggesting the need for stronger multi-dimensional training to adequately respond to different needs and expectations. Over 80% received formal academic training in fields relevant for restoration and most respondents also reported attending interdisciplinary courses. Training was more focused on the ecological dimension of restoration compared to socioeconomic or management dimensions. Respondents have similar education levels (i.e. most respondents have postgraduate degrees), independently from the organization type in which respondents work, and multi-dimensionality among organization types was slight. Professionals expressed a need for training opportunities not demanding full-time dedication. Although increasing training opportunities in socioeconomic and management dimensions is needed, we highlight opportunities to reinforce multi-dimensional training on restoration through organizational and institutional training, and collaborations among organizations.

Do you really want to use organic matter amendments in your wetland restoration?

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Organic matter (OM) amendments have been suggested as a strategy to improve wetland restoration success. We performed a critical review of restoration studies where OM was utilized. Using a scoring system, we identified the likelihood that amended soils would improve evaluation metrics in several categories, including plant growth, soil physical properties (e.g. bulk density), long-term carbon accumulation, denitrification and development of redoximorphic conditions. Results using allochthonous OM were surprisingly poor, in some cases favoring undesired species and reducing diversity. Salvaged wetland soil, sometimes used as a source of OM, performed somewhat better. Wetland restoration is a complex process, and no one study, or even one review, can provide definitive answers concerning the best strategies. OM amendments do have benefits, and in most cases do little harm, but based on our review, we conclude that our efforts would be better directed away from OM toward more effective remediation strategies.

Effect of light control and irrigation on seed germination of translocated forest soil in SW China

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The poor germination of woody species from translocated top soil in relation to their mother forest had blocked the practices of top soil translocation in forest restoration.
Determination of limiting factors and mechanism is theoretically and practically significant. We applied 2 factors (light control and irrigation), 4 levels, 9 orthogonal treatments designed after an optimum regression model to determine quantitatively the effect of light and irrigation on propagule germination of translocated forest top soils. The experiment was conducted at the end of dry season (May, 2017) on manual translocated semi-humid natural forest soil with 4m x 4m per site, 10 replicates each treatment in SW China. The monthly seedling census indicated that larger number of woody species stored in soil propagule bank, both present, or not identified in the mother forest germinated, making an even richer woody species assembly than its mother community. Light controlling level had linear or quadratic correlation with the number of species and seed density of month census data during the germination season (June-November). Irrigation had only significant effect on propagule germination at the first month, which might due to the natural water supply followed by the coming rain season. The moderate level of light had lead to the highest woody density and richness of the germinated community. In conclusion, controlling of key germination factors, such as light can improve the germination of translocated top soils. However, further survival data will be needed to approve those countermeasures on flora community assembly.

Soil seed bank as an indicator of resilience in areas with tailings mining deposits of the Fundão Dam breach, Minas Gerais, Brazil

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In this study, the soil seed bank with or without the influence of tailings transported and deposited by the Fundão dam failure in Mariana, Minas Gerais, Brazil, was evaluated. These are: 1) Natural regeneration on tailings, 2) Planting of seedlings on tailings, 3) Native forest (reference ecosystem). A total of 30 fixed plots of 2x2 m were located in each area. The soil was harvested to the depth of 5.0 cm (43.5x29.6x7.5 cm) for evaluation, for 6 months by the germination method. In the natural regeneration area, there were 11,766 individuals, 64 species and 23 botanical families. In the planting of seedlings, 5,456 individuals, 69 species and 23 botanical families. The reference ecosystem there were 3,880 individuals, 94 species and 36 botanical families. For the Shannon Index (H’) and Equability (J’), the following values were obtained: (H’) = 2.087 and (J’) = 0.502 - natural regeneration on tailings; (H’) = 2.550 and (J’) = 0.602 - planting of seedlings and; (H’) = 2.945 and (J’) = 0.645 - reference ecosystem. It was verified that in the natural regeneration area, there was a higher density of tree species than in the area of planted seedlings. This study reflected the differentiated resilience of the areas affected by the tailings, the proximity of native forests being a determinant factor. These results demonstrate that the seed bank is a good indicator of the forest restoration in the areas affected by the iron tailings.

Saving Critically Endangered Cape Flats Sand Fynbos from extinction: Managing fire, alien invasives, and plantings at Tokai Park

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Tokai Park is a core conservation site for the Critically Endangered vegetation type Cape Flats Sand Fynbos (CFSF), endemic to the Cape Town Metropole, South Africa. The national conservation target of 30% (required to conserve 70% of CFSF species) is unattainable as only 10% remains, mostly as degraded urban areas. Tokai Park constitutes one of the largest patches of CFSF available for restoration from pine plantations. Although spontaneous regeneration of remnant seedbanks occurs after pine removal, a post-clearing burn is necessary for the optimal regeneration of indigenous plant species. Both plant abundance and species richness were significantly higher at sites with hot fires than at those not burned or burned with cool fires. Importantly, annual invasive alien species (mainly Mediterranean grasses and herbs) were significantly reduced (both in cover and
abundance) by hot fires. Although fires flushed alien invasive Acacia seed banks, they also drastically reduced pine regeneration. Two guilds are largely absent from the seedbanks: resprouting shrubs and overstorey plants with canopy-stored seed banks. Attempts at restoring the latter with seeds sown post-fire have been very successful. By contrast, plantings of rooted material of resprouting and locally extinct species have generally been a failure. Further work is needed, but the successes indicate that habitat matching and clumped plantings may be critical factors with summer drought and winter flooding accounting for most of the mortality. Restoration can be achieved, but improving the collaboration between various role players is necessary for efficient management.

Characterization of adult functional traits of local populations and cultivars of the perennial bunchgrasses Sandberg bluegrass and bottlebrush squirreltail

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Plant functional traits offer an understanding of the plant's ability to cope with varying environmental stresses. The objective of this study was to evaluate the above and belowground adult morphological and chemical composition traits of local populations of Sandberg bluegrass (Poa secunda J. Presl) and Bottlebrush squirreltail (Elymus elymoides (Raf.) Swezey) collected in Nevada and their cultivated varieties. One seedling from each local population and cultivar was transplanted into individual tree pots (20.4 kg of Orr sandy loam soil) in November 2015 and remained in the pots until June 2016. Traits evaluated were, plant height, leaf length, inflorescence length, shoot biomass, root morphological traits, and root carbon and nitrogen content. Traits means were considered different at P < 0.05. For Sandberg bluegrass, the cultivar ‘Mountain Home’ and the population from Panther Valley tended to have greater biomass than the population from Button Point, but overall, the average of the two cultivars (10.8 g/plant) did not differ in shoot biomass relative to the local populations (7.6 g/plant). For squirreltail, plant height for the George St. Sonoma and Grass Valley populations (71.3 cm) was greater than for the cultivars ‘Toe Jam Creek’ and ‘Vale’ (40.5 cm) but cultivars had greater biomass (12.6 g/plant) than the local populations (5.8 g/plant). Total root length and root diameter were not different among the Sandberg bluegrass and squirreltail populations. Results indicate the similarity of these populations and may ease the fear of cultivar vigor and the notion of maladaptation of cultivars for restoration in degraded ecozones.

Germination potential of four palatable species of the semi-arid Karoo region of South Africa

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The rangelands of the semi-arid Succulent Karoo and Nama Karoo biomes of central and south-west of South Africa are often degraded due to injudicious livestock management. Palatable plants have been reduced in number or extirpated from some of these rangelands. Attempts have been made to return palatable plants by reseeding, often with disappointing results. The objectives of the study were to determine the causes of pre-sowing seed mortality and the effect of drying, planting depth, and storage time on seed germination. The seeds of four palatable Karoo plant species were selected to be subjected to viability testing and germination trails. The seed viability of all four species was found to be below 50%. Drying as a pre-treatment only significantly improved the germination of Osteospermum sinuatum (p<0.05). The seeds of O. sinuatum and Eriocephalus africanus germinated reasonably well throughout the study period of one year, while the seeds of Chaetobromus involucratus and Gorteria integrifolia germinated poorly during the first six months after harvesting, with germination improving markedly over time. Seedling
emergence of all four species studied was significantly higher when planted at the substrate surface compared to seeds planted at 10 mm depth (p<0.001). This study shows that while the viability of the harvested seeds is low, the appropriate pre-treatment, seed age, and planting depth result in a significant increase in germination. This should provide a greater chance of establishing palatable plants in rangeland restoration projects.

**Evaluating ecosystem services of restored Prairie Pothole wetlands: How long does it take for restored wetlands to resemble natural wetlands?**

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Wetland restoration plays a pivotal role in the conservation and management of wetland ecosystems, but little is known about the success of restoration when measured in terms of ecosystem services, particularly in the Prairie Pothole Region (PPR). The PPR is characterized by millions of small depressional wetlands resulting from glacial retreat. Many of these wetlands were drained for agricultural purposes. With a long history of restoration, the PPR is uniquely suited for assessing whether ecosystem services are restored, and how long newly restored wetlands may take to resemble natural habitats. Beginning in the summer of 2019, we will assess differences in biogeochemistry, plant and invertebrate diversity, and water chemistry between undisturbed wetlands, older restorations, and more recent restorations. We predict that restored wetlands will not match the ecosystem service provisioning of undisturbed sites, but will become more similar with time since restoration.

**Sustainable pasture management: Traditional approaches. A case study of Bel-Aldy ayl aimak in Jalal-Abad Province, Kyrgyz Republic**

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The Kyrgyz Republic is a landlocked country with mountains covering 94% of the country. Sixty-six percent of the population is involved in pastoralism. The most important resource base for livestock production is the pastures, which comprise 85% of the agricultural land. Eighty-four percent of the country’s pastures have been subjected to different types of degradation. Much pasture land is situated on steep slopes (> 30 degrees), a natural obstacle for agrotechnical measures for restoring pastures. The Bel-Aldy municipality has been conducting an experiment on revival of the traditional approach for ecological restoration of pastures. A feature of this approach is adaptation to natural conditions of the specific territories. The culture of local herders is associated with nature, and traditional knowledge of seeding native grasses has been passed on from generation to generation. Traditional practices following the seed cycle include all steps for restoration purposes. For instance, seeds are mixed with moist local soil, which guarantees the ingress of seeds into the soil. A special part of the traditional approach is to ensure that seeds get into the soil by trampling with livestock hooves. At first glance, these traditional practices are very primitive, but they have passed the test through the centuries and have proven to be a reliable tool for the ecological restoration of pastures through the efforts of the herders themselves. The result of the research project will be the development of an adapted guide for herders on the ecological restoration of pastures based on traditional knowledge and practices.

**Drivers of natural regeneration in Desa’a forest, northern Ethiopia: Its implication for conservation and restoration of Dry Afromontane forests**

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Natural regeneration is one of the primary restoration strategies for disturbed forests. The impact of natural regeneration is influenced by environmental factors such as soil type and rainfall. In the Desa’a forest, northern Ethiopia, natural regeneration is an important process for the conservation and restoration of the Dry Afromontane forests.
In forests such as Desa’a where anthropogenic disturbances prevail, diagnosing multiple factors and their effect on the availability and abundance of natural regeneration is critical. The study area was divided into 2 km distant transects. Within each transect, 2 km distant 400 m² plots were laid and the centre of the plots was extracted using GIS, fed to Garmin GPS, and navigated during the field inventory. Inside every north-most corner of the square plots, 9 m² subplots were nested. In the 400 m² plots, tree and shrub parameters and possible disturbance severity, biophysical and climatic variables were measured and extracted physically and using GIS techniques. In the 9 m² plots, seedlings were counted and identified. Environmental factors were screened using PCA and VIF. Determinants of seedling availability and abundance were analyzed using binary logistic and negative binomial regressions respectively. Species diversity was calculated using Shannon indices. 1913 individual seedlings from 56 species and 35 families were recorded. 77.5% of the seedlings were from ten species. The most abundant species and family were Dodnaea angustifolia and Fabaceae respectively. The presence of seedlings was controlled by a combination of climate, the presence of specific species in the seeding, and disturbance variables (p<0.01). Seedling abundance was dictated by the presence of specific species in the canopy and seeding, climate variables, canopy species richness and location gradient (p<0.01). Species that are important to initiate restoration and the most important variables that can increase the success of restoration in the Dry Afromontane forests were identified.

Local knowledge and landscapes in Caatinga restoration in the rural community “Serra do Retiro”, Bahia, Brazil

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Involving local people when planning ecological restoration projects can be crucial in engaging stakeholders. Often, actions aimed at restoring certain areas, e.g. areas of collective use, may be critical to ensure resource use sustainability by local communities. We analyzed the landscape context of the rural community “Serra do Retiro” in the Brazilian Caatinga (Glória municipality, Bahia state), characterized by environmental degradation and water scarcity, through the lens of social representation on aspects related to landscape changes. We therefore identified issues to be focused on for restoration projects. We conducted six semi-structured interviews using the snowball method with residents known to have experienced changes in the landscape, as well as a focus group activity (residents' association) on landscape perceptions and preferences. Participants reported that the local landscape underwent significant changes that considerably affected people's way of life. Hunting and harvest of medicinal plants and trees were reported to have become difficult due to the decreased availability of resources. Increased difficulty in accessing water was also reported. Participants demonstrated willingness to recover the landscape, though they find it difficult or even impossible unless support from the government and research institutions is provided. In the focus group activity, which had a younger audience, more positive perspectives were presented regarding alternatives for the local landscape's future. Restoration initiatives should aim at restoring vegetation cover, especially in key areas such as around springs. A joint effort between local communities, government, and research institutions can contribute to restoring the local landscape, especially through local awareness-raising.
Impact of a subtropical thicket restoration project in Baviaanskloof Nature Reserve (South Africa): An insight into the changing climate

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The Baviaankloof (South Africa) is popularly known as “Valley of Baboons”. It is one of the global biodiversity hotspots that contains endemic species. But overgrazing by goats has degraded this region. The South African government invested in planting cuttings of Spekboom (Portulacaria afra) to restore the degraded landscape. In the period 2004-2016 Spekbooms were planted under the Subtropical Thicket Restoration Project (STRP) in the Baviaanskloof Nature Reserve. Many studies have been done to analyse the survivorship of planted Spekboom. Some studies also focused on studying the effect of restoration methods on the condition of the soil, water, carbon sequestration and biodiversity. It would be also interesting to study the change in meteorological variables over a long period to understand climate change in this area. The impact of STRP on climate can be also studied over the area. We have analysed meteorological parameters using re-analysis dataset ERA 5 over Baviaanskloof Nature Reserve for the period 1990-2018. We have observed a decrease in precipitation and cloud cover in recent years. However, surface net solar radiation and temperature have shown an increasing trend. These climatic variables indicate that there is a need for more extensive and long term projects like STRP to improve the degraded ecosystem.

A geomorphological approach to the prioritisation of wetlands for sediment trapping: Tsitsa River Catchment, South Africa

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Wetlands play an important role in water and sediment dynamics in the Tsitsa River catchment, South Africa. They are most common along lower gradient reaches in the upper to mid-catchment. Construction of two multipurpose reservoirs has been proposed for the lower catchment, but high sediment delivery from upstream threatens the longevity of the impounded reservoirs. Wetland gully and channel incision has increased landscape sediment connectivity, so current catchment management efforts are focused on restoring wetland sediment trapping potential (buffering function) to curtail future reservoir sedimentation. While rehabilitation schemes are ongoing in the upper catchment, there is a need to broaden these schemes to the middle and lower catchment where wetlands have larger catchment areas. Given that resources for wetland rehabilitation are limited, it is important to prioritize management efforts for those wetlands that: 1) have relatively high sediment trapping potential; and 2) are capable of being rehabilitated sustainably with little cost. Here, we use geomorphological insights to address this management prioritization issue. We have undertaken a catchment-wide wetland assessment in terms of their landscape setting, geological controls, spatial extent, degree of incision, and sediment input. Wetland slope, upstream catchment area, and degree of incision were identified as the key factors, suggesting that moderate to low gradient wetlands in mid-catchment positions with limited incision should be the main focus. Low cost, sustainable management options for wetland rehabilitation need to be designed, preferably measures that promote good vegetative cover (e.g. grazing management and reed bed establishment) to maximise sediment trapping potential.

Active rehabilitation following alien clearing in the Berg and Breede River Catchments, Western Cape

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¹307
Active rehabilitation of riparian habitat is underway to improve ecological infrastructure at various sites in the Berg and Breede River Catchments of the Western Cape, South Africa. If these efforts are to be efficient, successful, able to compete for funding, and adaptive, they must be evidence-driven. Thus, the aim of this study is to evaluate the effectiveness of various rehabilitation efforts at ten sites along the Berg and Breede Rivers. We aim to: (i) evaluate rehabilitation success by quantifying native vegetation recovery, plant species richness, and diversity; (ii) investigate the effect of other factors on rehabilitation success; and (iii) determine the effect of initial investment or input on rehabilitation success. The study will be conducted in ten paired rehabilitated and degraded sites in the two study catchments. To quantify native vegetation recovery, three 5 x 5 m plots will be surveyed within rehabilitated areas and in adjacent non-rehabilitated areas at each site. Path analysis will be conducted to establish the direct or indirect effect of key variables, such as various aspects of local geomorphology and hydrology as well as management interventions on native vegetation recovery. These variables, including other abiotic parameters, will be measured during the vegetation surveys. Establishing the extent to which active rehabilitation initiatives have been successful in promoting native vegetation recovery is vital for further up-scaling and replication across the region and possibly also nationally.

Case study - Environmental recovery in a permanent preservation area after an emergency intervention in the Santo Antônio do Grama's Creek, Minas Gerais, Brazil

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Due to two leaks from a pipeline in the municipality of Santo Antônio do Grama, state of Minas Gerais, Brazil, mitigating and compensatory measures were proposed to stabilize and recover Permanent Preservation Areas (PPAs) of the creek. The recovery actions include 18 rural properties, encompassing 8 km of the creek channel and were based on the Federal Law 12.651/12 to define the width of the PPAs. The extension of PPAs vary according the audit modules of the properties, resulting in narrow strips amidst man-made fields. According to this premise, out-of-conventional methods were proposed specifically for the study area, with priority for the recovery and reintroduction of hygrophilous and heliophilous species, with a predominance of herbaceous and shrub habits and, in particular, pioneer trees. In addition, bio-engineering techniques were applied for restructuring and stabilizing the forest planting, edges, and channel of the creek. Firstly, all iron ore deposits were removed from the creek bed and margins. Subsequently, flora were rescued, transplanted, and reintroduced, and manual sowing and plantings of native seedlings were made to cover the edges, channels, and PPAs. The activities finished in March 2019, after months after the incident. After that, monitoring activities were started in the areas for approximately 30 months and, thus, new scientific data were produced. The results already demonstrated that the area features an environmental gain, with higher quality than the previous scenario.

Degraded area recovery and socio-environmental development of small family farmers in the Mucuri river basin in Brazil, through the Nascentes do Mucuri project

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The Mucuri river basin begins in the cities of Ladainha, Malacacheta, and Poté in Minas Gerais state, Brazil. These municipalities have some of the lowest ratings on the human development index of the state, marked by drought events and by the poorly developed economy. Within this context, the Nascentes do Mucuri Project aims to strengthen the families in the territory, stimulate preservation and restoration actions on permanent protection areas, social and economic development by seeking to improve families' income, food security, and water conservation in the Mucuri River basin. The team, comprising mostly regional technicians, works directly with the local people, valuing their knowledge, exchanging knowledge, and identifying productive potentials and individual family needs. The project team also promotes pedagogical workshops adapted to the region in order to qualify these actors, aiming to promote a greater autonomy in their decisions within the property, not only for them to be able to choose the restoration techniques which will be used in their farms, but also for them to manage the practices redefinition considering soil and water conservation within their property. Beginning in July 2018, the project has already visited more than 1300 properties, working in a format that respects and values traditional knowledge. In this way we are building knowledge together with rural producers.

The challenge of restoring salinized environments in irrigated arid lands of Western Argentina: Salt tolerance thresholds in Prosopis species

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The irrigated oases of the arid lands of western Argentina present large areas with low suitability for traditional crops due to soil salinization caused by inappropriate irrigation practices and the ascent of the phreatic level. Forestation with the native trees Prosopis flexuosa and P. chilensis has emerged as an alternative to the environmental and productive recovery of these areas. These species could be useful owing to their stress resistance and multiple uses (posts, firewood, and hardwood) and environmental benefits they provide. In order to select suitable genetic material for restoration, we assessed the salinity tolerance of P. flexuosa and P. chilensis from three different origins by conducting field experiments on typical agrosystems at Media Agua, San Juan, Argentina (31°52' S - 68°23' W). Sixteen plots were experimentally forested (2 species x 3 origins x 20 plants) in a salinity gradient on the irrigated oasis. At each plot, we measured plant survival and growth annually. Additionally, we analyzed the spatial heterogeneity of soil salinity within each plot and we correlated it with spatial variability in survival and growth. We observed a significant and negative correlation between soil electrical conductivity and biological variables. Survival was higher than 50% up to 40,000 µS/cm. Differential growth and mortality within the plot was observed as a response to heterogeneity in soil salinity. Our data suggest tolerance of both species up to high salinity levels. This tolerance was relatively independent of the origin, the differences in growth observed among origins growing in optimal conditions were maintained.

Limitations of indigenous tree species colonization in subtropical plantations: Implications for restoration

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Increasing colonization of indigenous tree species in subtropical plantations in South China has been an important objective of current restoration and forest management research. In this study, we examined the species composition of soil seed banks in four typical plantations and assessed seedling establishment and performances of introduced
indigenous tree species by sowing seeds and transplanting seedlings. Results showed that no viable indigenous tree seeds were found, and species diversity in the seed banks was low in the plantations. Removal of understory vegetation and litter could increase seedling emergence but could decrease survival of emerged seedlings. Seed size was important in affecting seedling establishment. The large seeded species had higher seedling emergence and the emerged seedlings were robust. Survival and growth of transplanted seedlings were generally increased by removal of understory vegetation and litter. Responses of the transplanted seedling to environmental factors was species specific, e.g., the effects of light on seedling survival and growth were correlated with the shade tolerance of the species. In conclusion, the absence of indigenous tree species seeds in the soil seed banks limits regeneration and has probably contributed to arrested succession at the pioneer community stage. Sowing seeds or planting seedlings of suitable species in conjunction with suitable site preparation may be an effective method of establishing indigenous tree species in established plantation where seed sources are absent and accelerate succession to a more natural and desirable plant community.

The creation of “Ecosystem Core” hypothesis to explain ecosystem evolution

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Humans have dramatically changed natural ecosystems around the world as their capacity to manage their environment for multiple uses has evolved in step with agricultural, industrial, and green revolutions. Numerous natural ecosystems have been replaced by various semi-artificial or artificial ecosystems, the ecosystem has changed. So far, there is no definite theory about the mechanism for evolution of an ecosystem. Even though the discipline of community ecology has a relatively well-described and comprehensive theory of succession, at the different research levels, is it the same mechanism for ecosystem evolution and community succession? What is the factor that drives ecosystem evolution? This abstract puts forward the “Ecosystem Core” hypothesis to scientifically address the above problems. We explain the basic meaning of this hypothesis, review its theoretical foundation, and provide a demonstration (based on emergy theory) of the hypothesis, and discuss the mechanism of ecosystem evolution. The “Ecosystem Core” hypothesis reveals the quantitative relationship between the energy input and ecosystem evolution. The input of artificial auxiliary energy is the fundamental cause of ecosystem evolution. Different combinations of natural and purchased emergy are coupled to maintain the same ecosystem under different environmental conditions. Ecosystem evolution is related to, but distinct from, the theory of plant community succession in that it includes succession and systematic reconstruction. The former is the functional evolution of the ecosystem without structural change. The latter is a new ecosystem that is reconstructed according to human purpose and need.

Relative changes in the dominant and non-dominant species influence species richness and biomass after long-term grazing exclusion in the alpine grassland in the Qinghai-Tibet Plateau

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Fencing to exclude grazing is an effective measure to recover the biomass and species richness of the degraded alpine grassland in the Qinghai-Tibet Plateau. However, it seems that the restoration effects are negative after long-term grazing exclusion due to intensified competition induced by an increase in the dominant species. Here, two grazing exclusion experiments with 9-year and 10-year grazing exclusion were selected to assess the hypothesis. Results showed that species richness decreased after 9 y of grazing...
exclusion and 10 y of grazing exclusion while aboveground biomass was significantly reduced after 10 y of grazing exclusion. The changes in dominant, subordinate species and rare species were different; grazing exclusion obviously reduced the number and the biomass of subordinate species and rare species, while the enhancement in biomass of dominant species was observed after 9 y of grazing exclusion. Grazing exclusion obviously changed the dominance-diversity curve and promoted the relative abundance of the most dominant species. The high correlations seemed to suggest that the increase in the relative abundance of the most dominant species might induce the loss of the subordinate species and rare species. Thus, after long-term grazing exclusion, subsequent measures, for example, light to moderate grazing, should be considered to release the competition exclusion effect of the dominant species.

**Determining the suitability of dredged sediments and carbon-based soil amendments for mitigating sea level rise effects in drowning coastal marshes**

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Thin layer sediment placement (TLP) is a method used to mitigate sea level rise and extend the lifespan of drowning wetlands, but recent work has highlighted the development of acid sulfate soils in TLP projects. The purpose of this study is to determine the viability of dredged benthic sediments with three distinct sediment textures in TLP projects (medium silt, fine sand, medium sand) and to test the ability of soil amendments (biochar, compost) to facilitate plant re-establishment and ameliorate acidic conditions. We grew Salicornia pacifica, Spartina alterniflora, and Spartina patens in a greenhouse for 130 days under simulated tidal conditions in raw benthic sediments of varying textures and in one type of quarry fines. Additionally, we tested the effectiveness of soil amendments by growing S. alterniflora in low nutrient coarse sand with and without biochar and compost and by growing S. pacifica in soils prone to develop acid sulfate conditions with and without biochar. Net ecosystem exchange measurements suggest that coarse sediment textures were associated with higher rates of productivity, particularly in S. patens and S. pacifica, presumably due to increased growth caused by better drainage conditions as they are less flood tolerant. Soil additives were not found to enhance growth or mediate soil acidification; however, they were observed to increase total alkalinity. These results suggest that coarse sediments may overall be best for TLP and incorporating biochar may have added benefits unrelated to plant productivity, although further testing of biochar is required.

**Opportunities for success: The future of ecological restoration on the Colorado Plateau**

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The Colorado Plateau is one of North America’s five major deserts and encompasses 340,000 km² in the western US. In addition to its vast spatial extent, the Colorado Plateau offers a number of opportunities for nationally-relevant restoration because of the large proportion of public lands and dominant tourism and recreation industries. For example, ca. 75% of the Colorado Plateau is managed by federal and tribal agencies and > 30 million people visit the Plateau’s public lands each year. While clearly important and utilized, our knowledge of effective ways to manage Plateau ecosystems remains poor relative to other U.S. deserts. Colorado Plateau ecosystems also maintain restoration challenges and opportunities that are unique from other systems given the multiple land management agencies managing substantial tracks of land. Each of these subscribe to varying policies that determine allowable land use practices and impacts, restoration needs and desired outcomes, and perceptions of management needs in a changing climate. The Colorado Plateau is also expected to undergo large ecosystem shifts in the face of climate change. Here we describe the current state of Colorado Plateau restoration science and underscore key challenges and opportunities to improving our capacity to maintain the myriad of services provided, including energy development, recreation, grazing, and wildlife habitat. We highlight past research and future needs related to key restoration concepts including considering and designing novel ecosystems, impacts related to climate change, the importance of utilizing genetically appropriate seed, and values and perceptions of restoring systems on the Colorado Plateau and beyond.

Vegetation restoration alters the diversity and composition of bacterial communities in a derelict manganese mine site

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Vegetation restoration is vital for the rehabilitation of degraded ecosystem functions in mining areas. However, the effect of vegetation restoration on bacterial communities following the establishment of plants remains unclear. In the present study, the diversity and composition of soil bacterial communities of three vegetation types (Zoysia matrella, Chamaecyparis obtusa and Koelreuteria paniculata) were investigated three years after planting in a derelict manganese mine site in Hunan, China. The results showed that vegetation restoration improved soil properties and resulted in higher soil organic matter (SOC) and total nitrogen (TN) concentrations compared to the bare tailings. The soil showed higher SOC (19.85 g/kg) and TN (0.11 g/kg) in Z. matrella than those in C. obtusa and K. paniculata. Molecular analysis found that the highest Shannon Diversity was in C. obtusa, followed by Z. matrella, and the lowest was in K. paniculata. Taxonomic composition analysis showed that bacterial communities in the planted soils were dominated by Actinobacteria, Chloroflexi Proteobacteria, Acidobacteria and Gemmatimonadetes, and the bacterial profiles of different vegetation restoration types were distinguished from each other as revealed by redundancy analysis. However, a large number of OTUs were still shared by different vegetation types, indicating that some taxa were not sensitive to the heavy metal pollution. Correlation analysis showed that TN was the main environmental factor regulating the structure of bacterial community. These results improve our understanding of the response of bacterial communities to vegetation restoration and provide a scientific basis for the ecological restoration in derelict manganese mine sites.

Plant community responses to management techniques applied to control Hedychium coronarium invasion and restore Atlantic Forest on a protected area in southern Brazil

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Alien plant invasions may affect the biotic and abiotic components of an ecosystem, leading to impacts that may constrain recolonization by native species after invasive alien species removal. In such a scenario, restoration techniques such as topsoil transposition might accelerate native species occupation. Hedychium coronarium J. Koenig (Zingiberaceae) is an herbaceous, rhizomatous Himalayan plant, considered invasive in several countries. This study evaluated plant assemblage response to topsoil transposition on a site invaded by H. coronarium after chemical control. An experiment was conducted in Ibirama National Forest, a protected area in southern Brazil covered by Atlantic Rainforest. Four treatments were applied: cutting, topsoil transposition; cutting, herbicide application; cutting, herbicide application and topsoil transposition; and the control treatment. Plots were evaluated prior to treatment application and monthly for eleven months. Parameters regarding H. coronarium (number of ramets, ramet height, coverage) and other species (species richness, abundance, coverage) were evaluated. LMMs and GLMMs were adjusted to detect different responses to treatments; species composition differences were evaluated through PCoA and Permanova. Chemically-controlled plots (regardless of topsoil transposition) were similar in all measured parameters and also species composition, which showed a predominance of herbs and shrubs. Plots managed solely by topsoil transposition showed lower species richness, abundance and coverage, but with more diverse life forms - they were equally rich in lianas, trees and herbs. Therefore, chemical control was sufficient to control H. coronarium invasion and increase species richness and abundance on the managed site. Topsoil transposition promoted colonization by species that may accelerate restoration.

Phytoremediation of phenanthrene contaminated soils by plant root exudates

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Polycyclic aromatic hydrocarbons (PAHs) have caused severe negative effects on human health, ecosystem services, and environmental security. To investigate the mechanisms by which goldenrain tree (Koelreuteria paniculata Laxm.) enhances phenanthrene (PHE) biodegradation, a pot experiment was conducted to investigate the degradation of PHE and changes in bacterial community characteristics on PHE contaminated soils through four treatments designed as (1) planting goldenrain tree seedlings (GTS), (2) adding high concentration of goldenrain tree root exudates (HRE), (3) adding low concentration of goldenrain tree root exudates (LRE), and (4) control treatment without plants and root exudates (CK). After 180 days, PHE concentration in soils was reduced by 74.7, 71.7, 63.3, and 46.4% in GTS, HRE, LRE, and CK treatments, respectively. At the phyla level of bacterial community, the abundance of Proteobacteria accounted for the total phyla number found in the soil decreased in HRE (93.1%) > LRE (90.7%) > GTS (89.5%) > CK (22.8%). At the genera level, the proportion of burkholderia-paraburkholderia in the total genera number was GTS (78.5%) > HRE (33.0%) > LRE (20.3%) > CK (0.4%). The diversity indexes of soil bacterial community were decreased in an order CK > GTS > LRE > HRE, but the activity of three typical PHE-degrading bacteria (Sphingomonas, Massilia, and Azospirillum) was enhanced in the plants and root exudates of treated groups compared to the CK group. Our results suggested that root exudates of goldenrain tree significantly enhanced PHE biodegradation in PHE soils by increasing key microbial population activity.
Bioremediation of diesel-polluted soil by Cinnamomum camphora or Magnolia grandiflora

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Bioremediation of diesel-polluted soil with plants is considered as an environmentally friendly way for removal of pollutants, however, the effects of green trees on diesel removal remain unclear. Therefore, a one-year pot experiment was conducted to compare the bioremediation potential of Cinnamomum camphora and Magnolia grandiflora grown in garden soil contaminated with 0.2% (L1), 1% (L2) or 5% (L3) diesel. The results showed that Cinnamomum camphora and Magnolia grandiflora promoted the degradation of diesel and resulted in better removal rates in comparison with contaminated soils without plants. The removal rate of diesel with Cinnamomum camphora was 85.86% (L1), 91.95% (L2), and 80.80% (L3), whereas the removal rate with Magnolia grandiflora was 81.02% (L1), 95.60% (L2), and 72.08% (L3). Molecular analysis showed that Cinnamomum camphora and Magnolia grandiflora planted soils had lower microbial populations (bacteria, fungi, and actinomyces), but higher polyphenoloxidase activity compared to unplanted contaminated soils. For contaminated soils with Cinnamomum camphora, the actinomyces population was significantly negatively correlated with the diesel removal rate (<0.05) whereas polyphenoloxidase activity showed a significantly positive relationship with the diesel removal rate (P<0.05). However, no significant relationship was observed in Magnolia grandiflora planted soils. This indicated that polyphenoloxidase activity may be important in promoting diesel degradation in Cinnamomum camphora planted soils. In conclusion, the work suggested that Cinnamomum camphora might be a promising bioremediation plant for diesel-polluted soils.

Spatial–temporal changes in soil carbon pools respond to shrub growth in desert grassland

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The trends of increasing shrubs may contribute substantially to the arid and semi-arid ecosystem carbon (C) sink. Recently, considerable vegetation restoration work has been done in arid and semi-arid areas. However, there is considerable uncertainty as to the extent to which shrub growth processes alter desert soil carbon pools. Studies of the response of soil carbon pools to shrub proliferation have not explicitly assessed the variability caused by shrub growth and subcanopy spatial gradients. This has become a major obstacle to C storage assessment and policy formulation at national and regional scales. In view of this situation, a large number of investigations and systematic studies have been carried out using shrub size as a proxy for age around the Tengger Desert, Northern China. Our research reveals that the growth of shrubs has significantly changed the horizontal and vertical spatial distribution of soil organic carbon (SOC), soil inorganic carbon (SIC) and total carbon (TC). To estimate carbon storage of shrub patches more accurately, the optimum estimation models (power function) of SOC, SIC and TC pools of shrub patches were constructed using crown area (S) as the independent variable, SOC pool = 4.5479 × S 0.9862, SIC pool = 23.5035 × S 0.8100 and TC pool = 28.2046 × S 0.8359, respectively. Combining estimation models of shrub SOC, SIC and STC pools and shrub biomass, we can more comprehensively understand the geochemical cycle of C in desert ecosystem.

The Grand Forks Prairie Project: A case study of public-private collaboration to promote natural resource conservation

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In fall 2000 citizens of Grand Forks County, North Dakota, USA, located in the northern reaches of the North American tallgrass prairie region, began a focused effort to improve grassland conservation in response to regional land-use changes. Over the past two decades, this grassroots project has grown to involve multiple conservation partners and recently gained support through Natural Resource Conservation Service Regional Conservation Partnership funding. Through a combination of soil health workshops and hands-on field tours, conservation partners have accumulated and responded to unique regional concerns related to agroecosystem conservation over the past decade. In 2018 partners started a local soil health monitoring project involving 11 producers and nearly 700 ha of working fields. There were clear differences in soil characteristics among reference grassland, working grassland, and row-crop fields. Not surprisingly, row crop soils were drier and more compacted relative to soils from fields with permanent cover. The ability for soils to infiltrate water and the extent to which they are biologically active formed a second soil health axis, which is of particular concern given that the area is prone to extensive seasonal flooding. Over the next five years, on-going work will involve continued monitoring and feedback steps with local producers to enhance regional soil health. This unique, public-private partnership allows for accumulation and dissemination of local knowledge alongside cutting edge academically based research projects. As we move forward with conservation with increasingly limited funds, such local, multi-stakeholder projects are important for creating measurable landscape changes.

Soil nutrient levels: The difference between intact and transformed thicket

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The Albany Thicket Biome which has been described as the convergence of different phytochoria is typified by its complex structure and variable species composition across its range. The biome has been exposed to degradation and transformation across all of the 14 vegetation types. This study focuses on soil properties of the intact and transformed thicket of the Greater Addo Elephant National Park, South Africa. We compare soil nutrient levels, such as C, N, P, pH and selected physical soil properties such as texture, structure and moisture. The aim is to quantify the differentials, and determine how these affect the ecosystem services provided by the soil. The two degradation extremes have significantly different nutrient levels and physical soil features with the intact thicket showing higher levels of nutrients, similar pH values, better soil structure, no soil capping and better soil moisture status when compared to transformed thicket. This can all be attributed to the differences in vegetation cover (biomass, percentage cover and complexity).

A spatio-temporally differentiated strategy for wind erosion control of topsoil handling in China based on potential wind erosion evaluated with the Revised Wind Erosion Equation

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In ecological restoration, topsoil handling is widely used in engineering to maintain biodiversity and land productivity. However, wind erosion, a major form of soil loss, has not received enough attention and corresponding control regulations are usually over simplified. We take China as an example to demonstrate the high incidence and severity of potential wind erosion of unprotected topsoil handling (hereinafter the PWE) and propose a spatio-temporally differentiated control strategy. We simulated a 200 m X 200 m topsoil
handling site in each cell in a raster map of 1 km resolution of China, and calculated the PWE by the Revised Wind Erosion Equation in a geographic information system with 30 years of meteorological data and spatial data of soil properties. Results show that 76%, 45.4% and 8% of the country’s area has a PWE exceeding 1, 10 and 100 times of the annual soil loss tolerance, respectively. Meanwhile, the PWE also shows remarkable temporal heterogeneity. Therefore, three grades of cells with the PWE exceeding monthly soil loss tolerance in every month, in particular months and in no month through a year were determined. Based on these results, we developed a spatio-temporally differentiated strategy for wind erosion control down to the county-level. The differentiated strategy is an explicit guidance for practitioners to control wind erosion and helps the government sector supervise topsoil handling practices with clear management goal. It provides a management philosophy for other regions, and for other soil loss control management, such as water erosion and freeze-thaw erosion.
All that work for one graph? Time-lapse video of conducting a multi-site restoration research trial from start to finish across North America's sagebrush sea

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Conference attendees likely see hundreds of figures and graphs every day, each one articulating important results and patterns. What goes unseen, but is familiar to all, is the massive and often daunting amount of work that went into conducting the project or experiment that produced each figure. This three-minute video of time-lapse photography is a quick and vibrant journey through the entire process of preparing for, installing, and monitoring a year-long restoration research field trial at three sites in North America's semi-arid sagebrush sea and ends with a humble graph of the results. The experiment itself aimed to refine both the formulation and delivery of a promising new seed enhancement technology designed to increase restoration success of native plants in highly-invaded ecosystems. Our sites, in the three western US states of Oregon, Nevada, and Wyoming, boasted dramatic views and unpredictable weather, and were typical of areas in need of restoration within the sagebrush sea, a large and relatively intact but highly imperiled series of ecosystems. As in many places, time-lapse video brings to life the motion and patterns in these stark landscapes that often go unnoticed to the naked eye, especially when those eyes are busy installing experiments or counting plants.

All about colours – creation of a demonstration green infrastructure along a grey infrastructure

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The proliferation of linear infrastructures is a recent feature of human societies, and it has expanded exponentially since the middle of the last century. Linear infrastructures have negative effects on biodiversity, increasing fauna mortality from collisions or electrocution and the barrier effect that results from habitat fragmentation. Roads are also effective channels for the introduction and spreading of alien invasive species. The project LIFE-LINES (LIFE14NAT/PT/001081*) aims to essay, evaluate, and disseminate practices directed to mitigate the negative effects of linear infrastructures and simultaneously promote a demonstrative Green Infrastructure based in corridors and stepping stones, incrementing connectivity, and conservation of regional biodiversity. The role of marginal areas associated with transportation routes as biodiversity refuges and green corridors has been ignored but if properly managed, can increase landscape connectivity and diversity. To potentiate verges and marginal parcels of roads as refuges or food areas while promoting native plant diversity in linear infrastructures, we are developing biodiverse regional seed mixtures. First, appropriate plant species were selected considering their resilience to mowing, food, refuge and aesthetic value, fire behaviour, and height. Seed was then
collected from local donor populations and sown in experimental plots to evaluate their behaviour. According to these results, the initial set of species was reduced and sown in autumn 2018 in their definitive locations. Evaluations are on-going (spring 2019) and will contribute to the final fine-tuning of seed mixtures.

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**On pushing innovation boundaries of wetland rehabilitation on Palmiet wetlands: The Pietersielieskloof case in the Agulhas Plain, South Africa**

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Wetlands are the most threatened type of ecosystem. They constitute small facets of the landscape and yet deliver disproportionately important functions and services. It is therefore imperative to protect them, promote their sustainable use, and to rehabilitate degrading ones. Wetland rehabilitation is often constrained by poorly developed methodologies and associated high costs. This video illustrates a balance between tremendous innovation and cost optimisation in the rehabilitation of a Palmiet peatland in Pietersielieskloof located in the Agulhas Plain, South Africa. Palmiet wetlands are endemic to South Africa. A combination of catchment land use and and wetland degradation by invasive alien plant invasion, draining, and road crossings has led to erosion and subsequent rapid loss of peat from the Pietersielieskloof system over the past 12 years. Significant erosion occurred between 2003 and 2006, and since then, many of the eroded areas have been invaded by alien vegetation. The wetlands have almost entirely lost their unchannelled valley-bottom characteristics. Conventionally huge and costly concrete or gabion structures would have traditionally been employed to address erosion gullies. However, because of resource constraints, the Working for Wetlands programme is undergoing a strategic shift from addressing heavily degraded wetlands to addressing smaller wetland problems with “softer” or smaller, low cost interventions. This project however defied the odds and applied a highly innovative “softer” and low-cost intervention using a chute-drop inlet approach to address big erosion headcuts with much success. Unique methodologies have been applied from planning, implementation, and monitoring, and evaluation.

**Twenty years in ten: Can we shorten the time for the restoration of ecological processes?**

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Restoration is a long-term process to establish conditions for natural recovery of the ecological auto-sustainability. With the objective of restoring ecological processes in a short time, we evaluated a restoration in the dense-diverse functional model (DDF) in a dry forest in southeastern Brazil. The DDF model seeks to recreate the ecological functions, beauty and diversity of the natural forest in its first years. Tree and shrub species were chosen from local forest communities to restore a multilayer structure. We selected the species based on functional traits and ecological services such as attraction of pollinators and dispersers, input of nutrient and biomass, and nitrogen fixation. An equal proportion of intermediate-late successional and pioneer species were mixed and densely planted (3 plants/m²). To compare species at the same conditions in five plots (0.423 ha, 0.605 ha, 0.489 ha, 0.432 ha and 0.590 ha), we prepared the soil by excavating plots to 1 m deep and adding successive layers of topsoil until the central part reached a height of one meter. In 2011 we planted 142 species. Trees were distributed in the central part of the plots and the treelets and shrubs on the sides. After five years we monitored a local fragment and 5116 ± 529 individuals of 140 species of the DDF using a standard protocol of ecological
sustainability. Ecological processes related to structure and functional characteristics were similar to the monitored 20-year initial secondary dry forest. This process will be shown through a short video with a series of images with narration.

Re-greening Burkina Faso's arid land through the expanding Africa's Great Green Wall programme

Moctar Sacande, Damas Podá
Food and Agriculture Organisation (FAO), Rome, Italy

Exacerbated by drought and climate change, land degradation is a serious threat to Burkina Faso's sustainable development. One-third of the country, more than nine million hectares of productive land, is considered degraded. To find an urgent answer to remedy this, FAO and its partners have responded by working to support the Great Green Wall in the northern Sahel region since 2016. Communities are involved in choosing the sites to make sure that there are no land tenure conflicts and to set up village management committees in order to oversee work and provide surveillance. Village degraded lands of 50-200 hectares are mechanically ploughed to make 300 to 400 micro-catchments per hectare. Two years after planting, the sites are restored with great land vegetation cover for fodder and small-scale crop farming for food and feed production. Research into the contribution of micro-organisms is also carried out by establishing test fields that are regularly monitored on site. Concomitantly, income generation activities are developed through non-timber forest products, including herbaceous fodder, beekeeping, balanites (desert date) oil, and soap production. The programme has achieved planting of 104 sites with 7,120 ha under restoration in 60 villages and training 9,000 agricultural producer's beneficiaries. Similar operations are implemented in five other countries including Ethiopia, Gambia, Niger, Nigeria and Senegal, and the programme is currently being extended to Eritrea, Mauritania and Sudan and several other GGW countries.

Teatime4science: How to use the Tea Bag Index to measure decomposition

Judith M. Sarneel
Umeå University, Umeå, Sweden

Decomposition is a critical step in the carbon cycle and by the release of carbon dioxide during this process, it has clear feedbacks to the global climate. Traditional methods to measure decomposition are labor intensive which results in a lack of comparable data with a global distribution. Recently, a new method has been developed that uses tea bags as standardized litter bags. Tea bags of Green tea and Rooibos tea are buried, and their weight loss is determined after three months. As the two tea types differ distinctly in litter quality and hence their decomposition, it becomes possible to model a two phased decomposition curve with just one sample moment. With this revolutionary method it becomes possible to obtain high quality, standardized measures across gradients and experimental treatments. In the teatime4science project, we aim is to create a global soil map of (tea) decomposition, by collaborating with networks, schools, citizen scientists, and interested researchers. If you want to contribute to this global effort, contact Judith@decolab.org or check www.teatime4science.org

Krom River restoration project: Blending ecological monitoring and postgraduate education in South Africa

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The Krom River in the heart of South Africa’s Cederberg Mountains was the focus of two three-week field trips attended by postgraduate students from universities across South Africa during January 2017 and 2018. The project is the first of its kind to merge river ecosystem monitoring, postgraduate education, and capacity building in South Africa. Led by the South African Institute of Aquatic Biodiversity (SAIAB), and funded by the Water Research Commission, the project set out to undertake robust ecological monitoring for assessing river ecosystem responses to restoration efforts targeting water abstraction, pollution, and non-native species impacts. The students who took part in the programme used data collected during the field trips to complete dissertations required for their respective degrees, and some of them have since enrolled for further degrees in the field of freshwater ecology and conservation. This film showcases the project’s unique approach of blending ecological monitoring and postgraduate education and illustrates student experiences and training ranging from collecting invertebrate samples for monitoring river health to using snorkel surveys to estimate the abundance of some of the regions' unique and threatened freshwater fishes.
WORKSHOP 1

How to co-design a community-driven landscape rehabilitation intervention: A role-playing exercise

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Living Lands pursues ecological rehabilitation by facilitating collaborations between people who work together to solve a shared challenge. Collaborations thus enable collective action. This is applied to living landscapes: a variety of healthy ecological, agricultural and social systems, which are managed to function sustainably. While community-based rehabilitation actions call for collaboration between multi-level stakeholders (international funders, national policy makers, scientists, practitioners and community beneficiaries), there is a limited capacity for stakeholders to establish effective collaborations. This challenge not only reflects directly on the achievement of Sustainable Development Goal 17 – which seeks to strengthen partnerships for sustainable development – but also has implications for achieving multiple land, water and poverty-related development goals. Building on theoretical perspectives addressed in the Symposium “Linking land and water conservation to community development in ecological restoration policy and projects”, the proposed workshop will advance capacity of multiple stakeholders to work collaboratively by drawing on an active learning technique, called 4D modelling. This is a form of role playing, where participants embody specific roles within a given scenario. A real-life socio-ecological challenge, related to landscape degradation, will be presented to the group. Participants will be divided into sub-groups and tasked to co-design an intervention to address the challenge. Each participant will embody a specific stakeholder role assigned to them, which is different from their actual stakeholder role. Active listening, negotiation and sensing skills will be practiced. Through this process, participants will get to grips with the barriers and opportunities associated with multi-level stakeholder communication and collaboration in ecological rehabilitation.

WORKSHOP 2

Knowledge Café: International Principles and Standards for the Practice of Ecological Restoration

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This Knowledge Café led by authors of the SER international Standards for ecological restoration, offers an opportunity for new users of the Standards to ask questions, as well as gain insights from seasoned users from around the world on how to effectively use the Standards and its many excellent tools.
WORKSHOP 3
Can we move beyond tradition? Embracing innovation in the new era of restoration

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Global change is posing one of the most significant challenges to effective ecosystem restoration. Innovative approaches and technologies are emerging which, if embraced, offer the potential to improve decision-making, increase the long-term resilience of plantings, and transform the way restoration success is monitored. However, restoration notably lags in the up-take of innovation to tackle modern-day problems. In this workshop, we continue the discussions raised in the symposium and begin to explore the fundamental issues and challenges that are limiting the uptake of innovation. We explore (i) whether restoration has an innovation problem, (ii) the context dependency of innovation (e.g. what does innovation mean in the context of restoration?), (iii) ways to rank the cost/benefit/potential of innovations in restoration, and (iv) emerging approaches and technologies that will benefit restoration. The expected outcomes of this workshop will be compiled into an opinion piece for publication and wider dissemination.

WORKSHOP 4
Landscapes for Livelihoods: Restoring Land, Water & Community Resilience in the Umzimvubu watershed

Nicky McLeod¹, Betty Mubangizi², Rosanne Stanway³, Sarah Frazee⁴, Samir Randera-Rees⁵, Japie Buckle⁶, Mahlodi Tau⁷
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The uMzimvubu Catchment Partnership Programme (UCPP) is a 6-year old civil society-driven collaborative of state, NGO, communal and private sector role players, with a common vision of restoring the watershed, and which recognizes the potential of the catchment to provide a wide range of ecosystem services to sustain livelihoods and build resilience of local and downstream rural communities. Local implementing partners work closely with communities, governance structures, donors, and policy makers, applying a range of adaptable approaches which suit the receiving socio-ecological landscape, exploring “practice into science, and science into practice”, to support monitoring of trends in the resource base. The partnership focuses on securing ecological infrastructure in communally utilized landscapes, applying a collaborative custodianship approach and through piloting innovative communally appropriate approaches to complement and augment state-driven EPWP ‘Working For’ programmes and secure their investments. It functions through effective collaboration, building on local and indigenous knowledge and practice, open communication, and pooling of resources to implement actions towards achieving this common vision.

The ecological infrastructure along the communal watershed landscape shared with Lesotho’s south eastern boundary provides a range of ecosystem goods and services that benefit society, including water security and purification, flood attenuation, grazing, fuel and building materials, as well as recreational, social and spiritual services, indirectly supporting economic growth and the livelihoods of downstream users, providing a basis for a sound catchment economy. The workshop will share local collaboration experiences, including innovative models for red meat and alien biomass value chains, which link
restored rangelands and market through equitable stewardship-based governance approaches, whereby stock farmers generate cash returns off healthy grasslands managed through conservation agreements. The workshop will provide outlines of the key elements of the programme and aims to clarify how this can influence policies which will underpin increasing resilience through ecosystem-based adaptation.

WORKSHOP 4 - SPEAKER ABSTRACTS

**Investing in ecological infrastructure at the catchment level**

**Dan'sile Cindi**  
South African National Biodiversity Institute, Silverton, South Africa

There are a number of landscape and/or catchment partnerships piloting interventions that are necessary to build a portfolio of evidence for investment in ecological infrastructure. These pilot projects are driven by multi-sectoral partnerships consisting of government organisations, civil society, academia and the private sector, amongst others. The key focus of many of these flagship projects is on multi-sectorial integration of ecological infrastructure into policy and decision-making support tools. Ecological infrastructure (EI) refers to naturally functioning ecosystems that deliver valuable services to the people. Little effort is made to capture and share important lessons, results, and innovations from these successful pilot interventions. It is for this reason that catchment-based Ecological Infrastructure Research; Development, and Innovation (RDI) platforms were established in uMzimvubu and the Berg and Breede river catchments. The establishment of these platforms yielded more positive outcomes that led to expansion to other strategic catchments with strong emphasis on convening spaces, social learning, and generation of policy evidence. Concerted efforts are made to promote multi-sectorial involvement through integrated policy planning and development, as well as mobilisation of human and financial resources for investment in maintaining functionality and restoration of the degraded ecological infrastructure for the benefit of society. This investment is necessary for environmental sustainability and resilience to natural disasters as required by South Africa’s National Development Plan’s Ten Critical Actions.

**Demonstrating the socio-economic benefits of investing in ecological infrastructure in the Umzimvubu and Pongola Catchments**

**Joyce Loza, Ayanda Cele**  
Maloti Drakensberg Transfrontier Programme, Pietermaritzburg, South Africa

The uMzimvubu Catchment under the custodianship of the Partnership Programme (UCPP) is a 6-year old civil society-driven collaborative of state, NGO, communal and private sector role players, with a common vision of restoring the watershed of the Umzimvubu Catchment, and which recognizes the potential of the catchment to provide a wide range of ecosystem services to sustain livelihoods and build resilience of local and downstream rural communities. Since its establishment, UCPP has driven restoration interventions aimed at securing the Ecological Infrastructure (EI) in communally utilized landscapes. Applying a collaborative custodianship approach has yielded not only tangible ecological benefits but also catalysed marked socio-economic benefits such as skills development, wage incentives, and household level income generated from livestock sales that contribute to sustainable livelihoods and social cohesion of the local communities in the Umzimvubu Catchment. It has promoted inclusivity across historically excluded groups (women and youth). The presentation will share the tangible and non-tangible socio-economic benefits of the restoration initiatives of the Umzimvubu Catchment, and also demonstrate similar benefits and lessons learned from the Pongola Catchment.
The Landscapes for Livelihoods approach

Sissie Matela
Environmental & Rural Solutions and Umzimvubu Catchment Partnership, Matatiele, South Africa

Recognizing the importance of traditional approaches to land and livestock management with integration of appropriate technical information has underpinned the pioneering approach by implementing partners with rural communities in the headwaters of the Umzimvubu Catchment. Landscapes cannot be effectively restored unless good governance is first restored: this was the guiding response strategy to address the increasing land degradation in these rural areas where there is still a high community dependence on the productive potential of the natural resource base. The strategy is underpinned by recognition that there must be a balance between the governance-livelihoods-ecology nexus if the core objectives of restoring land production and potential for household income generation are to be achieved. The basic principle underpinning the approach is that resource-poor communities are not willing to participate in conservation unless they can accrue benefits that will take care of their immediate needs. There must be very clear strategies for addressing rural poverty within the resource conservation model for the restoration of the landscapes, otherwise conservation has no appeal for the majority of these livestock farming traditional rural communities. The approach is founded on rebuilding good governance, along with resilience and complementary community livelihoods, with landscape benefits as a supplementary outcome to secure livelihood improvements. Since inception, household incomes have increased significantly across the landscape, with growing awareness of the relationship between livelihoods and improved quality of landscapes and associated resources.

Collaborative stewardship: Restoring degraded landscapes through innovative mechanisms linked to rangeland value chains

Nicky McLeod
Environmental & Rural Solutions and Umzimvubu Catchment Partnership, Matatiele, South Africa

Communal landscapes have long been perceived as a challenge for effective restoration through the notion that their open access status leads to a ‘tragedy of the commons’ outcome. This presentation shares some positive experiences from the Umzimvubu catchment in the former Transkei of the Eastern Cape, where Traditional Authorities work together with implementing partners, research institutions, and local government as part of the civil-society driven Umzimvubu Catchment Partnership (UCP). As a key role player in the UCP, ERS has co-pioneered several innovative mechanisms, which foster sound collaborative stewardship actions that both secure intact landscapes and restore degraded areas, including:

- tackling invasive alien plant infestation as a leading degradation agent;
- restoring cleared areas to rangelands through timely, innovative follow-up activities;
- linking with biomass value chains and markets to drive restoration and stewardship actions and contribute to livelihood security;
- involvement of marginalized youth as ‘Ecofutures stewards’ and citizen scientists to support monitoring of restoration actions; and
- establishing a core protected area of intact ecological infrastructure along the upper uMzimvubu watershed, incorporating six traditional authorities, which shares a transfrontier boundary with the Kingdom of Lesotho.

This presentation will share some of the ground-up, collaborative action-learning approaches and outcomes that make use of bundles of livelihood incentives to
complement and secure state-funded programmes. The strategy is underpinned by recognition that there must be a balance between the governance-livelihoods-ecology nexus in order for restoration gains to be sustained, livelihoods to become more resilient, and socio-economic impacts to be really meaningful.

**Governance and effectiveness of institutional configuration for enhanced landscape stewardship**

**Betty Mubangizi**  
University of KwaZulu-Natal, Durban, South Africa; National Research Foundation, Pretoria, South Africa

Governance refers to processes that society uses to make shared decisions in the interactions between role-players and stakeholders that are involved in activities geared towards the attainment of a common good. The livelihood activities of managing livestock and rangelands, clearing alien vegetation, and spring protection, among others, require the actions of a multiplicity of actors drawn broadly from government, civil society, communities, and traditional leaders. In such a scenario, where variously positioned actors contribute to the attainment of the common good, the need for good governance is critical. Practitioners in the catchment find the need to have a clear understanding of how the various role players and stakeholders interact with each other to advance the ideals of the uMzimvubu Catchment Partnership Programme (UCPP). In this regard, governance is the bedrock on which the effectiveness of institutional configuration for enhanced landscape stewardship rests. Specifically, the objectives of UCCP's five-year plan are geared towards formalising governance and policy influence through advocacy; supporting governance structures to adopt working models for improved catchment management with a stronger policy focus and influence; and providing ongoing support for improved governance and continued monitoring and advocacy. Drawing on practical experiences, observations, and workshops within the context of uMzimvubu Catchment Partnership Programme (UCPP), we share with you our views on:

- What governance processes positively contribute to a sustainable relationship between rural communities and their ecosystem;
- The challenges therein; and
- How best to monitor good governance for the restoration of rural livelihoods.

**Landscapes and livelihoods for national water security: Governance, stewardship, and the water source areas**

**Samir Randera-Rees**  
WWF South Africa, Johannesburg, South Africa

Ten percent of the area of South Africa, Lesotho, and Swaziland supplies 50% of the area's surface water resources. These areas have been coined the Strategic Water Source Areas (SWSA’s), and recent research has found that 50% of South Africa's population, 64% of its economy, and 70% of its irrigated agriculture is dependent on water from these areas. Because of this, the SWSA's are receiving increasing attention from policy makers and practitioners alike to ensure their continued ecological functioning. Many of these areas have already experienced significant ecological degradation from invasive alien trees, erosion, fire, and other poor management practices. Restoration of degraded ecological infrastructure is essential for the water security of South Africa, but increasingly there is a recognition that this degradation is a consequence of a breakdown in governance, and that the livelihoods that depend on those systems tend to degrade along with the landscape. Any solution that aims to restore these systems must by necessity restore all three factors. Multi-stakeholder platforms provide the governance basis upon which restoration relies, and regenerative economic activities linked to real value chains can restore
landscapes to the economic benefit of local stakeholders. These activities improve the quantity and quality of water flowing from the SWSA and the resilience of those communities, while decreasing the costs and risks to downstream users. The experience in the Umzimvubu catchment highlights the innovative and collaborative approach towards achieving an effective nexus of all three restoration factors.

Conservation agreements: A communal stewardship mechanism for rangeland restoration and livelihood enhancement

Rosanne Stanway
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Conservation agreements are defined as a ‘negotiated exchange of benefits in return for changes in resource use, depending on verified performance. We know that in many parts of the world, natural resources are used unsustainably, simply because there is no economic alternative. When we can provide tangible, concrete benefits to local communities to protect their environment, this pathway quickly becomes the chosen approach. Conservation agreements are currently used globally with 35 000 people in 14 different countries, and are designed to be flexible, transparent, and impactful. In the uMzimvubu catchment, conservation agreements are structured between uMzimvubu Catchment implementing partners and communal livestock farmers, whereby the livestock farmers agree to practice planned grazing on pre-identified, mapped and monitored areas of their communal grazing lands, and in exchange, are able to access fair price, locally-situated auctions that are designed to offer reduced rates for conservation agreement participants. Through this negotiated, informed, and voluntary approach, the uMzimvubu Catchment Partnership has facilitated improved rangeland management on over 5,000 ha of valuable grasslands and generated over $1.4 million for communal livestock farmers in South Africa’s poorest province. These communities have also experienced significant indirect benefits of increased ecosystem resilience and indirect social benefits of enhanced governance and empowerment. In this session we will discuss the critical factors for the design, implementation, and scaling of this model and provide examples of how conservation agreements are a successful mechanism to deliver benefits for people and nature.

WORKSHOP 5
Harnessing emerging ideas about priority effects to improve ecological restoration outcomes

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The effects of order of arrival of species, called priority effects (in which organisms that first arrive at a site significantly affect the performance of the species arriving later), is attracting increasing attention in a restoration context. Restoration involves directly intervening in assembly to direct communities along particular desired trajectories. Thus, effective implementation of restoration projects requires knowledge about the assembly process, including the extent to which order of species arrival influences assembly trajectories. Although priority effects can lead to alternative states in vegetation, questions remain about the magnitude and scope of priority effects within and among ecosystems and over time. Thus, before being able to use priority effects in restoration on the ground, we need to better understand how generalizable and strong priority effects are and test them in more habitats.
This workshop aims to highlight and discuss aspects of priority effect studies of relevance to restoration. Our priority symposium at SER 2017 was very well attended and although a lively debate ensued, there was not enough time for in depth discussion. This proposed follow-up workshop will utilize a world-café format, with five sub-groups discussing key innovative / controversial points related to priority effects raised by the five speakers, to ensure that group intelligence is harnessed. The overall outcomes will be synthesized on flipcharts and discussed at the end of the session. We aim to bring together speakers and an audience from a range of different habitat types & biomes as well as geographical locations and cultural backgrounds.

WORKSHOP 5 - SPEAKER ABSTRACT

Being late and rare: Rare plant species suffer most from priority effects in riparian zones

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Priority effects occur when early-colonizing plant species affect the establishment of later-arriving species. The debate moved from proof-of-concept to discovering interactions with species traits and habitat conditions, as this has important implications for restoration. We tested effects of species arrival and soil moisture in a controlled greenhouse experiment and in a large-scale field experiment in boreal riparian zones. We observed strong priority effects as early-arriving species germinated and grew better compared to later-arriving species, both in the greenhouse and after two growing seasons in the field. Priority effects were strongest under dry and dry fall conditions in the greenhouse and similar and transient interactions between arrival order and soil moisture were observed in the field. Priority effects were strongest for rare species as we observed a strong correlation between strength of priority effects and relative abundance in communities where all seeds arrived simultaneously. When changes in soil moisture increased the relative abundance of a species, the strength of priority effects decreased. Especially because flooding regimes will not only affect habitat conditions, but also the phasing of the seed arrival, our observations suggest that priority effects should be considered when addressing the effects of shifts in flooding regimes such as during restoration.

WORKSHOP 6

Are you being heard? The power of communication in ecological restoration

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What can we learn from the advertising world? How often does critically important information regarding ecosystem restoration fail to reach funders, stakeholders and communities? Learn how to effectively translate scientific knowledge and ecological restoration project information into compelling communication material for diverse audiences, including international stakeholders and partners, local communities and governments. Five international forest communication professionals from around the world will present global best practices and effective techniques in this ground-breaking
session. Drawing on both traditional and modern communication approaches, and on the lessons learned from international case studies, the session will show how to create powerful communication campaigns that can help with raising awareness, fundraising, and supporting research. Discover what makes a communication campaign successful, why gender matters, how to make yourself heard and how to develop crisis communications.

WORKSHOP 8

The Global Arid Zone Project – Pooling knowledge and data gathering for global progress in arid and semi-arid restoration

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The Global Arid Zone Project is a grassroots project that aims to bring together arid and semi-arid restoration researchers globally to pool existing data and knowledge for a deeper understanding of restoration science. Started in January 2018, the project has participants from around the world who have contributed their time and research to build a global database of restoration efforts and outcomes. The database to-date has focused on seed-based restoration and vegetation results in arid and semi-arid ecosystems. As of January 2019, the database had 94 data sets spread across 6 continents. The project is continuing to expand, both in the collection of restoration data and in the incorporation of a global experiment to inform seed-based restoration in the coming decades. This session will be a productive workshop that will direct next steps in the GAZP process. We will discuss both primary aspects of the project, the database and the global experiment, and brainstorm avenues of research and development. It will offer an important point for participants and stakeholders to give feedback and offer guidance to a growing project of global significance.

WORKSHOP 9

Cultural landscapes: A concept explicitly applied in Europe in Ecological Restoration – how is it implemented elsewhere?

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International agreements and conventions on ecological restoration aim high when it comes to fixing the amount of degraded areas to be restored. Therefore, restoration is recently moving from “derelict land” to areas marked by traditional uses that are not exactly abandoned. Human traditional activities have significantly shaped landscapes - not only in Europe as it was once believed -, but also in many other regions including, for example, the Amazon and the Andes. They have created semi-natural ecosystems (i.e. created by a relationship between human activity and the environment, generating biodiverse systems, e.g. grazed or/and mowed alpine meadows) and cultural ecosystems and landscapes (i.e. created by a relationship between human activity and the environment, generating cultural ecosystem services, such as aesthetics, spiritual, etc. e.g. ancient dam on a river creating a derivation for a watermill). These activities are sometimes still run, sometimes have been altered through time, but landscapes have kept traces of
these relationships and are valued by stakeholders. Taking these relationships into account in restoration would reinforce stakeholder engagement through the consideration of traditional ecological knowledge and other social and cultural aspects and might help scaling up restoration actions at the landscape scale. This workshop’s main objective is to bring the cultural landscape concept, which is widely applied in restoration in Europe, into focus when considering ecological restoration being planned or performed elsewhere. We will discuss its suitability to regions such as Latin America and Africa considering their different contexts.

WORKSHOP 9 - SPEAKER ABSTRACT

Using Traditional Ecological Knowledge (TEK) to restore cultural landscapes in the Western Hemisphere

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For millennia, the Western Hemisphere provided a home to many Indigenous people. During the Colonial Era, which began 1490 CE when Euro-American settlers arrived, many tribes were the victims of extensive genocide and lost the right to live on and manage their lands in keeping with their Traditional Ecological Knowledge (TEK). Today some of these tribes have regained their rights with the strongest land-tenure rights held in Canada and the US. Landscapes managed using TEK are considered cultural landscapes and contain within them cultural ecosystems. The paleoecological record furnishes evidence that tribes once intensively managed most ecosystems in the Western Hemisphere by modifying them with fire, by altering the movement of wildlife species such as bison (Bison bison) and caribou (Rangifer tarandus), and by coexisting with and honoring species such as beaver (Castor canadensis), wolves (Canis lupus), bears (Ursus spp.), jaguars (Panthera onca), eagles (Haliaeetus spp.), and the Andean condor (Vultur gryphus) that have powerful ecological effects. Colonialism, defined as a foreign polity seeking to extend or retain its authority over other people or territories to develop or exploit them to benefit the colonizing country and to help colonies modernize in terms defined by the colonizers, has created extensive ecological degradation globally in what has come to be known as the Anthropocene Epoch. We present case studies that demonstrate the benefits of using TEK to restore cultural landscapes and heal the damage done by colonialism, how this creates healthier ecosystems and human communities and ecosystems more resilient to climate change.

WORKSHOP 10

Getting published in Restoration Ecology: A workshop for students and early career professionals

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Though several ecological studies have a local or regional framework, if they produce high quality results then they have the potential to significantly contribute to advance global ecological concepts, theories and paradigms. Publishing scientific results in international journals is nowadays a ‘vital’ and constant requirement to researchers and graduate students and may pose several challenges. In this workshop, we — the EIC, Prof. Stephen Murphy, and ME, Dr. Valter Amaral, of Restoration Ecology (journal) — will discuss how to effectively publish in Restoration Ecology: what are the main challenges, from making global generalizations with local and regional results to the language barrier, and how to effectively overcome these. We will also discuss the relative importance and growth
potential of the research and practice of restoration ecology in Latin America and how to translate this in publications in international scientific journals of wide visibility.

WORKSHOP 11

Land...with compensation of an alien kind – the role of Invasive Alien Plant clearing in releasing water, restoring land, and securing livelihoods

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Land is an age-old asset that can unlock tremendous resources beneficial to society. Invasive Alien Plants (IAPs), a big threat to sustainable land management and livelihoods, are spreading across South Africa at a rate of 5-10% per year. They are driving biodiversity loss, destroying rangelands and grazing lands, soaking up fresh water from the landscape and contributing to massive soil erosion issues. The Department of Environment, Forestry and Fisheries spends close to R2 billion per annum on efforts to clear the land of Invasive Alien Plants through its Working for Water programme, which is mobilized through thousands of SMMEs. But R2 billion is not enough to make a significant mark; the Programme needs close on R12 billion per annum. The Green Business Value Chain, a catalytic, national programme funded by the Department, and implemented by the consultancy Avocado Vision, is working to close the shortfall through a multi-billion Rand commercial pull strategy. It is doing this by researching and establishing viable value chains associated with the invasive alien biomass (wood), capacitating local SMMEs to take up new value chain opportunities, opening up markets which will demand products created from invasive biomass and advocating corporate South Africa to be a part of this solution. This virtuous cycle of environmental benefit (clearing), social benefit (improved rangelands and SMME capacity building), and financial benefit (sustainable land use and viable trading) has many applications but is best exemplified in the case study of the June 2017 Knysna fires. Invasives – a fire risk – from the area were cut by local SMMEs, converted to land rehabilitation products, which were instrumental in the eventual rehabilitation of the Knysna slopes that were devastated by the fires. The objectives of this workshop are to raise awareness about a virtuous cycle that directly connects land to water to communities; to influence key role players to consider changing specifications on restoration material to catalyse this virtuous cycle; and to influence key role players to consider amending procurement processes to products manufactured from IAP biomass to catalyse this virtuous cycle.

WORKSHOP 11 - SPEAKER ABSTRACT

Invasive alien plants - friend or foe? A link between land rehabilitation and livelihoods

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Invasive Alien Plants (IAPs) are a big threat to water security, sustainable land management and livelihoods, and are spreading rapidly across South Africa. They are driving biodiversity loss, destroying rangelands and grazing lands, soaking up fresh water from the landscape, and contributing to massive soil erosion issues. The Department of Environment, Forestry and Fisheries (DEFF) spends close to R2 billion per annum on efforts to clear the land of Invasive Alien Plants through its Working for Water programme, which is mobilized through thousands of SMMEs. But R2 billion is not enough to make a significant mark; the Programme needs close on R12 billion per annum. Using a case study-based method, the DEFF will showcase a viable economic model that creates a multi-billion Rand commercial pull strategy...
that plays a role in closing the R10 billion short-fall. Located in the aftermath of the historic June 2017 Knysna (Western Cape) fires, the case study will show how producing a locally manufactured land rehabilitation product from invasive alien biomass creates a virtuous cycle between the environment (water security, land management), society and economy. After using 440 fibre blankets (approximately 5.4 km²), over 8000 fibre rolls (approximately 53 kms), and an innovative application called hydro-seeding, (all manufactured from IAPs), the re-growth of indigenous plants after a year of rehabilitation was prolific. In conclusion, invasives – a fire risk – cut from the catchment by local SMMEs, converted to land rehabilitation products were instrumental in the eventual rehabilitation of the Knysna slopes that were devastated by fires.

WORKSHOP 12

**Greening the seas? Sharing our successes and challenges in marine and coastal restoration**

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The complexities of undertaking restoration projects in ocean and coastal areas are vast, and include mobile environments, climate change effects, allochthonous inputs, jurisdictional overlaps, conflicting uses, and inadequate regulation. Overlaying this complexity is the growing recognition of indigenous sovereignty rights and growing capability within the environmental restoration sector. Practitioners around the globe work on coastal and marine ecosystem restoration. There are commonalities in our experiences and potential to develop common solutions; however, emphasis at restoration meetings is often placed on terrestrial and freshwater ecosystems. This international conference in a complex coastal city is an excellent forum for those working on, planning, and aspiring toward restoration projects in coastal and marine areas to share stories, challenges, and lessons learned. Dual world (western and indigenous) restoration methodologies provide innovative frameworks that can be amalgamated with contemporary methodologies for net gain outcomes. This workshop will be highly interactive and participatory. It will include perspectives from the coastlines of Canada to Maori communities of Aotearoa (New Zealand), and embrace everything in between. Participants will have an opportunity to learn from others working in related environments, with particular consideration for Cultural Health Frameworks and Ecosystem-Based Management approaches based on traditional epistemologies. Each participant will share a success story and a challenge in their experience with coastal or marine ecosystem restoration. Each participant will also contribute to helping others find solutions to their challenges. Solutions will include those that participants have already developed, as well as brainstorming solutions not yet found. Come prepared to share!

WORKSHOP 13

**Why post-fire management is so different among Mediterranean-climate countries? Looking for an integrated strategy**

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Fire is a major disturbance driving landscape transformation in the five Mediterranean climate regions of the world (MCRs, SW South Africa, Mediterranean Basin, California, central Chile, S/SW Australia). MCRs share similar plant physiognomies, drought and, in many cases, fire adaptations. By contrast, dominant soils are quite different among MCRs. Having similar fire incidence, vegetation characteristics and bioclimate, post-fire management and restoration approaches are extremely different among regions.
Approaches range from the almost compulsory intervention for soil stabilization and restoring pre-fire vegetation, as adopted in Spain, to the no intervention approach often taken in Australia. In addition to possible biophysical differences justifying those contrasting approaches, differences in forest management traditions might also play a role. The challenge is understanding the scientific and managerial rationale of the various approaches in order to achieve a general strategy for fire-prevention vegetation management and post-fire ecosystem management/restoration. This workshop will bring together fire and restoration ecology experts from all the five MCRs. The workshop will promote facilitated discussion for developing an integrated approach for post-fire restoration in Mediterranean climate regions: identification of gaps in the knowledge and progress pathways and the creation of a specific working group to animate the discussion and to explore the elaboration of review papers.