RESTORING INDIA'S TERRESTRIAL ECOSYSTEMS

Needs, Challenges, and Policy Recommendations

Including Key Messages for Policy Makers

BIODIVERSITY COLLABORATIVE

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Needs, Challenges, and Policy Recommendations

AUTHORS

Manaswi Raghurama[1], Sumana Dutta[1], Tanaya Nair[2, 3], Mahesh Sankaran[1], T.R. Shankar Raman[4], Divya Mudappa[4], Anand M. Osuri[4], Jagdish Krishnaswamy[5], Uma Ramakrishnan[1], Nitin Pandit[6], Pradip Krishen, Ashish Nerlekar[7], Ishan Agrawal[8], Paul Blanchflower[9], Noopur Borawake[4], Godwin Vasanth Bosco[10], Arundhati Das[1], Mandar N. Datar[11], Aparajita Datta[4], Arun Mani Dixit[12], Ketaki Ghate[13], Ankila Hiremath[6], Pankaj Joshi[14], Atul Joshi[6], Justus Joshua[15], Danish Khan[16], Vijay Kumar[17], Mayur Nandikar[18], Rohit Naniwadekar[4], Goutam Narayan[19], Vikram S. Negi[20], Siddharth Rao[21], Vasant Saberwal[22], Vivek Saxena[23], Anita Varghese[24], Aparna Watve[11], S.R. Yadav[25], Ravi Chellam[6, 26], Kamal Bawa[6, 27]

AFFILIATIONS

[1]National Centre for Biological Sciences - Tata Institute of Fundamental Research, [2]University of Oxford, [3]University of Witwatersrand, [4]Nature Conservation Foundation, [5]Indian Institute for Human Settlements, [6]Ashoka Trust for Research in Ecology and Environment, [7]Texas A&M University, [8]Foundation for Ecological Security, [9]Auroville Botanical Gardens, [10]Upstream Ecology, [11]Agharkar Research Institute, [12]Centre for Environment & Social Concerns, [13]Oikos, [14]Sahjeevan, [15]Green Future Foundation, [16]Vattakanal Conservation Trust, [17]Gujarat Institute of Desert Ecology, [18]Naoroji Godrej Centre for Plant Research, [19]Pygmy Hog Conservation Programme, [20]G.B. Pant National Institute of Himalayan Environment and Sustainable Development, [21]Timbaktu Collective, [22]Centre for Pastoralism, [23]International Union for Conservation of Nature (IUCN) India, [24]Keystone Foundation, [25]25 Shivaji University, Kolhapur, [26]Metastring Foundation, [27]University of Massachusetts

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Kalyan Verma

Graphic Design

Tanaya Nair

For further information contact
contact@biodiversitycollaborative.org
Biodiversity Collaborative
C/O ATREE, PO
Royal Enclave, Srirampura
Jakkur, Bengaluru
Karnataka 560064

TABLE OF CONTENTS

PREFACE

India's proposed 'National Mission on Biodiversity and Human Well-being', which aims to strengthen biodiversity science to comprehensively address major environmental challenges in the country, provides an ideal platform to promote and facilitate successful restoration of landscapes across India and achieve the ambitious restoration targets set through the Bonn Challenge.

The United Nations declared 2021-30 as the 'Decade on Ecosystem Restoration' with the objective of significantly scaling up global restoration efforts, and bolstering existing restoration goals such as the Bonn Challenge of 2011 which aims to bring 350 million hectares of deforested and degraded land into restoration by 2030. India was one of the first countries in Asia to commit to the Bonn Challenge, and has pledged to restore 26 million hectares of degraded and deforested land by 2030. Achieving this target will help enhance biodiversity and ensure the livelihoods of millions, but will require:

1. widespread adoption of scientifically rigorous restoration practices;
2. engagement of multiple stakeholders including local communities;
3. innovative partnerships among Government organizations, non-governmental organisations (NGOs), scientific institutions, local landowners and stakeholders, and restoration practitioners;
4. removal of institutional barriers and the creation of enabling policies for restoration, development of clear monitoring and assessment guidelines and;
5. concerted efforts to raise awareness amongst the general public about the benefits of restoration.

This document is a product of the precursor phase of the National Mission on Biodiversity and Human Well Being and is the outcome of a series of stakeholder consultation meetings on ecological restoration of terrestrial landscapes and climate change in India. The insights from these meetings have been used to develop this document which highlights the challenges and best-practices in the restoration of terrestrial ecosystems, can serve as a guide for successful restoration of landscapes across different biomes of the Indian subcontinent, and help achieve India's commitments to the Bonn Challenge and the goals set by India for biodiversity conservation, land restoration, climate mitigation and adaptation.

Details of stakeholder meetings

Online stakeholder consultations on issues relating to the ecological restoration of forest and grassland biomes in India were held on 29th July, 2020 (22 participants) and 24th August, 2020 (23 participants), and included both restoration practitioners and scientists. Discussions centered around the biophysical as well as socio-economic challenges to restoration efforts across different terrestrial biomes in the country. The consultations were also aimed at strengthening the network of restoration practitioners across India and the sharing and dissemination of knowledge, practices and policies related to ecological restoration. This document incorporates the main findings and recommendations arising from these consultations.

Disclaimer

No community-level (particularly tribal) consultations have been carried out in the making of this report. Further, no community-based restoration efforts were carried out during the making of this report. However, such consultations have been carried out in many of the examples of restoration activities cited in this report, and we highly recommend throughout the report that such consultations and efforts be done during the execution of any restoration intervention.

Key Messages for Policy Makers

KEY MESSAGES

ONE

Restoring India's degraded ecosystems makes sound economic and ecological sense; it can help reverse the significant losses arising from land degradation and biodiversity loss while also contributing to mitigating climate change and improving human well-being and quality of life.

Land degradation negatively impacts millions of people in India (1.1). While avoiding land degradation is always the preferable and cost-effective option (1.3), restoration of India's degraded ecosystems can benefit biodiversity, increase food and water security, mitigate climate change, generate livelihood opportunities, promote gender equality, improve human well-being, and contribute to fulfilling India's commitments to international agreements such as the Bonn Challenge and Sustainable Development Goals (1.2, 1.4, 1.5, 1.6, 2.7). Restoration of India's degraded lands also makes sound economic sense; the cost of inaction in degraded lands can be more than 3 times the cost of restoration, and investments in restoration can generate multiple benefits for societies worth as much as 10 times the cost (1.3).

TWO

Restoration is a long-term intentional activity that requires continued and long-standing commitment in terms of both effort and funding.

Restoring degraded ecosystems takes time, from decades to longer, depending on the level of degradation and ecosystem type (2.1). One-off activities such as ambitious large scale tree plantation drives or invasive species clearance programs rarely succeed when there is a lack of follow-up (e.g., as a result of high seedling mortality or reinvasion by exotics) resulting in wasted resources and effort (2.6). Rather than setting over-ambitious targets that are un-achievable, it is more prudent to set smaller-scale, locally-achievable objectives, and focus on improving the quality of restoration efforts (e.g., improving seed and seedling quality, planting appropriate species, affording greater protection to seedlings, appropriate monitoring and follow-up efforts) as these can improve ecological outcomes and decrease economic costs (2.6). Innovative policies that foster novel financial mechanisms and business opportunities, and encourage long-term commitments in terms of institutional and human resources as well as funding, can encourage states, private entities and local communities to restore lands and improve restoration outcomes (8.5).

THREE

Restoration is not the same as tree planting, and climate mitigation actions do not necessarily equate with restoration.

While reforestation – the planting of trees in once forested areas – is a valid and viable restoration strategy, afforestation – planting of trees in areas that were not previously forested, such as grasslands and savannas – can threaten unique biodiversity, disrupt the provisioning of key ecosystem services, and negatively impact human livelihoods (2.2). Although tree planting in these ecosystems can lead to short-term increases in aboveground carbon stores, it can also drive the loss of carbon from soils and result in a net reduction in overall ecosystem carbon stocks (2.5). Aboveground carbon in these systems can also be lost periodically as a result of fires and grazing which are integral components of these ecosystems (2.5). Recognizing that open natural ecosystems such as savannas and grasslands are not appropriate for large-scale tree planting, and that fires and grazing are defining features of these systems that should not always be suppressed, can help protect these ancient ecosystems and avoid wasted effort and funds in ineffective restoration and climate mitigation activities (8.6). In India, under the CAMPA Fund, thousands of crores of rupees are allocated for 'compensatory afforestation', a major portion of which happens in grasslands and savannas, and such policies need amendments to follow global best practices in restoration.

FOUR

Identifying and addressing the drivers of land degradation is critical to ensure the success, long-term sustainability and cost-effectiveness of restoration efforts.

The success and sustainability of any restoration effort rests on clearly identifying and addressing the direct (e.g., land clearing, overgrazing, over-harvesting) and more importantly, the indirect drivers of land degradation (e.g., poverty, lack of livelihoods, unclear land tenure and access to land; 5.1). Failure to do so can undermine restoration success and result in wasted effort and funds, or lead to the displacement of land degradation to other areas (e.g., shifting deforestation, land clearing and grazing to other areas; 2.7).

FIVE

Restoration efforts that aim to maximise biodiversity and ecosystem functioning by reintroducing diverse mixtures of native species can provide greater benefits than approaches that employ monoculture or low-diversity plantations.

Restoring a diverse mix of native biodiversity, including endemic and threatened species, can have much greater positive impacts (e.g., higher levels of provisioning of a range of different ecosystem services) than those that simply aim at planting large numbers of trees of one or a limited number of species (2.2, 2.3, 2.6). Maximising biodiversity in restoration efforts can also enhance ecosystem resilience to future climate change and increase resistance of ecosystems to (re)invasion by exotic species, while also simultaneously providing co-benefits for biodiversity conservation (5.3).

SIX

Building effective community partnerships, involving indigenous and local communities, ensuring women's participation and encouraging active participation of NGOs, businesses and private investors from the planning to the implementation and monitoring stages can greatly enhance the success of restoration efforts.

Involving local communities in discussions from the beginning (planning stage) of the restoration program can ensure community buy-in and increase the probability of restoration success (3.1, 3.2, 3.3). In particular, Joint Forest Management Committees can be potentially leveraged in these activities. Further, greater involvement of women in various stages can increase efficiency and success of restoration programs, and improve gender equity (3.7). NGOs can help integrate community perspectives during planning, help design livelihood alternatives, and strengthen public support for restoration programs (3.6). With the development of innovative financial mechanisms, incentives and opportunities for business and private investors, and the right investment environment, the growth of a 'restoration economy' can create huge employment opportunities (8.3), increase financial support for restoration programs, and contribute to the long-term sustainability of these programs (3.6).

SEVEN

Restoration programs that plan for multi-use and multi-functional landscapes can help balance the needs of different interest groups, optimise cost-effectiveness, and provide greater social, economic and ecological benefits, thereby ensuring long-term sustainability of restoration efforts.

Because the motivation for, and understanding of, restoration can vary between different stakeholders, restoration targets (the desired ecosystem state post-restoration) can also differ among stakeholders based on social and ecological contexts (3.1). Understanding and accommodating the motivations of different stakeholders during the planning stages can help resolve stakeholder conflicts and establish targets which balance the needs of different stakeholder groups. Landscape level prioritisation exercises that capture the expectation and values of multiple stakeholders can enable stakeholders and decision makers to evaluate the potential benefits and opportunity costs of different restoration approaches, identify areas in the landscape where different restoration targets should be established (mosaic restoration; multifunctional landscapes), optimise restoration efforts to deliver the greatest benefits at the lowest cost, and avoid the displacement of land degradation to other areas (2.2, 2.7, 3.3, 4.1).

EIGHT

Successful scaling up of restoration efforts will require awareness generation efforts to change entrenched philosophies that are detrimental to restoration, greater multilateral coordination between implementing nodal agencies, and the removal of institutional and socio-economic barriers that hinder restoration efforts.

Restoration efforts are often hindered by the prevalence of many outdated philosophies regarding ecosystem management and restoration in different government departments, and amongst practitioners, involved in restoration. For example, widely held views such as tree planting is good everywhere, grasslands and open natural ecosystems are wastelands, all wildfires are bad everywhere, or excluding human settlements is necessary to protect natural ecosystems, can actually cause more harm than good (8.6, 8.7). Significant awareness generation through mass media campaigns, on-the-job training, and technical and scientific capacity building through the establishment of restoration 'knowledge hubs' can help to continuously update the knowledge base of restoration practitioners and forest managers (6.1, 6.6, 8.7). Lack of institutional and governmental support and channels (both financial and institutional) also create barriers to successful restoration (6.2), and enabling policies that encourage restoration by diverse stakeholders can help overcome such barriers (8.2). Greater coherence between different national level policies (e.g., National Afforestation Programme, the Green India Mission) and greater multilateral coordination among different government departments, ministries and nodal agencies can greatly facilitate the success of large-scale restoration efforts in the country (8.1).

NINE

Scaling up of restoration efforts to meet India's national and international commitments requires establishing an effective network of nurseries and seedbanks, developing restoration knowledge hubs and atlases for native species, creating strong financial and institutional frameworks, and generating awareness to encourage active engagement of stakeholders in restoration efforts.

Generating the large volumes of high-quality native seeds and seedlings that are needed to scale-up restoration efforts to meet commitment to the Bonn Challenge will require the establishment of a coordinated network of nurseries and seed banks across the country (6.4). Detailed species atlases and databases that provide information on native and threatened species to use for the restoration of different ecosystems, disseminated through 'restoration knowledge hubs' across the country, are also needed for practitioners to effectively scale-up restoration efforts (6.3). Finally, strong financial and institutional frameworks that foster business opportunities, employment generation and the creation of a 'restoration economy' (8.5), and large-scale awareness generation programs can encourage the active engagement of diverse stakeholders and greatly facilitate the scaling up of efforts to achieve the shared vision of restoration.

TEN

Well-designed, transparent, and rigorously executed monitoring efforts that track both the ecological and social outcomes of restoration efforts are critical to evaluate progress, adaptively manage restoration methods and identify strategies to enhance future restoration success.

Monitoring of restoration outcomes (which include ecological, biophysical and socio-economic variables) can help managers determine which strategies are effective and which are wasteful, allowing them to apply corrective actions if progress is not as planned (7.1), and increase cost-effectiveness of restoration programs. Effective monitoring requires strong certification and auditing mechanisms (8.4), with monitoring and auditing data transparently available. Importantly, centralised, spatially-explicit, publicly accessible databases that document the location, extent and status of restoration programs being implemented by different government departments, ministries, NGOs and independent practitioners is crucial for assessing progress towards meeting India's national and international restoration commitments (7.2).

Background

BACKGROUND

1. Restoration of India's degraded lands makes both ecological and economic sense, and is vital to avert ongoing biodiversity losses and ensure human well-being and quality of life.

1.1 Land degradation is a pervasive issue in India, negatively impacting the lives of millions of people.

The Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services (IPBES) defines 'degraded land' as "the state of land which results from the persistent decline or loss in biodiversity and ecosystem functions and services that cannot fully recover unaided within decadal time scales" (IPBES 2018). Although estimates of the extent of degradation in India vary substantially depending on the specific criteria used and methods employed (Ajai et al. 2009, Mythili & Goedecke 2016, SAC 2016), a recent assessment concluded that nearly 30% of India's land area (96.4 Mha which amounts to the combined surface area of the states of Rajasthan, Madhya Pradesh, and Maharashtra) is currently degraded due to a range of factors including deforestation, invasive species, overharvesting, improper land management, overuse of agrochemicals, and mismanagement of water (TERI 2018). Land degradation and associated losses of biological diversity can affect agricultural production, increase food and water insecurity and result in the loss of livelihoods, negatively impacting millions of people, particularly lower-income groups and marginalized communities (IPBES 2018). The annual economic losses due to land degradation was estimated to be ~2.5% of India's GDP in 2014-15 (3177 billion or $46.9 billion), or the equivalent of ~16% of the Gross Value Added (GVA) from the agriculture, forestry and fishing sectors (TERI 2018).

1.2 Urgent action to avoid and reduce land degradation, while actively promoting restoration efforts to reverse land degradation losses, can benefit biodiversity, increase food and water security, mitigate climate change impacts and ensure the sustained long-term provisioning of multiple ecosystem services from India's diverse biomes.

Ecological restoration – any intentional activity that initiates, assists or accelerates the recovery of a degraded or damaged ecosystem (SER 2004; Box 2.1) – and sustainable land management can have cascading positive impacts on ecosystems by increasing biodiversity; improving soil health, ecosystem productivity, carbon storage, water flow and quality; and enhancing habitat quality for wildlife (Benayas et al. 2009, Dowarah et al. 2009, Barral et al. 2015, Osuri et al. 2019, Singh et al. 2019). Although restoration efforts take time, restored ecosystems can often provide ecosystem services (e.g., pollination, carbon sequestration) and support biodiversity at levels comparable to reference ecosystems (Barral et al. 2015). Restoration and sustainable land management practices can also enhance food and water security; it is estimated that sustainable land management can increase crop production globally by 2.3 billion tons per year (ELD Initiative 2013). Restoration and other nature-based solutions also provide co-benefits for climate change mitigation through increased carbon sequestration and reduced GHG emissions, and increase ecosystem resilience to climate change and climate related disasters (IPBES 2018, 2019, Woolf et al. 2018, Osuri et al. 2019, Pörtner et al. 2021a, 2021b).

1.3 Restoration of degraded lands makes sound economic sense; the costs of inaction exceed the costs of action, and the benefits of restoration typically exceed the costs.

Land degradation is often the result of unsustainable land management strategies that prioritize short-term gains at the cost of long-term losses (IPBES 2018). Avoiding land degradation in the first place is always the preferable and cost-effective strategy, but restoration of degraded ecosystems can provide positive net benefits to both humans and nature. The cost of inaction in degraded lands can be more than 3 times the cost of restoration, and investments in ecosystem restoration can generate multiple benefits for societies worth as much as 10 times the costs (IPBES 2018). Restoration activities can create green jobs and income opportunities (e.g., cottage industries based on non-timber forest products) and generate financial incentives to increase government and private investment in rural areas through restoration and allied activities (Lambooy & Levashova 2011, Poffenberger 1996, Sietz et al. 2011), while also protecting ecosystem services on which these communities depend (BenDor et al. 2015, Cao et al. 2017, Goswami et al. 2020). For example, it was estimated in the late-2000s that additional investment in India's National Rural Employment Guarantee Act (NREGA) had the potential to create 8-10 million jobs towards restoration, agroforestry and allied activities (Matta 2009). Globally, restoration of degraded and deforested lands has been estimated to generate, on average, net benefits of ~$560 dollars per hectare of restored land (i.e. after accounting for costs of restoration; Borah et al. 2018). Estimates for India similarly indicate that it costs far less to restore land than to degrade it; conservative projections indicate that the cost of degradation can be as much as 2 – 200 billion more than the costs of land reclamation in 2030 (TERI 2018). Investing in well-planned, large-scale restoration efforts today therefore makes sound economic and ecological sense.

1.4 Restoration activities can help avoid alienating people from their land, while also contributing to the preservation of indigenous and local knowledge and culture.

Local involvement in restoration activities can avoid land alienation and help safeguard the rights of indigenous people and local communities (Widianingsih et al. 2016, IPBES 2018). Increased local participation and incorporation of indigenous and local knowledge in the planning, execution, and monitoring of restoration activities can promote eco-cultural restoration by providing short-term direct benefits to the communities, and long-term support for monitoring and maintenance of restored landscapes by local communities (Zedler & Stevens 2018, Reyes-García et al. 2018). Thus, restoration strategies integrating scientific knowledge and traditional ecological knowledge (TEK) play a pivotal role in conservation of cultural legacy of the area by contributing to the preservation of indigenous and local culture and ecosystem services which can favour the long-term restoration of biocultural landscapes (Velázquez-Rosas et al. 2018).

1.5 Restoration initiatives can make substantial contributions towards fulfilling India's commitments to international agreements including the Sustainable Development Goals, and can benefit several national policies aimed at agriculture, sustainable land and water management and poverty alleviation.

India was one of the first countries in Asia to commit to achieving land degradation neutrality, and restoring 26 million hectares of degraded land by 2030 under the Bonn Challenge. Restoration of degraded land is central to meeting most of the Sustainable Development Goals contained in Agenda 2030 (IPBES 2018), and is also critical for achieving India's Nationally Determined Contributions under the 2015 Paris Agreement of creating an additional carbon sink of 2.5 to 3 billion tonnes of carbon (TERI 2018). Restoration activities are also central to the planning and execution of several land and water schemes at the national level including the National Afforestation Programme, the National Mission for a Green India, the National Mission for Sustaining the Himalayan Ecosystem, the National Mission for Sustainable Agriculture, and the National Action Plan on Forest Fires.

2. Restoration and rehabilitation are intentional activities to counteract land degradation, preserve ecosystems and biodiversity, maintain landscape integrity and enhance the provisioning of ecosystem services across multiple scales. Successful restoration and rehabilitation efforts are guided by the integration of ecological, social, economic and cultural considerations, address the needs of key stakeholders including local communities, and ensure equitable distribution of benefits and livelihood opportunities.

2.1 Restoration and rehabilitation are long-term initiatives that incur initial financial costs, but provide long-term benefits for biodiversity, provisioning of ecosystem services and employment generation.

Restoration provides net benefits and should be considered as not just profitable, but also as an investment with high yields (de Groot et al. 2013). Restoration efforts can foster the recovery of biodiversity and multiple ecosystem functions in even the most degraded ecosystems (Beneyas et al. 2009, Jones & Schmitz 2009), and generate and diversify livelihoods and incomes (Adams et al. 2016, de Souza et al. 2016, Das 2017, Erbaugh et al. 2020). Although restoration efforts can provide many immediate (2-3 years) benefits (Jansen 2005), recovery typically takes time and can range from decades to longer, depending on the level of degradation, ecosystem type and specific response being considered (Jones & Schmitz 2009, Standish et al. 2014, Shoo et al. 2015, Kotiaho & Mönkkönen 2017, Haapalehto et al. 2017, Osuri et al. 2019, Veldkamp et al. 2020). Rather than focussing on short-term gains, restoration should be viewed as a long-term investment with returns for both nature and society, and policies should be encouraged that will allow the time needed to achieve restoration goals (de Groot et al. 2013, Haapalehto et al. 2017).

2.2 Restoration is not the same as tree planting; planting trees in grasslands, savannas and open woodlands can threaten unique biodiversity, disrupt the provisioning of key ecosystem services, impact rural livelihoods, and serve as a driver of land degradation.

Although tree planting is an ecologically appropriate and integral part of restoration in deforested landscapes and degraded forest ecosystems (Raman et al. 2009, Osuri et al. 2019), afforestation or the indiscriminate planting of trees in habitats that were previously non-forested such as grasslands, savannas and open woodlands can have severe negative consequences (Box 2.1, Box 2.2, Ratnam et al. 2011, Veldman et al. 2015b, Bond 2016, Griffiths et al. 2017, IPBES 2018, Veldman et al. 2019, Fleischman et al. 2020). Grasslands and savannas are ancient ecosystems that harbor unique biodiversity (Veldman et al. 2015a, Bond 2016, Murphy et al. 2016, Nerlekar & Veldman 2020), and provide important services to millions of people (Jackson et al. 2005, Veldman et al. 2015b). Tree planting in such areas is detrimental to biodiversity and ecosystem services such as water provisioning and carbon sequestration, can threaten rural livelihoods, and exacerbate land degradation, and should not be considered ecological restoration (Jackson et al. 2005, Veldman et al. 2015b, 2019, Bond et al. 2016, Griffith et al. 2017, Woodworth 2017, IPBES 2018, Malkamäki et al. 2018, Fleischman et al. 2020, Listen 2020). In India, under the CAMPA (Compensatory Fund Management and Planning Authority), the loss of forest land diverted to non-forest uses is offset by allocating funds for large-scale plantation activities in other areas, often in 'open natural ecosystems' including natural grasslands and savannas (Tambe et al. 2022). Such compensatory afforestation policies needs to be suitably amended to reflect global best practices in restoration, avoiding tree plantation drives in grasslands and savannas.

2.3 Restoration efforts that focus on multiple dimensions (biodiversity, ecosystem services and ecosystem functioning) in a landscape (i.e., plan for multifunctional landscapes) can provide greater ecological, economic and social benefits, than efforts which target a limited number of aspects.

Restoration efforts that focus only on a specific ecosystem service can run the risk of adversely affecting the provisioning of other ecosystem services or biodiversity (Bullock et al. 2011). In contrast, efforts which enhance multiple ecosystem services and biodiversity can provide multiple benefits (IUCN & WRI 2014, Marttila 2017, Gann et al. 2019). A win-win solution which balances the conservation of critical biodiversity with ecosystem service provisioning is to plan for multifunctional landscapes, comprising a variety of natural, semi-natural and human-modified land cover types (Lovell & Johnston 2009, O'Farrell & Anderson 2010, Sayer et al. 2013, Chazdon & Laestadius 2016, Temperton et al. 2019). For example, in an agricultural landscape, agricultural productivity can be intensified in certain areas to create new areas for restoration in marginal areas (Lü et al. 2012, Latawiec et al. 2015, Chazdon et al. 2017).

2.4 Successful restoration programs acknowledge and seriously consider social, ecological, and economic aspects at all stages from the planning to execution and monitoring phases.

Restoration programs that consider not just ecological benefits, but also social and economic benefits at all phases, and that are implemented within strong legal, governance and institutional contexts, have higher chances of success (Brancalion et al. 2013a, IUCN & WRI 2014, FAO 2015, Nkonya et al. 2016, Laestadius et al. 2015). In particular, ensuring the full and effective participation of local communities, and including their needs and knowledge in decision-making contributes substantially to successful restoration (Nkonya et al. 2016).

2.5 Restoration activities can be used as a means to sequester carbon and mitigate climate change, but all activities aimed at climate mitigation should not be confused with restoration.

Restoration of degraded lands, when appropriately implemented, can be an effective nature-based solution to sequester carbon and mitigate climate change (IPBES 2018, Wheeler et al. 2016, Lewis et al. 2019, Osuri et al. 2019, Yang et al. 2019). However, large-scale afforestation projects involving indiscriminate planting of monocultures can have negative impacts on biodiversity and ecosystem health, and can sometimes serve to decrease carbon sequestration (Wang & Cao 2011, Veldman et al. 2015b, Joshi et al. 2018, Veldman et al. 2019, Temperton et al. 2019, Fleischman et al. 2020). Tree planting in arid and semi-arid regions can also result in the deterioration of soil quality, and decrease groundwater levels, i.e., result in the 'trading of water for carbon' (Jackson et al. 2005, Cao et al. 2011; Li et al. 2017, Temperton et al. 2019). Other climate mitigation strategies like expansion of bioenergy crops, solar – and wind-farms can directly result in the replacement of natural vegetation, or displace croplands into natural vegetation, thereby increasing land degradation and biodiversity loss (Immerzeel et al. 2014). Plantations typically store lower amounts of carbon, show greater variability in inter-annual carbon capture rates in response to climatic fluctuations, and sequester carbon for shorter periods of time (as a result of regular harvesting which releases stored carbon back to the atmosphere) when compared to more biodiverse forests (Poorter et al. 2016, Lewis et al. 2019, Osuri et al. 2020, Fleischman et al. 2020). Thus, restoration planting that aims to maximise biodiversity is also the preferred option for climate mitigation, and can deliver co-benefits for other ecosystem services as well as biodiversity conservation (Alexander et al. 2011, Pörtner et al. 2021a, 2021b).

BOX 2.1

KEY DEFINITIONS

Restoration is any intentional activity that initiates, assists or accelerates the recovery of a degraded or damaged ecosystem to its pre-degraded state (SER Primer 2004, IPBES 2018). Restoration is an engaged human activity and can, therefore, restore human relationships to nature as well. Full ecosystem recovery may not be possible or appropriate everywhere, and even where possible, it may take decades or centuries to achieve because of the long-term nature of some recovery processes (SER Primer 2004, IPBES 2018).

Rehabilitation, a related concept, refers to activities that serve to repair ecosystem processes and enhance biodiversity and ecosystems services provided by degraded and damaged ecosystems, but not necessarily restore ecosystems to their pre-degraded states (IPBES 2018).

Reclamation can be defined as actions undertaken with the aim of returning degraded land to a useful state. While not all reclamation projects enhance natural capital, those that are more ecologically-based can qualify as rehabilitation or even restoration (SER Primer 2004).

Afforestation is the planting of trees in areas where they did not historically occur (such as grasslands and savannas) and their subsequent conversion to forests or tree plantations (Veldman et al. 2015b, IPBES 2018). Afforestation can have negative environmental consequences and serve as a form of degradation by reducing land available for biodiversity (both plants and animals) and livestock adapted to open environments.

Reforestation refers to the planting of trees on land that was previously forested but that has been converted to non-forested land (Veldman et al. 2015b, IPBES 2018).

RESTORATION CASE STUDY: 1

Rao Jodha Desert Rock Park, Jodhpur

Restoring the intensely rocky, arid conditions in the western desert of Rajasthan

Led by Pradip Krishen

The project area in 2006 when it was filled with invasive *Prosopis juliflora.*

The same area in 2020, with *Prosopis juliflora* removed and replaced with native desert plants.

Another view of the highly eroded, rocky site in 2007, after removing most of the *Prosopis juliflora.*

The same site in 2020, restored with desert flora.

Background

The project area encompasses 70 hectares of highly eroded land on top of an outcrop of volcanic rock (rhyolite) overlooking the city of Jodhpur, Rajasthan.

When Pradip Krishen and his team began work in 2006, their objective was to try and restore the natural ecology of the tract in order to create a sustainable landscape of desert plants that would also become an attractive adjunct to Mehrangarh Fort, which functions as a public museum.

Key problems and issues at the start

- Extremely dense infestation of invasive *Prosopis juliflora* which had outcompeted and edged out other trees and shrubs. They needed to get rid of *P. juliflora* in order to move ahead but digging it out from the rocky substrate presented big problems. They chose not to use toxic chemicals, nor ruin the historic natural landscape by blasting or by using heavy earth-moving machinery.
- They needed to compile a suitable list of desert plants adapted to survive in rocky situations (xeric lithophytes). There are excellent floras of the Thar desert, but these are entirely taxonomic and provide little ecological information about what the plants needed by way of soils, pH, minerals, moisture, site quality, etc.
- Barely any of the native desert plants required were available in nurseries.
- They had to find ways of dealing with the paucity of water – Jodhpur is arid, and the rocky substrate compounds the issue.
- Finally, it was important to try and create a landscape that was visually attractive. They hoped to welcome visitors into the Park after the first 5 years or so of restoration work.

Here are some of the most important ways in which the Project was realized

- *P. juliflora* was removed manually, with the help of skilled miners (Khandwaliyas) who 'understand' rocky terrain and how to cut into it using just a hammer and chisel. It took 7 years to clear all the invasive bushes and trees from the entire tract – which made it expensive, but entirely successful.
- They quickly learnt how to propagate and build a large and diverse stock of lithophytic plants from the Thar desert in their own nursery.
- The team needed to understand what each plant species 'needed' by doing extended trials on site. They kept records about each pit – its depth, what soil mix was used, the species planted in it, the site quality, and so on – and learned to plant in such a way that our initial survival rates of about 65% improved to near-total survival.
- For adequate moisture, they began by using conventional ways of gully-plugging but found this laborious, expensive and not very useful. They then re-structured their outlook to try and understand how these plants survive unassisted in the wild. By year 4 of the Project, plants were watered only for the first 4 months after they were placed in the ground. And then weaned so that they could survive without any watering after that. Key to this strategy was understanding how individual species are adapted (to

different degrees) to surviving in dry, rocky conditions. If they come upon a plant dying for want of moisture, it is pulled out and replaced with a more drought-hardy species. Today, the entire Park is not watered at all.

- To make an 'attractive' natural landscape, they had to decide what density to plant in (some restoration projects tend to create dense woodlands even where the natural ecology is open and sparse). All their initial planting of trees and large bushes was done only in pits that had been created where *P. juliflora* had been removed from.

Today – nearly 15 years after the restoration work began – Rao Jodha Desert Rock Park has become a beautiful, and more importantly, a sustainable landscape. There are still costs involved in keeping it going, but the major portion of these costs relate to the upkeep of a Visitors Centre, to employing trained naturalists to show visitors around, and in extending their system of habitat boards and interpretive signage for the benefit of visitors. The restoration work on this plot of land offers a protocol (that can be replicated) of how to deal with intensely rocky, arid conditions in the western desert.

Restoration needs to move beyond just tree planting

The Bonn challenge takes the 'Forest and Landscape Restoration' approach, the principles of which recognize that restoration is much more than just planting trees, and emphasizes the need to take local context and ecology into account.

However, because of the name of the approach, and widespread misunderstandings that grasslands originate from degraded forests (a colonial hangover which has resulted in misinterpretation of grasslands and savannas as wastelands), and that planting trees is always good, there has been excessive focus on tree planting in restoration activities in the recent past.

Contrary to these ideas, these activities are not appropriate in all ecosystem types. Afforestation, or the planting of trees in previously non-forested areas such as grasslands and savannas, can decrease biodiversity, make carbon sequestration susceptible to losses or even reduce overall carbon stocks, alter hydrological flows and exacerbate water issues. Further, afforestation efforts in such habitats often fail because of prevailing arid and semi-arid conditions, and because of disturbances such as fire and herbivory that are intrinsic to these systems.

Different restoration strategies should be used in different ecosystem types and contexts. For instance, the Ecological Restoration Alliance-India has proposed an approach that pays heed to the 51 terrestrial ecoregions of India when carrying out restoration: https://era-india.org/map/

2.6 Restoration efforts that focus on restoring ecological functions and processes can yield greater net benefits than efforts that focus solely on the quantity or spatial extent of tree planting.

In India, there has been a major focus on simply re-greening or re-planting landscapes through large-scale programmes of afforestation and tree planting (monocultures), while negligible efforts have been made to restore ecosystem functions, processes and biodiversity (Mudappa & Raman 2007). In fact, ambitious large-scale planting programs, although well-intentioned, have high failure rates when there is a lack of follow-up, resulting in wasted resources (James et al. 2011, Fehmi et al. 2014, Fleischman et al. 2020). Further, such efforts can negatively impact ecosystem service provisioning when there is a paucity of expertise on both how and where trees are planted (Holl & Brancalion 2020, Listen 2020). Efforts that focus on improving the quality of restoration (e.g., improving seedling quality, protecting seedlings, planting appropriate species and targeting appropriate restoration actions for different types of ecosystems) can not only improve ecological outcomes, but also decrease longer-term economic costs, and help make restoration efforts economically efficient (Madsen et al. 2016, Brancalion & Chazdon 2017, Schmidt et al. 2019, Di Sacco et al. 2021, Raghurama & Sankaran 2021). Often, it may be prudent to set a small number of locally achievable objectives that are implemented over time, rather than setting over-ambitious targets that are un-achievable (Ota et al. 2020).

2.7 Restoration activities, even at small scales, can provide multiple benefits, but there is an increasing need for adopting broader-scale approaches to counter degradation at landscape scales, and to meet India's commitments to multiple international agreements including the Bonn Challenge.

The effects of land degradation are not just felt locally, but also in downstream ecosystems. For example, intensive agriculture in upstream areas can cause water scarcity and eutrophication both in upstream and downstream regions (Schilling et al. 2008, Rodell et al. 2009, Swallow et al. 2009, Wang et al. 2010, FAO 2021). Restoration, even at scales of a hectare or less, can thus have significant positive effects not just locally (Mudappa & Raman 2007, Kremen & M'Gonigle 2015, Osuri et al. 2019), but also in downstream locations (de Groot et al. 2013, Comín et al. 2014, Liu et al. 2015). However, ignoring the wider implications of local restoration efforts can sometimes inadvertently displace degradation to other areas (Andam et al. 2008, Armsworth et al. 2006, Meyfroidt & Lambin 2009, Latawiec et al. 2015, Lenzen et al. 2012, Liu et al. 2015). For example, fencing a plot of land that is overgrazed, can just result in the grazing pressure being transferred elsewhere. Adopting landscape-level approaches to restoration can help reduce and avoid such displacement of land degradation, and is particularly important when scaling up restoration efforts in the country to meet national restoration targets for the Bonn Challenge.

3. The motivation for restoration, as well as the perception of what constitutes restoration, differs between stakeholders. Achieving consensus amongst different stakeholders on 'what' to restore is therefore key to the success and long-term sustainability of restoration efforts. Consensus regarding restoration targets needs to be established during the planning stages through consultations involving all relevant stakeholders, including women. Ensuring the participation of diverse stakeholders, from the planning to the execution and monitoring stages, increases community buy-in and the chance of longer-term success of restoration efforts.

3.1 Restoration targets (the desired ecosystem state post-restoration) can differ among stakeholders based on social and ecological contexts. Participation of all stakeholders during the planning stages can help build consensus in establishing targets, increase community buy-in, and the probability of restoration success.

The motivation for, and understanding of, restoration can vary between different stakeholders depending on social and cultural identity, and economic, ecological and political context (IUCN & WRI 2014, Hagger et al. 2017). In some cases, the focus might be on restoring biodiversity, while in others on improving ecosystem functioning and the provisioning of ecosystem services (Perring et al. 2015). Restoration targets can also vary depending on the scale of the effort; smaller scale projects typically focus on restoring locally important species and services, while larger scale projects work towards meeting national and international targets such as enhancing carbon stocks (Yin & Yin 2010, Mace et al. 2012).

Understanding and accommodating the motivations of different stakeholders during the planning stages can help resolve stakeholder conflict, deliver multiple benefits, and ensure long-term sustainability of restoration efforts (Hagger et al. 2017, Guerrero et al. 2017, Jellinek et al. 2019). Wherever possible, restoration should nevertheless focus on enhancing biodiversity as it provides co-benefits in terms of multiple ecosystem services, and can promote ecosystem resilience and long-term adaptive capacity in the face of climate change (Benayas et al. 2009, IPBES 2019, Osuri et al. 2019, Temperton et al. 2019, Pörtner et al. 2021a, 2021b).

RESTORATION CASE STUDY: 2

Ecological restoration of degraded rainforests in the western Ghats

Led by Nature Conservation Foundation

A degraded rainforest fragment in Valparai prior to tree planting in 2002 by volunteers from a nearby school.

The same site in 2020 with a tall and dense canopy of rainforest trees.

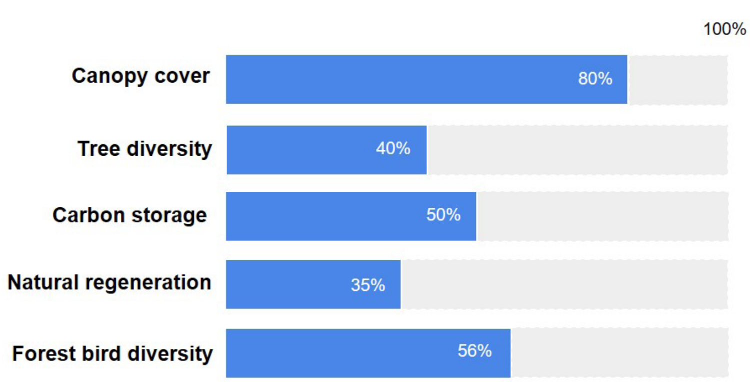
The rainforest nursery in Valparai. Saplings are transplanted from the nursery to the restoration sites typically when they are two to three years old.

The field team planting rainforest trees in a degraded site. Planting is typically undertaken over 1 - 1.5 ha at a time. Around 80-100 species per hectare are planted with trees spaced around 2 m apart.

Background

In the Western Ghats mountains of southern India, biodiversity-rich tropical rainforests have been severely deforested and fragmented over the past two centuries due to the expansion of plantation crops such as coffee, tea, cardamom and rubber. Rainforest remnants within these plantation landscapes have gained importance for conserving the region's unique biodiversity and contribute to human well-being in various ways. However, due to the combined influence of small patch size, isolation, anthropogenic pressure and invasive species, many of these rainforest patches exist in a perpetually degraded state.

A project led by Nature Conservation Foundation (NCF), in partnership with private plantation companies and the forest department, aims to recognize, protect and restore rainforests on the Valparai Plateau in the southern part of the Western Ghats. The project has identified over 1000 ha of rainforests spread over 50 patches across the plateau, and attempted ecological restoration of heavily degraded forests of around 100 ha over the past 20 years.



Extent of recovery 10-15 years after restoration (Osuri et al. 2019)

Strategies employed to restore degraded rainforests

Degraded rainforest fragments are restored using a maximum-diversity strategy. First, sites are prepared during the dry season by uprooting and removing non-native invasive species such as Lantana camara, while taking care not to disturb adults and juveniles of any native species. Next, a high diversity (80-100 species/ha) of native tree saplings is planted during the monsoon. The choice of species is informed by research and observations in intact rainforests of the nearby Anamalai Tiger Reserve. Saplings used for restoration are reared in NCF's rainforest nursery, from seeds rescued from roadsides and forest edges within the landscape.

Recent scientific evaluations of restoration success in the rainforest fragments show that forests 10-15 years after restoration have denser canopies, greater diversity and more similar species composition to intact rainforests of tree and bird communities, and store over thrice the amount of carbon as forests left to recover naturally.

However, most indicators of recovery in restored forests fall well short of levels characteristic of mature, intact rainforests. The research also shows that ecological restoration is most needed in isolated sites, whereas sites located closer to existing forests are more likely to recover on their own without restoration intervention. This project demonstrates that active restoration planting using a high diversity of native species enhances the biodiversity value of rainforest fragments and conservation values of lands outside protected reserves.

Further reading

https://www.ncf-india.org/western-ghats/52
Raman et al. (2009), Osuri et al. (2019),

BOX 3.1

Stakeholder mapping tools to help identify stakeholders and their interactions.

Social Network Analysis (SNA) is a technique that can be used to identify key stakeholders in a restoration project, map socially meaningful relations between them, the strength of these relations, and the influence of each stakeholder based on their linkages with other stakeholders (Hogan et al. 2007, Prell et al. 2009). Network Mapping, an extension of SNA, also considers the goals of different stakeholders, and helps detect stakeholder groups with conflicting goals, and potential for cooperation and synergy (Schiffer & Hauck 2010). These techniques can be used in the field by non-technical personnel with some training.

Social Network Analysis and Participatory Network Mapping have been widely used previously in public health and social work in India to: (1) identify opportunities to strengthen and support child nutrition programs in Maharashtra and Andhra Pradesh (Puri et al. 2017); (2) assess impacts of community mobilization on coordination between Self Help Groups and local health systems in Uttar Pradesh (Ruducha et al. 2019); (3) understand differences in governance of Water, Sanitation and Hygiene based on city types in south India (Narayan et al. 2020); and (4) understand COVID-19 transmission in Karnataka (Saraswathi et al. 2020), amongst others. These techniques are now being increasingly used in restoration programs globally (Sayles & Baggio 2017, Schröter et al. 2018) and can be effectively used in India too.

3.2 Identifying groups of people who should be directly involved in the execution of restoration programs and understanding their motivations can help better negotiate between different stakeholder groups.

Key stakeholders in restoration efforts can include such diverse groups as landowners, traditional forest dwellers and tribal communities, Joint Forest Management Committees (JFMCs),land users or people with land rights, women's groups, panchayats and gram sabhas, scientists and academic organizations, NGOs, and media.

Understanding different stakeholder motivations in a restoration project can help identify intervention points that the project can focus on, stakeholder groups that the project can leverage, and impediments faced by the project. Further, understanding how stakeholders are related to each other and influence each other, and their underlying power dynamics helps with negotiating between stakeholders and building consensus (Mansourian 2016). Stakeholder mapping tools (Box 3.1) can help identify stakeholders for a restoration project, define their stakes and motivations, and understand how they influence each other, all of which will help with effectively engaging them in restoration efforts (Stanturf et al. 2017). In particular, while the Joint Forest Management Committees (JFMCs) are involved in plantation and afforestation activities (Press Information Bureau 2019), they must also engage in eco-restoration activities.

3.3 Incorporating the expectations and preferences of different stakeholders at the planning stage can help formally establish restoration targets when there are multiple stakeholders with competing expectations and values.

Setting up quantitative restoration targets requires reaching a consensus on what aspects of the ecosystem to restore and where (biodiversity, ecosystem functions, ecosystem services or some combination thereof), to what extent to restore, and over what time frames (Kotiaho & Moilanen 2015, Nkonya et al. 2016, Hagger et al. 2017, Guerrero et al. 2017, Jellinek et al. 2019). Multi-stakeholder participation (either directly or indirectly through consultations, meetings, workshops and public hearings) ensures that everyone's concerns can be heard and addressed when the restoration plans are designed (Sayer et al. 2013, van Oosten et al. 2014, Guerrero et al. 2017, Kusters et al. 2018, Stanturf et al. 2019). Structured decision making approaches – a set of techniques that identify the target(s) which provides the most utility or benefits, based on multiple and competing expectations – can help design restoration plans with an inclusive set of objectives that capture the expectation and values of multiple stakeholders, identify areas of the landscape where different restoration targets should be established (mosaic restoration), and help determine the weights that different targets should be given in a landscape (Schwenk et al. 2012, Comino et al. 2014, Mendoza & Martins 2006, Langner et al. 2017, Adem Esmail & Geneletti 2018). Repeatedly asking "Why is that important?" (i.e. WITI test, Clemen 1996) can help narrow down a core set of fundamental targets or 'end points' from a larger set of objectives (Keeney 1992, Guerrero et al. 2017, Martin 2017). In particular, ensuring diverse participation at the planning stages increases the responsibility felt by various stakeholders towards the restoration effort, and increases the chance of its success (Raman & Mudappa 2003, Sayer et al. 2013, Reed et al. 2017, Kusters et al. 2018).

3.4 Establishing appropriate targets to restore or rehabilitate to, i.e. 'reference states' or 'baselines', either historical or more recent, is crucial to the actual restoration process, and to setting management goals.

Restoration efforts aim to return biodiversity, ecosystem structure and function to a pre-degraded state (i.e. natural or historical baseline), while rehabilitation efforts seek to partially re-establish some desired ecosystem services and regain vegetation cover (Box 2.1). In most cases, the targets of restoration efforts i.e. 'natural' baselines (vegetation state before degradation) are readily observable from protected areas and reserve forests in similar geographical and climatic areas

(Durbecq et al. 2020). In the absence of such example sites, earliest available historical records (e.g., pre-independence land surveys and forest surveys) and/or expert knowledge can be used to build a picture of what the natural state of the system was like before degradation (Barak et al. 2016, Wingard et al. 2017, IPBES 2018, Manzano et al. 2020). Although restoring to historical ecosystem states may not always be possible, identifying 'natural' or 'historic' baselines is nevertheless critical as it can help determine the extent of degradation, and thus give us an indication of the restoration efforts required, identify barriers to ecosystem recovery (Hulvey & Aigner 2014, Gann et al. 2019), identify naturally low-productive land that may be mistakenly classified as degraded (Prince 2016), and ensure that species typical of the historic ecosystem are included in restoration efforts at the landscape scale and thereby conserved (Temperton et al. 2019).

3.5 Setting up Specific, Measurable, Agreed-upon, Realistic, Time-bound (SMART) targets can improve the effectiveness of restoration programs and help monitor success.

The SMART framework (Doran 1981) is widely used in project management to frame structured and effective targets, and using this framework in setting restoration targets will help the planning, execution and monitoring of restoration programs (Wood 2011, Green et al. 2019, CMP 2020). Setting such targets helps decide management strategies, identify effective approaches, select relevant indicators to monitor restoration progress, periodically assess successes or failures, and apply course corrections as needed (MA 2005a, MA 2005b, Vogt et al. 2011, Dey & Schweitzer 2014, IPBES 2018).

3.6 Active participation of NGOs, businesses and private investors in restoration efforts will help integrate community perspectives during restoration planning, increase community participation during execution and monitoring, inject the required financial and entrepreneurial support, and create a 'restoration economy' that generates significant employment opportunities.

NGOs often have a good understanding of local needs and aspirations, and can help design livelihood alternatives in cases where restoration activities impact existing livelihood programs, and the capabilities to engage and cooperate with local communities in decision making and execution (Gupta et al. 2020). Restoration efforts also require a wide range of financing options and economic instruments – an area where private investors can have substantial contributions (Iftekhar et al. 2017, Löfqvist & Ghazoul 2019). With the development of innovative financial mechanisms and creating the right investment environment, incentives and opportunities, the growth of a 'restoration economy' can be encouraged, with businesses investing in restoration not only as philanthropic activities, but also as profit-making enterprises (e.g., through carbon and biodiversity offset markets, water provisioning services, ecotourism, monitoring and auditing) (Galatowitsch 2009, Lambooy & Levashova 2011, Maron et al. 2012, BenDor et al. 2015, Richardson 2016, Thomas et al. 2017). NGOs, businesses and private investors entering into partnerships with farmers, land owners, land managers, restoration practitioners and conservation organizations can help overcome existing barriers to restoration, create new restoration opportunities and scale-up restoration efforts to larger spatial scales (Ferwerda 2015, Perring et al. 2018, Löfqvist & Ghazoul 2019).

3.7 Greater participation of women in restoration efforts, from the planning to the execution and monitoring stages, can improve gender equality and also increase the efficiency and success of restoration programs.

Men and women have different perspectives regarding forest resources, and about forest and natural resource management for household and community well-being (Upadhyay 2005, Kelkar 2007, Agarwal 2009, Ray et al. 2016). Ignoring such gender differences can hamper restoration efforts, intensify existing gender inequalities, further restrict women's access to land and resources, and have their voices undermined and their work burden heightened (Sarin 1995, Agarwal 2001, Basnett et al. 2017). Ensuring the active participation of women in restoration programs, on the other hand, can increase restoration efficiency and success through increased local capabilities and broader community buy-in of these programs (Agarwal 2009, Basnett et al. 2017, Broeckhoven & Cliquet 2015, Petruzzello 2015), while also increasing gender equity and correcting gender-related power imbalances (Sendzimir et al. 2011, Broeckhoven & Cliquet 2015, Goswami et al. 2020). Increasing the participation of women in restoration programs will also help India achieve its commitments to Sustainable Development Goal 5 (Gender Equality) and the Convention on the Elimination of All Forms of Discrimination against Women.

RESTORATION CASE STUDY: 3

Water Harvesting Makes Jarur Hiwardhara Nala a Perennial Stream

Led by Foundation for Ecological Security

Jarur Hiwardhara Nala before the restoration work began.

Jarur Hiwardhara Nala after the restoration work was completed.

Restoration work at the Commons

Restored Commons

Background

Jarur, a remote village in Yavatmal District, Maharashtra, historically suffered from water scarcity. The Jarur Hiwardhara Nala, which passes through the village, dried up during summers and people had to buy tanker water to fulfill their drinking water requirements. The community also faced severe fodder and water scarcity for its livestock as the village commons were barren and depleted.

In 2014, the Foundation for Ecological Security (FES) brought together the community to restore and manage their commons. Community discussions identified the repair of the existing nala bunds on the Jarur nala as potentially important for recharging the community well. This was validated using the Composite Landscape Assessment and Restoration Tool (CLART), which indicated that repairing the nala bunds would help increase groundwater recharge. Construction of new bunds was ruled out as it amounted to ten times the repair costs.

Repairing the first bund in 2014, added 13,816 m^3 storage capacity to the nala, and increased groundwater levels, with the community well now having enough water to tide over the dry season. In 2016, renovating the second bund by de-silting and repairing cracks enhanced the water storage potential of the nala by 4,653 m^3. The increased water storage in the nala also enhanced water flows to the downstream Saikheda Dam, reiterating the importance of watershed approach for landscape restoration.

Simultaneously, communities were introduced to Crop Water budgeting exercises, and farm bunding and construction of two farm ponds were done to also improve water availability. As a result of these activities, the Jarur nala is now a perennial stream, recharges the community well all year round, recharges close-by farm wells, with fishing by the Bhoes community in the check dam enhancing their earnings.

The increased water availability created a conducive environment for undertaking restoration work on the adjacent 338 acres of village commons by leveraging Mahatma Gandhi National Rural Employment Guarantee Act 2005 (MGNREGA) after taking permissions from the Gram Panchayat. Along with trenches and planting on the Commons, the communities were introduced to a Package of Practices including farm preparation, cross ploughing and line sowing, application of cow dung, compost, inter-cropping, minimum usage of fertilizers and pesticides, demonstration of bio-decomposers etc. The engagement, which started with 23 farmers covering 28.6 acres of farmland in 2014-15, now covers 67 farmers undertaking kharif crops (cotton, red gram and soya bean) and 18 farmers undertaking rabi crops (wheat and gram), covering a total of 100 acres, 78 acres of which is also covered under micro irrigation practices.

The renovation of the bunds along with restoration of commons through MGNREGA has provided villagers with work during the off-season. This year, the pre monsoon MGNREGA work including Continuous Contour Trenches* and Cement Nala Bunds on the commons added 1,976 m3 to water storage potential, while also generating 1,220 person-days of work.

The communities of Jarur are committed to the upkeep of the nala bunds, and are moving towards water-efficient crops, so that their water resources never deplete again. Some farmers, overexploiting the groundwater, were penalized by disconnection of their electricity supply, which was restored only once the farmers agreed to abide by the rules and norms set by the institution.

The communities are working for further regenerating their common lands so as to become self-sufficient in terms of fuel and fodder availability, along with enhancing the ecological benefits like improved water flows, enriched soil nutrients etc. The collective action of Jarur has brought about positive changes in the lives of all in the village and the community is committed towards further bettering the governance and management of their Common resources for the common good of all. It must be kept in mind that contour trenches in savannas can be counterproductive in some cases as it could lead to a loss of endemic species that use shallow soil depths (e.g., tuberous herbs, grasses).

BOX 4.1

Prioritizing restoration areas involves multiple steps, many of which needs active participation of experts and researchers, and also local stake-holders

Stakeholder consultations (Table 3.1.) to identify priorities of the restoration program (list of potential priorities in Table 4.1.) →

Collate GIS datasets (spatial layers) related to the decided list of priorities (e.g., biodiversity, C sequestration)

↓

Generate spatial layers of ecosystem service provisioning. Where field data are unavailable, ecosystem service mapping tools (Table 4.2.) can be used to quantify services in different parts of the landscape.

←

Use optimization models (e.g., linear programming, Bayesian networks, etc.) based on efficiency frontier (Table 4.2.) to decide which parts of the landscape to prioritise restoration in.

4. Large scale restoration efforts need to balance funding and resource limitations with competing land-uses and the multiple demands and interests of stakeholders. Planning how to restore and which areas to restore using different criteria can reveal the benefits and costs of different options. This can help choose the best strategies and select areas where restoration can benefit the most.

4.1 Quantitative techniques that assess and balance trade-offs between different interest groups can help identify areas in the landscape where restoration efforts can deliver the greatest benefits at the lowest cost, and help harmonize biodiversity conservation with restoration. However, these techniques require expertise and hence, academic engagement and significant capacity building is required.

Lack of funds and competing land uses dictate the need to assess which restoration strategies and sites are likely to deliver the best results (Gourevitch et al. 2016, Neeson et al. 2016, Comín et al. 2018, Strassburg et al. 2019, Etter et al. 2020). Balancing stakeholder preferences can reveal trade-offs and synergies in ecosystem service provisioning, enable stakeholders and decision makers to evaluate the potential benefits and opportunity costs of different restoration approaches, and thereby identify optimal strategies to increase the impact and success of restoration (e.g., multi-criteria spatial prioritization; Gourevitch et al.. 2016, Strassburg et al. 2019, Li et al. 2020). Such strategic approaches can increase conservation gains (by as much as 8-fold in some cases) while substantially reducing costs (by as much as half) relative to non-systematic restoration approaches (Gourevitch et al. 2016, Strassburg et al. 2019).

TABLE 4.1
A non-exhaustive list of potential factors to consider while prioritizing between restoration opportunities. Tools for prioritizing restoration options are listed in Table 4.2.

Facts to consider	Why should this factor be considered?
Opportunity cost of restoration – what would be the benefits lost due to replacement of existing land use?	Restoration entails changing existing land uses which can have unintended consequences for different stakeholders. For example, restoration in agricultural areas can have a cost to farmers due to potential losses in agricultural activities. Restoration can be prioritized in areas with high potential ecological value and low value for other uses, thereby minimizing competition with other land uses.
Biodiversity and uniqueness of the pre-degraded state	Many ecosystems in India are ancient – the products of millions of years of evolution – and are extremely biodiverse. Losing these ecosystems would be a huge ecological and social loss to the nation.
Ecosystem services provided by the region	Different habitats in a landscape provide different proportions of various ecosystem services, and different stakeholders place differential importance on different ecosystem services. Ecosystem services flow from different habitats can be quantified using different tools, and weighted differently based on societal values, to integrate societal interests into prioritizing restoration areas.
Status of degradation and fragmentation, connectivity between habitats, recency of degradation	Biodiversity loss and impairment of ecosystem service provisioning is greater in areas where degradation is spatially extensive and has been occurring for long periods, and the time lag in ecosystem recovery due to restoration activities will be greater in such areas.
Poverty and developmental status	In rural areas with high poverty levels, employment generation through restoration activities can improve income levels, and increase public and private investment in education and livelihoods in the region. On the other hand, if vulnerable communities are highly dependent on particular existing land uses, restoration in such land uses may have associated economic and social risks. Stakeholder consultations can help figure out which existing land uses are highly valued by communities.

References: Ianni & Geneletti (2010), Tambosi et al. (2014), Rappaport et al. (2015), Neeson et al. (2016), Cortina et al. (2017), Comín et al. (2018), Erős & Bányai (2020), Etter et al. (2020)

TABLE 4.2

Some conceptual frameworks, ecosystem service mapping tools and mathematical techniques that can be used to prioritize between restoration options, and identify locations to restore in.

Tools to quantify and map multiple ecosystem services

Tool	Description	References
Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST)	Ecosystem service models that use production functions to convert maps of land use and land cover (LULC), land management, and biophysical conditions into maps of ecosystem services for different management options. Easy and quick to use.	https://www.naturalcapitalproject.org/ Kareiva et al. (2011)
Artificial Intelligence for Ecosystem Services (ARIES)	AI-based modeler which provides access to a library of ecosystem service models to provide spatial maps of ecosystem service flow in the landscape. Adapts to best available data, allows customized models, can integrate Bayesian networks.	https://aries.integratedmodelling.org/ Villa et al. (2014)
Land Utilization & Capability Indicator (LUCI)	LUCI is an ecosystem service modelling tool which demonstrates the land use impact on different ecosystem services. Easy-to-use with basic GIS skills, and has a built-in trade-off tool that allows identification of 'win-win' areas. Available upon request on case-by-case basis, and can be used on site-scale too (finer scale than landscape scales).	https://www.lucitools.org/ Bagstad et al. (2013)

For information on other ecosystem services assessment/mapping tools, please see Bagstad et al. (2013). Different tools have different strengths and weaknesses, with some tools being easy to use but either not allowing spatial analyses (e.g., Ecosystem Services Review by WRI; Landsberg et al. 2013) or not allowing assessment of individual ecosystem services separately (e.g., Co$ting Nature; http://www.policysupport.org/costingnature). One more potentially usable tool in semi-literate village communities, and in the absence of expertise, is the 'Composite Landscape Assessment and Restoration Tools' (CLART; https://www.indiaobservatory.org.in/tool/clart) developed for the Android platform by the Foundation for Ecological Security.

TABLE 4.2 continued

Mathematical Techniques to guide prioritization

Once stakeholder consultations have been carried out, restoration targets identified and weighted, and ecosystem service supply quantified using ES models, optimization models can be used to identify spatial restoration configurations that maximize the provisioning of multiple services. The efficiency frontier (or production possibility frontier) is commonly used to identify optimal and cost-effective restoration solutions by explicitly considering trade-offs between multiple services. Several approaches including linear programming, Bayesian decision networks and genetic algorithms can be used to find optimal solutions, and can incorporate multiple benefits, costs and policy scenarios, and compare trade-offs between different scenarios. These techniques also allow greater flexibility than pre-designed SCP (Spatial Conservation Prioritization) softwares. Participation of experts and significant capacity building in India is needed to execute and use these mathematical techniques.

References: Stewart-Koster et al. (2010), Vogler et al. (2015), Gourevitch et al. (2016), Elliot et al. (2019), Singh et al. (2019), Strassburg et al. (2019), Li et al. (2020), Reith et al. (2020)

4.2 Along with capacity building and participation by experts, prioritizing restoration efforts requires detailed, readily available and open access datasets on various environmental and social variables to allow local-scale decision making by land managers.

Effective prioritization of areas to focus restoration efforts requires detailed, spatially explicit data on multiple environmental and social variables, including species distribution maps, land-use and land cover data, crop areas and cropping yields, degradation maps and data on the multiple ecosystem services of interest (Gourevitch et al. 2016, Gann et al. 2019, Strasburg et al. 2019, Ruiz-Benito et al. 2020). Coarse resolution maps at the national scale can identify large areas or regions where restoration efforts should be targeted (IUCN & WRI 2014), while mapping exercises at the local scale can help delineate areas that need to be kept aside for protection of biodiversity, identify where in the landscape production can be intensified, identify areas where restoration efforts should be undertaken, and also where on-site restoration may not be possible and 'off-site restoration' would be needed (Kotiaho & Mönkkönen 2017, IPBES 2018, ArroyoRodríguez et al. 2020). It is critical to ensure that grasslands and other open woody vegetation formations such as savannas are not mistakenly classified as 'wastelands' during this exercise (NRSC & ISRO 2019) so that inappropriate restoration is not done in such areas. To truly take restoration efforts to the grassroots, all relevant data and maps need to be made freely available in digital form in the public domain and accessible to restoration practitioners, scientists, managers and the general public. For example, open natural ecosystems (including grasslands and savannas) in India have been mapped and the data is available publicly (Madhusudan & Vanak 2022). Additionally, the Ecological Restoration Alliance-India has developed publicly-accessible maps of terrestrial ecoregions of India with relevant digital map layers that can be overlaid to help inform and guide restoration efforts in different parts of India (see: https://era-india.org/map/).

5. Successful restoration depends on identifying and dealing with both the direct and indirect drivers of degradation, and choosing approaches that are appropriate for the landscape and habitat in question. Inappropriate techniques can result in failed restoration efforts, potentially increased degradation, and wasted resources.

5.1 Identifying, assessing and addressing the drivers of degradation is the first step to successful restoration.

Land degradation is a complex process, and is the outcome of multiple drivers – both direct and indirect – that operate at scales ranging from the local to national to global (Barger et al. 2018; Box 5.1). Direct drivers are those that result from the 'direct' actions of humans (e.g., land clearing, overgrazing, over-harvesting; Díaz et al. 2015, Barger et al. 2018). Indirect drivers, on the other hand, are those that operate by altering the magnitude or rate of change of direct drivers (e.g., access to land, poverty, lack of livelihoods, consumer demand, labour markets, international agreements etc), are often external to the system in question, and are the ultimate underlying causes of degradation (Díaz et al. 2015, Barger et al. 2018). The success and sustainability of any restoration effort rests on unequivocally identifying and addressing the direct, and more importantly, the indirect drivers of degradation. For example, fire and grazing levels are integral components of grassland and savanna ecosystems, and, contrary to popular opinion, treating them as direct drivers of degradation and suppressing them can in fact serve to degrade such ecosystems (Kumar et al. 2020). While direct drivers of land degradation are typically easily observed and identified, the identification of indirect drivers is more complicated given the highly interconnected and globalized nature of the drivers (Díaz et al. 2015, Barger et al. 2018). For example, growth of global coffee markets and the increased demand for organic fertilizer has been linked to increases in livestock numbers and large-scale export of dung from villages abutting Bandipur National Park, aggravating grazing pressure and local degradation (Madhusudan 2005). Investing time and effort in identifying the drivers of degradation, both direct and indirect, at the initial stages ensures that appropriate interventions are adopted (Pandit et al. 2019), and that restoration efforts do not result in 'displaced degradation' (refer 2.7).

BOX 5.1

Drivers of Land Degradation

Direct drivers of land degradation can be conceptualized as the set of actual 'activities' that humans 'do' that results in the degradation of land. These are the proximate causes of land degradation and include activities like the clearance of land, overgrazing, setting of fires, harvesting of wild populations, excessive use of fertilizers and so on.

Indirect drivers of land degradation, on the other hand, are the 'reasons' why people do what they do. These are the ultimate causes of degradation and act by altering the rate or extent of direct drivers. Indirect drivers include factors such as access to land, property rights, poverty, consumer behavior, power imbalances, world views, regulatory policies, access to information etc.

Reference: IPBES 2018

5.2 Both 'passive' and 'active' restoration are viable and effective strategies for restoration; the choice of approach is context-dependent and driven by ecological and financial considerations, restoration time-frames and choice of targets.

The choice of restoration strategy – active versus passive – depends not only on desired ecological outcomes and restoration time-frames, but also on financial considerations (de Groot et al. 2013, Brancalion et al. 2016). Both approaches can be equally effective in restoring biodiversity and ecosystem functions and services, but their efficacy is context sensitive and can differ depending on the level of degradation, time since degradation, land-use type, landscape context and restoration targets (Meli et al. 2013, Shoo et al. 2015, Molin et al. 2018, Meli et al. 2017, Prach et al. 2019, Atkinson & Bonser 2020, Table 5.1). Passive restoration typically incurs lower financial costs, and can be effective in areas with low to moderate degradation levels, where invasive species are rare, and where 'natural' vegetation is already present in the landscape (Table 5.1; Chazdon & Guariguata 2016, Crouzeilles et al. 2017, Jones et al. 2018, Shimamoto et al. 2018, Gann et al. 2019, Huang et al. 2019, Prach et al. 2019, Reid et al. 2018). However, more costly active restoration approaches may be necessary in highly degraded areas (e.g., mined sites and highly degraded forests), where invasive species are abundant, where restoration sites are isolated or distant from non-degraded patches or contiguous forest sites, or when target native species are not readily available in the seed bank or adjacent habitats (Holl 2002, Meli et al. 2013, Zahawi et al. 2014, Osuri et al. 2019, Prach et al. 2019). Detailed cost-benefit analyses (e.g., IUCN cost-benefit framework; Verdone 2015) can help determine the techniques, and the conceptual and technological approaches, that provide the most ecological and economic benefits in return for the lowest investment (Brancalion et al. 2012, de Groot et al. 2013), and help adjust restoration models to those that are attractive to investors and stakeholders (Verdone 2015). It is often worthwhile to consider passive restoration as the first approach, switching to more active interventions where recovery is slow (Holl & Aide 2011, Jones et al. 2018, Reid et al. 2018). However, in many cases, using both approaches within a site, with greater effort and proportion of funding being allocated to parts of landscapes where natural regeneration is hindered, may be the most cost-effective approach (Holl 2002, Holl & Aide 2011). It has been recognised that interventions are not merely categorised as active-versus-passive, but exist along a gradient of intervention intensities and must consider restoration goals, while providing sufficient detail for reproducibility (Krishnan & Osuri 2022).

TABLE 5.1

Comparison of Active and Passive restoration strategies, and the salient features of each strategy.

	Active Restoration	Passive Restoration
Preferred in what type of landscapes?	• High degradation levels (Gann et al. 2019, Prach et al. 2019) • Invasive species are abundant (Ruwanza et al. 2013, Prach et al. 2019) • Depauperate soil seed banks of native species (Ruwanza et al. 2013, Thomas et al. 2014) • Source plants for seeds of target species are rare or can't easily disperse to restoration site (Bannister et al. 2014, Osuri et al. 2019)	• Low to intermediate degradation levels (Gann et al. 2019, Prach et al. 2019) • Invasive species are rare (Prach et al. 2019) • Intact soil seed banks of native species (Chazdon 2008) • Source plants for seeds of target species are abundant, or can disperse to, restoration site (Chazdon 2008)
Costs of the approach	Typically more expensive. Can incur high costs in the initial years of restoration as resources are allocated for activities like replanting, water management, nursery management, weed control etc. (Zahawi et al. 2014, Powell et al. 2017)	More cost effective in most scenarios. Direct costs only typically include material for fencing, labour costs for vigilance, monitoring etc. However, there may be hidden costs to passive restoration given the longer recovery times (Zahawi et al. 2014)
Time taken for restoration to be achieved	Typically lower (Zahawi et al. 2014, Larkin et al. 2019)	Typically longer (Zahawi et al. 2014, Brancalion et al. 2016)
Post-restoration community	Although outcomes of active restoration strategies are variable (Brancalion et al. 2016), these strategies allow greater control over the restoration trajectory (Bechara et al. 2016).	Outcomes of passive restoration can be highly variable (Brancalion et al. 2016, Reid et al. 2018), and can sometimes result in arrested succession or the emergence of novel ecosystems (Bechara et al. 2016).

5.3 Restoration planting using diverse mixtures of native species, including endemic and threatened ones, supports on-site conservation and helps build more resilient ecosystems in the face of climate change, and should be preferred over the use of exotic species.

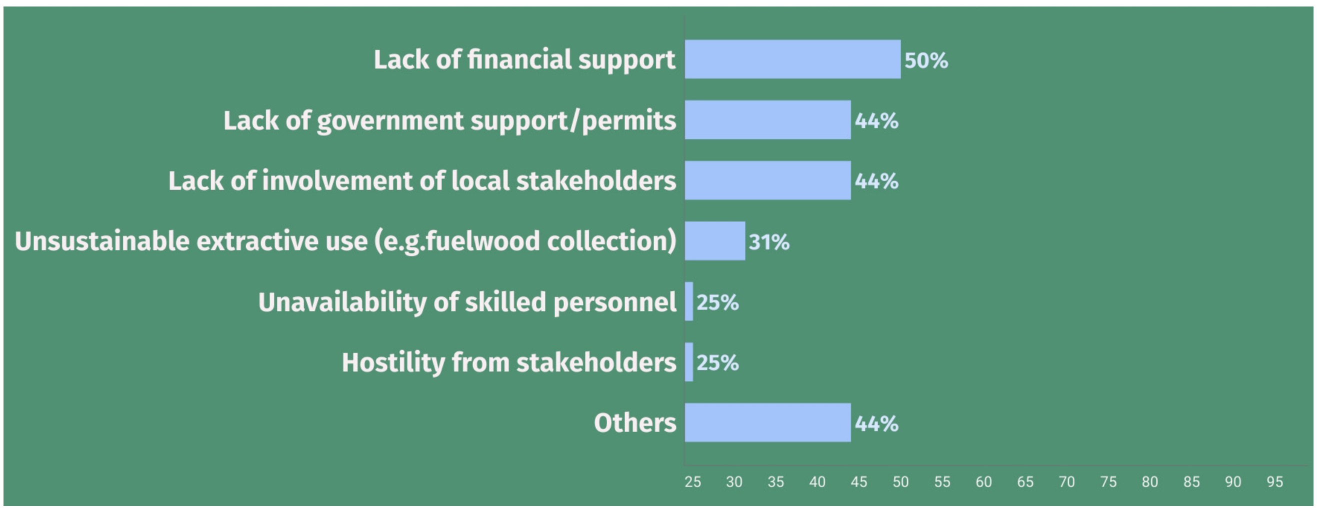
Planting a diverse mix of native species, including rare, endemic and threatened ones, species that are important to local communities for their everyday needs, and using seeds from genetically diverse sources (e.g., from multiple parent trees and from different local populations) can provide greater benefits for ecosystem functioning and service provisioning compared to monocultures and less diverse plantations. It can also increase ecosystem resilience to future climate changes and to (re-)invasion by exotic species, while also simultaneously contributing to biodiversity conservation (Harris et al. 2006, Funk et al. 2008, Rodrigues et al. 2009, Hall et al. 2011, Breed et al. 2013, Millet et al. 2013, Thomas et al. 2014, D'Antonio et al. 2016). Although exotic species have been previously used successfully in restoration programs as nurse plants, as engineers to restore nutrient levels and prevent soil erosion, or to help offset initial restoration costs by providing revenue in the form of timber and pulp (D'Antonio & Meyerson 2002, Stewart & Balear 2003, Blanchflower 2005, Lamb et al. 2005, Brancalion et al. 2020), exotic species do not generate a broad spectrum of ecosystem services, can impair the provisioning of some services, threaten native biodiversity, increase the risk of disease outbreaks, and can even be the source of new invasions (Tang et al. 2007, Aguiar Jr et al. 2013, Wingfield et al. 2015, Chazdon et al. 2020, 2.4, 2.5). Because the costs of using exotics can far outweigh the benefits, their use in restoration plantings is not advisable.

BOX 6.1

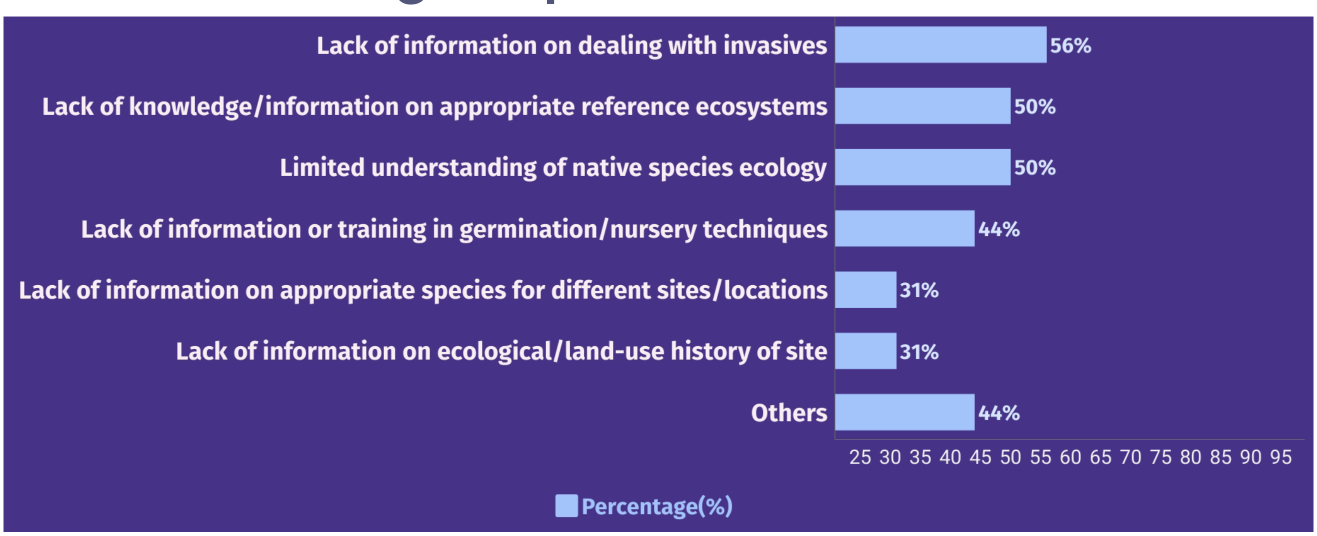
Knowledge gaps and socio-economic challenges that hinder restoration

The graphs below present the results of a survey of 16 restoration practitioners (10 working in forests, and 6 in grasslands) from India who participated in consultation meetings during the framing of this document. Practitioners were asked about the challenges associated with ecological restoration in different landscapes across India. Percentages in the graphs denote % of respondents who selected that particular knowledge gap or socio-economic challenge.

Socio-economic Challenges to Restoration



Knowledge Gaps in Restoration Efforts



6. Achieving targets requires scaling up restoration efforts across multiple landscapes by integrating expert scientific and technical knowledge to inform strategies across society, economic, policy and environmental sectors. Successful scaling up of efforts requires establishing an effective network of nurseries and seedbanks, developing restoration knowledge hubs and atlases for native species, creating strong financial and institutional frameworks, and generating awareness to encourage active engagement of stakeholders.

6.1 Enhancing technical and scientific capacity, and establishing restoration 'knowledge hubs' to effectively disseminate state-of-the-art information on best practices in restoration based on the collective knowledge and experience of practitioners, traditional ecological knowledge and latest scientific advances is a prerequisite for successfully scaling up restoration efforts to meet India's international and national commitments.

Restoration efforts are often hampered by a lack of ecological 'know-how' and information on what restoration techniques to use, where to restore, which native species to use, choice of reference states, techniques to deal with invasive species, and good germination practices and nursery techniques, amongst others (Box 6.1, Horne et al. 2017, IPBES 2018). Scaling up restoration efforts to meet national and international commitments requires such information to be readily accessible (Brancalion et al. 2013a, 2018). Development of national 'restoration knowledge hubs', both web-based and on-ground, whose function is to effectively transfer information on the experiences of restoration practitioners, both successes and failures, disseminate the latest scientific advances and techniques, and build capacity of local communities and practitioners is essential to increase the success of restoration programs and prevent repeating costly mistakes (Menz et al. 2013, Aguilar et al. 2015, Kotzen 2015, Bloomfield et al. 2017, Perring et al. 2018, Aronson et al. 2020).

6.2 Restoration planners should acknowledge and address prevalent institutional and socio-economic barriers that can hinder the success of restoration efforts including the lack of strong institutional and financial frameworks to support such programs, inadequate stakeholder participation and unsustainable land-use practices.

Several studies have shown that lack of institutional and governmental support (both financial and structural, e.g., permits and local government-sanctioned institutions to support restoration efforts), and lack of strong institutional channels are major challenges that decrease the success of restoration programs

(Box 6.1; Akhtar-Schuster et al. 2010, WWF 2011, Virto et al. 2018, Nandamudi & Sen 2020). Challenges related to stakeholder participation, availability of skilled labour, and unsustainable levels of extraction of natural products also pose major impediments to restoration programs and their success (Sayer et al. 2013, Kusters et al. 2018, Virto et al. 2018, Box 6.1). Engaging with social scientists at the planning stages to identify and potentially address these challenges can increase the success of restoration efforts.

6.3 Detailed species atlases and databases that provide information on native and threatened species to use for restoration of different ecosystems are needed for restoration practitioners to effectively scale-up restoration efforts.

Restoration efforts are often hindered by lack of knowledge, or access to information, on ecologically native (i.e. native to the ecosystem and location, and not just to the country) and threatened species for different biomes and ecoregions in the country (6.1, see also: https://era-india.org)). Creating digital databases and atlases of native species characteristic of different ecosystems and landscapes (e.g., endemic vascular plants; Singh et al. 2015), including information on their population status in the wild, dispersal capabilities, seed and germination traits (seed size, germination time, dormancy), seed availability in the wild, potential services that the species can provide (e.g., carbon sequestration rates and ability), and functional characteristics (e.g.,, their role as food sources for animals), can help in selection of appropriate native species for restoration planting depending on the targets identified in different landscapes and habitats (Aronson & Alexander 2013, Brancalion et al. 2013a, 2018, Engert et al. 2020). Building these databases requires active participation and data sharing by a large number of ecologists, botanists, regional experts, government institutions (e.g.,, Botanical Survey of India, Zoological Survey of India), and local citizens.

6.4 Establishing a nationwide network of nurseries and seed banks that can deliver large volumes of restoration-ready seeds and seedlings of diverse native plant species is a prerequisite to scaling-up restoration efforts to meet national and international commitments.

Even assuming a modest planting density of 500 trees per hectare (Haase & Davis 2017; Miyawaki forests on the other hand can have densities of 10000+ seedlings/hectare; Schirone et al. 2011) and a high seedling survival rate of 80%, a total of 1.3 billion high-quality seedlings (or 130 million seedlings per year over the next 10 years) are needed to restore 26 million hectares in India (calculations following Haase & Davis 2017). Delivering high-quality native seeds and seedlings at this volume for restoration programs will require the establishment of a coordinated network of nurseries and seed banks throughout the country

(Merritt & Dixon 2011, Haase & Davis 2017, de Urzedo et al. 2019). Importantly, these facilities need to move beyond being just 'stamp collections' of a limited number of species to being facilities that propagate a diverse mix of native species, including herbs and grasses, to cater to local restoration needs. In particular, there is a greater need for research efforts aimed at maximizing the germination and establishment of grasses, which have thus far received less attention relative to tree species. Restoration efforts need to leverage the latest scientific knowledge, adopt sustainable seed harvesting techniques and avoid overharvesting seeds from 'natural' populations, and contribute to capacity building and information dissemination for restoration projects (Box 6.2, Merritt & Dixon 2011, Haase & Davis 2017, de Urzedo et al. 2019). Localized and decentralized certification systems (such as the Participatory Guarantee System (PGS) for organic farming, Department of Agriculture & Cooperation 2015) can help ensure that restoration-ready planting material is available at local scales in large numbers. Practitioners should know the source and identity of seeds and planting material, and support should be provided to small and local businesses and nurseries to market their native planting material (Jalonen et al. 2017, de Urzedo et al. 2019). Botanical gardens can potentially serve as important knowledge and dissemination hubs in such networks (Hardwick et al. 2011, Merritt & Dixon 2011) by growing and popularizing native species, as opposed to the predominantly ornamental, alien and invasive plants that they currently do in many cases.

6.5 Restoration in urban areas, agricultural lands and agroforestry landscapes provide opportunities to scale-up restoration across the country, while also enhancing and ensuring sustained supply of ecosystem services to both urban and rural dwellers, and should comprise a key component of national restoration strategies.

India is becoming increasingly urbanized, with urban populations projected to account for 38.6% of the national total by 2036 (was 31.8% in 2011; National Commission on Population 2019). Such increasing urbanization poses major challenges to standards of living in, and the sustainability of, urban areas (Caprotti et al. 2017). While the concept of 'Smart Cities' has been mooted as a solution to improve human well-being in urban areas (Caprotti et al. 2017), sustainable urban environments need to be a core element of the planning of these them (Ministry of Urban Development 2015). Restoration in urban areas presents an opportunity to achieve this through gardening for biodiversity, designing green spaces, and restoration of rivers, lakes and woodlands in urban areas (Standish et al. 2013, Elmqvist et al. 2015) with co-benefits for biodiversity, ecosystem services and human health (Standish et al. 2013, Elmqvist et al. 2015, Mills et al. 2017, Pörtner et al. 2021a, 2021b). For example, Miyawaki forests (Miyawaki 1998) have been used to rapidly regenerate tree cover in urban areas. However, we caution against the use of this technique in other regions including forests, savannas and grasslands. In agricultural landscapes, restoring native communities in marginal and low-productivity lands (Latawiec et al. 2015), or conversion to multifunctional landscapes using activities such as agroforestry and permaculture (Sarukhán et al. 2015, IPES-Food 2018, Santos et al. 2019), or partial restoration such as diverse shady canopy in coffee plantations (Nesper et al. 2017) can reduce land degradation, improve soil health and increase agricultural output (TERI 2018), increase biodiversity and improve connectivity between natural habitats for different species (Tobón et al. 2017, IPES-Food 2016, IPBES 2018).

6.6 Raising awareness on the importance of restoration through mass media campaigns, including in local languages, and educating stakeholders through community outreach programs is critical for inspiring public support and participation, and for sustaining restoration efforts.

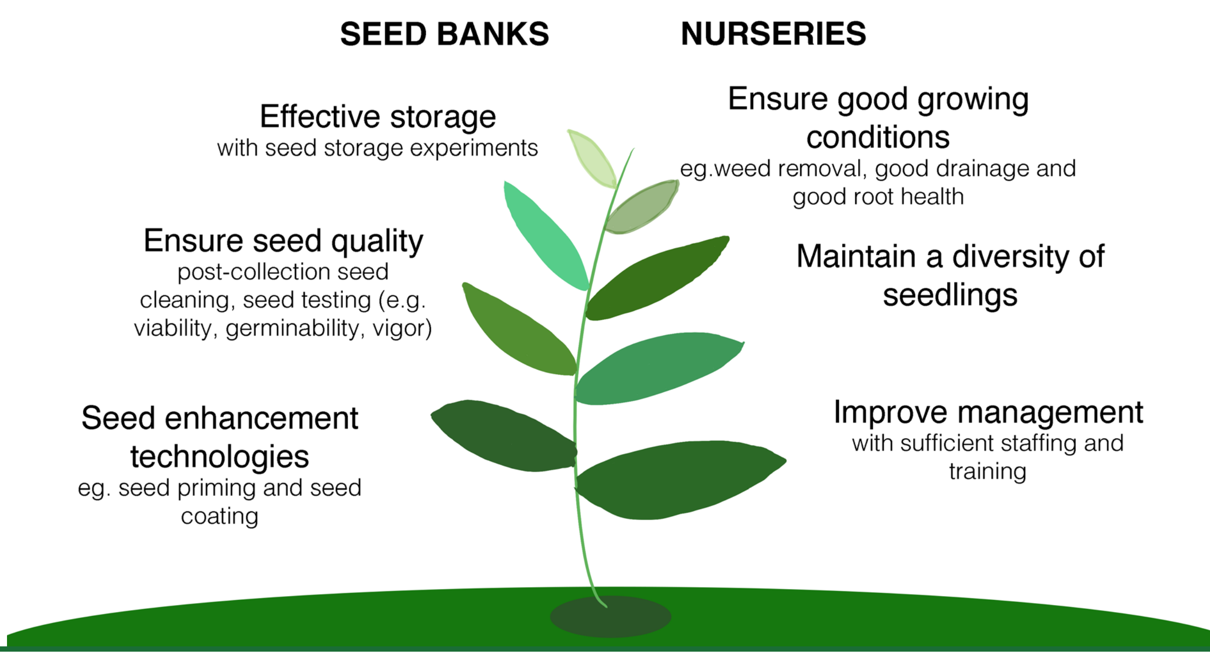
Restoration efforts often do not succeed because of a lack of awareness and, hence, buy-in from local communities and stakeholders (Druschke & Hychka 2015, Crossman et al. 2016). Effective and widespread communication of the importance of restoration programs, in a manner that resonates with the public, is central to ensuring broad public engagement and long-term support for restoration efforts (Druschke & Hychka 2015, Scholte et al. 2016). The media, particularly in local languages, has an important role to play here (Vogt et al. 2011, Ferwerda 2015, Vane & Runhaar 2016). Scientists need to more effectively communicate their findings to the public in a non-technical manner (Menz et al. 2013), while educational and research institutes need to strengthen and broaden their outreach efforts (e.g., webinars, workshops, creative exhibitions in science days), facilitate nature immersion programs and field tours (Brody 2005, Groffman et al. 2010, Sayer et al. 2014, Varner 2014), while also more effectively integrating restoration within their primary mandates of education and research (Kassab 2019). Finally, citizen science efforts that engage the public in restoration activities and monitoring can not only generate valuable data, but also strengthen public support and ensure the sustainability for restoration projects (Edwards et al. 2018).

BOX 6.2

Good seed bank and nursery practices can improve quality of seeds and seedlings

Several studies in the past decade have contributed to the growing understanding of how practices followed by seed banks and nurseries can help improve the quality of seeds and seedlings used for restoration planting. Seed banks need to employ state-of-the-art knowledge for effective storage (De Vitis 2020) and ensure high seed quality (Frischi et al. 2020), and seed enhancement technologies (e.g.,, seed priming and seed coating) to improve seedling performance (Pedrini et al. 2020) and break seed dormancy to make each seed count (Kildisheva et al. 2020, Shaw et al., 2020).

At the minimum, nurseries need to improve management with sufficient staffing and training to ensure good growing conditions (e.g., weed removal, good drainage, good root health) for seedlings before transplanting to restoration sites (Haase & Davis 2017). Nurseries also need to use knowledge about species characteristics, and performance of planted seedlings, to ensure that a good diversity of seedlings is available for restoration work (Dumroese et al 2016).Ethical seed collection needs to be practiced taking care not to overharvest from the wild or affect the regeneration of wild populations. Seed collection can be often avoided in habitat interiors and instead collected when they fall along roads, trails, and habitat edges where they have little chance of natural germination and these can be taken to nurseries to grow saplings for restoration (Mudappa and Raman 2010).



RESTORATION CASE STUDY: 4

Challenges of Grassland and Savanna Restoration

Insights from Pygmy Hog Conservation Programme and Aaranyak in the Terai grasslands and Upstream Ecology in the Nilgiri grasslands.

There are very few examples of successful grassland restoration worldwide as they are poorly understood landscapes and are often misunderstood as 'wastelands' and 'already degraded'. This has also led to a poor representation of these habitats in national and international policies. Here, we discuss the various challenges faced by grassland restoration and highlight efforts by the Durrell Wildlife Conservation Trust's Pygmy Hog Conservation Programme (PHCP) and Aaranyak in the Terai grasslands (Contributors: Dhritiman Das, Parag Jyoti Deka), and by Upstream Ecology in the Nilgiri grasslands (Contributor: Godwin Vasanth Bosco).

In Manas National Park, PHCP and Aaranyak are conserving grasslands (critical habitats for the endangered pygmy hog *Porcula salvania*) invaded by *Chromolaena odorata* and *Mikania micrantha* and fast-growing woody species, such as *Bombax ceiba* and *Dillenia pentagyna.* Upstream Ecology is restoring high-altitude grasslands in shola-grassland ecosystem in the Nilgiris, which are being invaded by woody nitrogen-fixing species – *Acacia mearnsii*, *Cytisus scoparius* and *Ulex europaeus*.

Key problems and issues in restoring open habitats

The lack of understanding of the unique ecology of grasslands and savannas hinders successful restoration of these ecosystems. For example, while forest species can be restored from seeds, many (if not most) native grassland and savannah species have poor germination rates. However, their underground storage organs (USOs) can regenerate after their aboveground parts are disturbed. So, restoration can be limited if only their seeds are used, or if USOs are not used. Further, using contour trenches in savanna ecosystems can destroy USOs of native species, and hinder restoration efforts.

To deal with this challenge, Upstream Ecology is growing perennial grass tussocks using vegetative propagation to a height of 10 cm to 30 cm in individual bags, before transplanting them in areas cleared of invasive species, giving grass tussocks a higher chance of survival. Further, in grazing sites, herbivory can destroy grass tussocks immediately post-transplantation. Here, additional protections measures (e.g., solar fencing for first year) are employed.

Managing invasive species

Invasive species, in particular woody invasive species, can have substantial impacts on various aspects of grassland ecosystems, and the use of restoration activities needs to be adapted to the invasive species and native ecosystem of interest. For example, evidence from the Upper Nilgiris shows that along with decreasing dry-season streamflow, *Acacia* invasion could also increase flood risk, especially under extreme rain in a changing climate (Nayak et al. 2022). As a result, the use of restoration activities needs to be adapted to the invasive species and native ecosystem of interest.

Manas National Park

- *C. odorata* infestation is first reduced by cutting stems before flowering, and then removing new *C. odorata* sprouts manually when they emerge during the monsoon. Woody species encroachment is prevented in the grasslands by employing manual debarking of woody individuals.
- Using fire to burn the cut biomass of *C. odorata* was observed to be unsuccessful, with the regrowth and re-emergence of invasive species and woody species like *Bombax* post-fire.

Cutting and removing freshly grown *Chromolaena*

Debarking *Bombax* trees

Nilgiri grasslands

- After clearing woody N-fixing invasives, the success of transplanted grass tussocks is maximized when regrowing invasive individuals are manually removed between 3 and 5 months post-transplanting. Using native hardy (less palatable) forbs and shrubs could create microhabitat conditions to facilitate initial grass community establishment.
- Other research has shown that fire may be effectively used to manage invasion by *C. scoparius* (Sriramamurthy et al. 2020), and that not managing burnt areas can actually result in increased invasion by *A. mearnsii* and *U. europaeus*. Further, the invasives are increasing soil N availability in these grasslands (Raghurama & Sankaran 2022), and restoration efforts may need to manage for soil nutrient levels after clearing invasives.

Before restoration work began in the Nilgiris

After initial restoration activity

Lack of funding and research on grassland restoration

Significant funds and collaborative research between scientists and practitioners are required to answer questions to guide grassland restoration, such as (i) How to manage multi-species invasion in grasslands which can naturally undergo various disturbances (e.g., grazing, seasonal flooding, periodic fires)?; (ii) How can native grassland re-establishment be increased?; (iii) Should natural disturbance regimes be re-introduced for long-term maintenance of restored communities?; (iv) Can fire be effectively used to manage invasion in grasslands and savannas?; and (v) How to prevent re-invasion in restoration sites?

Further, land use policies need to maximize restoration opportunities. For example, Upstream Ecology believes that in abandoned agricultural and tea estates, 80% of the land should be reserved for the restoration of sholas and grasslands. Cost-effectiveness and practicability of such policies, along with implementation of ideas like community-driven restoration ecosystem service-based payments, need to be explored through socio-ecological and economic studies.

BOX 7.1

Characteristics underpinning good monitoring plans

- Clear restoration targets (3.1, 3.5) on the basis of which monitoring indicators are chosen.
- Enough replication of sites under different restoration strategies so that change can be detected robustly (i.e. with enough statistical power) to guide adaptive management and future restoration efforts.
- Should be included in initial restoration program planning and budgeting, with a general rule of thumb being approximately 10% of overall budget dedicated to monitoring.
- Should include both desk-based (e.g., remote sensing) and on-the-ground monitoring activities, such as; photographic monitoring, survival monitoring, and vegetation, soil and water sampling and analysis.
- Should monitor not only ecological variables but also socioeconomic variables (e.g., participation in restoration activities).
- Should monitor not only activities, but also socio-economic outcomes (e.g., job creation, economic implications).
- Should be long-term and repeated in regular intervals (before program, during implementation, after restoration activities cease).
- Should include key stakeholders in planning and monitoring activities.
- Should include plans for management, analyses, and reporting and sharing of data.

References

Dey & Schweitzer (2014), Hooper et al. (2015), IPBES (2018), FAO & WRI (2019), Lindenmayer (2020)

7. Strategic monitoring is the key to evaluate restoration success and help achieve wider goals for the landscape. A well-designed and executed monitoring plan is essential to track and evaluate progress, adaptively manage restoration methods and goals, and identify successful efforts to attract and encourage additional long-term financial investments and achieve the set restoration goals. Transparency of monitoring data from restoration initiatives is also essential for assessing progress towards meeting national and international restoration commitments.

7.1 A well designed monitoring plan that considers biophysical, ecological and socio-economic responses is critical to assess the effectiveness of restoration efforts and to inform decision making to enhance future restoration outcomes.

Well-designed and rigorously implemented socio-ecological monitoring (Box 7.1) is the only way to determine the success or failure of restoration programs (Lindenmayer 2020). Effective monitoring helps maintain project transparency and accountability, is necessary to attract private investment (Gutierrez & Keijzer 2015, Evans et al. 2018), and to apply corrective actions (adaptive management) if restoration outcomes are not progressing as planned (Hooper et al. 2015, Camarretta et al. 2020). Without long-term monitoring, it is not possible to determine which restoration activities are effective and which are wasteful, and why, resulting in the same mistakes and ineffective restoration strategies being repeated in different landscapes (Clewall & Rieger 1997, Lindenmayer 2020). Monitoring plans should be designed and budgeted for during the project planning stage itself (Lindenmayer & Likens 2018), and should monitor not only the actions/activities that were done but also the outcomes of these activities (Hajkowicz 2009, Lindenmayer 2020). The indicators to monitor originate from the local context and restoration targets, and should include both ecological and biophysical variables (e.g., species composition, soil quality and stability, flow of ecosystem services, surface and groundwater hydrology, carbon storage, etc.; Martin et al. 2005, Herrick et al. 2006, Convertino et al. 2013, Stanturf et al. 2014), as well as socio-economic responses (e.g., livelihood generation, impacts on welfare and community development; Sachs et al. 2009, Wortley et al. 2013).

7.2 Transparency of monitoring data from restoration programs, and audits conducted by independent bodies, are critical for assessing if different national and international targets are being met, for assuring stakeholders about project progress, and for attracting greater private investment in ecological restoration efforts.

Although a lot of data is being generated from restoration and agroforestry programs around the world, much of it is not transparent (i.e. clear, up-to-date, easily accessible to stakeholders and the public; BBOP 2012). Since effective policies and best-practices require the best-available knowledge (Dicks et al. 2013, Cooke et al. 2018), data transparency and accessibility is essential (Waylen et al. 2019). Transparency of data generated from monitoring programs facilitates learning from previous restoration successes and mistakes (Bull et al. 2018), helps business and private investors track progress towards their investment goals, enhances their trust to foster additional private investment, and assures stakeholders that restoration programs meet international best practices (BBOP 2012, Viani et al. 2017, FAO & WRI 2019). The use of independent bodies (who cannot profit from false monitoring reports) as auditors to monitor the outcomes of restoration programs (Palmer & Filoso 2009), with the participation of local stakeholders (Evans et al. 2018), can ensure data quality and accurate reporting. Establishing decentralized certification schemes (e.g., PGS in organic farming; Department of Agriculture & Cooperation 2015) that acknowledge and recognize restoration efforts that meet requisite standards can motivate the widespread adoption of best practices in restoration. It is also critical that spatial data regarding locations and areas where restoration is being conducted by different organizations and governmental bodies be collated and made publicly available in a central location to facilitate ground-truthing and the independent verification of claims when needed.

8. Policies that ensure land tenure security, along with convergence of restoration programs with employment generation programs and multi-ministerial coordination, would help in the creation of a 'restoration economy'. This will help in scaling-up these local-scale restoration efforts to landscape-scale efforts. Establishing robust certification and auditing mechanisms, and on-the-job training of forest managers and other government officials regarding state-of-the-art restoration knowledge, will encourage the acceptance of best practices. Finally, policies that recognize grasslands and savannas as important ecosystems in their own right, rather than 'wastelands' that need to be planted with trees, will ensure that resources are not wasted in efforts that end up hurting the local ecology and economy.

8.1 Multilateral coordination between nodal agencies and other ministerial departments can foster a collaborative environment to overcome institutional silos and barriers to restoration, and support policy makers and practitioners in executing successful restoration programs at landscape scales.

Restoration policies interact across sectors, with implications for the activities of several ministries and governmental departments (IPBES 2018). For example, the National Afforestation Programme and the Green India Mission are implemented by the Ministry of Environment, Forest and Climate Change, while the Sub-Mission on Agroforestry is implemented by the Ministry of Agriculture and Farmers Welfare. Strong policy coherence between different ministries is important to prevent conflicting incentives and trade-offs, and to create a supportive environment with policy synergies that support restoration efforts (Akhtar-Schuster et al. 2011, Carter et al. 2018).

For restoration of agricultural landscapes in India, policy coherence is needed between the Ministry of Environment, Forest and Climate Change, the Ministry of Agriculture and Farmers Welfare, and the Ministry of Rural Development, among others (Singh et al. 2016). Ensuring policy coherence between national level policies such as the National Agroforestry Policy, the National Afforestation Programme, the National Mission on Biodiversity and Human Well-being, and establishing strong linkages between participating ministries and departments (with the National Biodiversity Authority as the potential nodal agency) can help scale-up restoration efforts across the country.

8.2 Enabling policies that encourage restoration by diverse stakeholders while ensuring land tenure security and assuring stakeholders of future benefits can greatly enhance long-term restoration success.

Degraded land can be owned by different stakeholders (private landowners, companies, government etc.) who have different relationships with the land, perceive degradation in different ways and have different motivations for, and expectations from, restoration (Chazdon et al. 2020). Policies that acknowledge these different motivations, remove barriers to restoration by different stakeholders, while also providing incentives (access to scientific advice, financial benefits, facilitating access to markets and other value chains) can greatly benefit restoration success. Importantly, clear delineation and enforcement of land tenure and usage rights are crucial as uncertain or insecure land tenure can negatively affect motivation and capacities to invest capital or labor to improve land (Prindex 2020), and thus are a major limitation to the sustainability of restoration projects (Lamb et al. 2005, Duchelle et al. 2014). Ensuring a secure and fair distribution of land and related benefits can encourage increased stakeholder participation at the grassroot level, increase investment in land management, and avoid land-tenure related conflicts (Larson et al. 2013, WBCSD 2015, UN-Habitat 2016, GIZ 2017). Extending recently launched programs such as the SVAMITVA scheme (aimed at ensuring land tenure using village-level mapping and drone technology; https://svamitva.nic.in/) in areas prioritized for restoration can help ensure land-tenure in these regions. Simultaneously, promoting 'avoided deforestation' through policy and economic incentives to rural families and local communities who voluntarily agree to conserve natural habitats can reduce the need for expensive future restoration efforts.

8.3 Using government livelihood generation schemes to employ local communities in restoration activities, and streamlining the convergence between different environmental legislations to decentralize environmental governance, can help in popularizing restoration on large scales.

Including restoration activities within the ambit of government employment generation schemes, such as the Mahatma Gandhi National Rural Employment Guarantee Act, 2005, as a way of employing local communities can improve their participation in restoration activities, as well as support the execution of these schemes (Matta 2009, Awasthi et al. 2017, Singh et al. 2021). Generating employment in these activities can also have positive impacts on local economies (Samonte et al. 2017). Additionally, speedy implementation of the Scheduled Tribes and Other Traditional Forest Dweller (Recognition of Forest Rights) Act, 2006, to recognize the rights of forest dwellers, and its alignment with the Biological Diversity Act, 2002 and the Indian Forest Act, 1927, will help democratize forest governance, empower gram sabhas as decision makers in case of many conflicts and as partners in restoration activities, and encourage rural and tribal communities to invest in restoration and benefit from them (Faizi & Ravichandran 2016, Dhar & Iyengar 2019). At the same time, there is also a need for the creation of a favourable policy environment for private landowners to facilitate restoration on private lands.

8.4 Policies to establish certification and auditing mechanisms can help ensure restoration programs follow best practices. At the same time, biodiversity safeguards are needed in policies and legislations to ensure that restoration of ecosystem services does not come at the cost of biodiversity conservation.

Certification systems for restoration projects, similar to the PGS for organic farming in India (Department of Agriculture & Cooperation 2015), can help ensure that restoration programs are monitored periodically by fellow practitioners and that they follow restoration best practices, which can also allow for course-correction in case observed results are not in the desired direction. This is especially important since restoration programs are often long-term (e.g., Nerlekar & Veldman 2020), and need adaptive management. Because restoration practitioners may have perverse incentives to prioritize short-term provisioning of ecosystem services in areas where biodiversity conservation is of importance, certification and monitoring systems should also ensure biodiversity safeguards in such areas (Brancalion et al. 2013b). Finally, in cases where managers and/or investors may have an monetary incentive to get good monitoring reports, auditing measures are needed, such as a mechanism wherein they pay a fixed fee to a common pool, from where the funds are used to pay auditors who are randomly assigned by the State to the restoration programs (with additional payments for accurate monitoring reports), along with 'backchecking' of randomly chosen programs using government's technical staff or independent science institutes (such a system has been tested for the Gujarat Pollution Control Board previously through a Randomized Control Trial; Duflo et al. 2013).

8.5 Policies that foster long-term innovative financial mechanisms and novel business opportunities can encourage states and local communities to restore lands and stimulate private investment in these projects.

Restoration requires long-term commitments, both in terms of institutional and human resources, as well as in funding. At the level of states, the recently employed ecological fiscal transfers, wherein a share of disbursal of central government funds to states is based on the state's forest cover (Busch & Mukherjee 2018), provides a guide to how states can be incentivized to protect their environment. However, similar policies are needed to incentivize states to restore degraded lands, rather than just protect existing forests, or increase forest cover through monocultures or inappropriate afforestation. The use of CAMPA funds should also shift to projects which follow compensatory restoration, with restoration best practices being followed, rather than compensatory afforestation (Tambe et al. 2022). At the level of local communities, putting in place innovative funding mechanisms, such as payment for ecosystem services, sale of products emerging from restored areas (e.g., agroforestry produce), and charging a visitor fee/cess from tourists, can incentivize local communities and private landowners to restore their lands, and help fund long-term monitoring and management of restoration areas. One particular challenge is funding initial restoration activities, especially in the first few years, which can have high costs without immediate benefits. Governmental funds, and channeling funds from global agencies to grassroot restoration practitioners, need to be put in place to fund at least the first few years of restoration programs, when funding through other mechanisms might be difficult. Finally, building an enabling environment to encourage restoration businesses and increase private investment in restoration can create a restoration economy stimulating development in rural areas. For example, developing relationships between business schools and restoration projects can influence future business leaders, and encourage the adoption of sustainable business models by both restoration programs and by other businesses (Ferwerda 2015).

8.6 Policies are needed to explicitly recognise that grasslands and savannas are not wastelands, and are not appropriate for tree planting initiatives.

Treeless ecosystems such as grasslands and savannas are ancient biomes that harbor unique diversity and provide several critical ecosystem services (Ratnam et al. 2011, Veldman et al. 2015a, b, Bond et al. 2016, Madhusudan & Vanak 2021), and are not 'wastelands' as commonly classified (NRSC & ISRO 2019). Development of a comprehensive grassland management policy that explicitly recognizes the value of natural tree-less ecosystems for their biodiversity, as well as for the ecosystem services they provide, is critical to ensure that they are not subject to perverse afforestation efforts. Where degraded, efforts should focus on restoring the herbaceous layer, maintaining native tree cover at historic levels, and removal of invasive trees and shrubs where appropriate. Current laws (e.g., Maharashtra Felling of trees Act, 1964) which are based heavily on woody components of ecosystems can serve as obstacles to restoration of grassy biomes (e.g., by restricting the removal of invasive species). Existing funding mechanisms, such as the Compensatory Afforestation Fund Management and Planning Authority, need to be reformed to ensure that forest plantation is not done in natural grasslands/savannas and diverse suites of native herbaceous species are used in restoration plantings. Finally, India's fire and grazing policies, that currently encourage complete suppression of these disturbances in natural areas, need to be revised to recognize their importance in open ecosystems, and their use in managing and restoring these landscapes (Thekaekara et al. 2017, Buisson et al. 2019).

8.7 Policies to train members (both existing and new inductees) of government departments involved in restoration efforts, including the Forest Department, about scientifically-sound restoration practices and state-of-the-art knowledge on ecological restoration can improve restoration outcomes by ensuring that inappropriate management actions are not widely implemented.

The Forest Department is one of the largest land managers in the country, and will play a key role in determining the success of large-scale ecological restoration efforts. However, the Forest Department often conducts large-scale tree-planting exercises in ecosystems where tree planting is inappropriate and can cause more harm than good (2.2, 2.5.). For example, tree planting initiatives composed of alien or invasive Eucalyptus and *Pongamia* are common in areas of Maharashtra and Telangana, in part due to the lack of appreciation of contexts in which such tree planting exercises are inappropriate, and partly due to other reasons such as a push from policy makers for such exercises (irrespective of ecological context), and institutionalized incentives that increase visibility and ease of monitoring of such efforts (Fleischman 2014). Although training courses have been significantly reformed since 2000, there is a need for incentivizing periodic on-the-job training through various platforms such as workshops, placements in research labs, work-integrated learning programs and online MOOCs (massive open online courses) to ensure that foresters and trainers are up-to-date on the latest scientific knowledge. Such efforts can also help with the establishment of large-scale nurseries of native species and mobilize local academic and research institutes to generate site-specific knowledge to guide restoration activities (Fleischman 2016).

Glossary

Land Degradation

The Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services (IPBES) defines land degradation as "the many human-caused processes that drive the decline or loss in biodiversity, ecosystem functions or ecosystem services in any terrestrial and associated aquatic ecosystems".

Degraded land

"Degraded land" as defined by IPBES is "the state of land which results from the persistent decline or loss in biodiversity and ecosystem functions and services that cannot fully recover unaided within decadal time scales" (IPBES 2018).

Restoration

Ecological Restoration is defined as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed" (SER Primer 2004).

Rehabilitation

Rehabilitation is used to refer to restoration activities that may fall short of fully restoring the biotic community to its pre-degradation state, including natural regeneration and emergent ecosystems (IPBES).

Reforestation

Reforestation is the planting of trees on deforested land, that was historically forested (Veldman et al. 2015).

Afforestation

Afforestation is the planting of forests where they did not historically occur (Veldman et al. 2015).

Ecosystem functions

The flow of energy and materials through the biotic and abiotic components of an ecosystem. It includes many processes such as biomass production, trophic transfer through plants and animals, nutrient cycling, water dynamics and heat transfer (IPBES).

Ecosystem services

The benefits people obtain from ecosystems. In the Millennium Ecosystem Assessment, ecosystem services had been divided into supporting, regulating, provisioning and cultural. This classification, however, is superseded in IPBES assessments by the system used under "nature's contributions to people". This is because IPBES recognises that many services fit into more than one of the four categories. For example, food is both a provisioning service and also, emphatically, a cultural service, in many cultures (IPBES).

Provisioning services

The products obtained from ecosystems, including, for example, genetic resources, food and fiber, and freshwater (MA 2005).

Supporting services

Ecosystem services that are necessary for the production of all other ecosystem services. Some examples include biomass production, production of atmospheric oxygen, soil formation and retention, nutrient cycling, water cycling, and provisioning of habitat (MA 2005).

Regulating services

The benefits obtained from the regulation of ecosystem processes, including, for example, the regulation of climate, water, and some human diseases (MA 2005).

Cultural services

The non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experience, including, e.g.,, knowledge systems, social relations, and aesthetic values (MA 2005).

Nature's contribution to people (NCP)

Nature's contributions to people (NCP) are all the contributions, both positive and negative, of living nature (i.e. diversity of organisms, ecosystems, and their associated ecological and evolutionary processes) to the quality of life for people. Beneficial contributions from nature include such things as food provision, water purification, flood control, and artistic inspiration, whereas detrimental contributions include disease transmission and predation that damages people or their assets. Many NCP may be perceived as benefits or detriments depending on the cultural, temporal or spatial context (IPBES).

Desertification

Land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities (UNCCD).

Traditional Ecological Knowledge (TEK)

Traditional knowledge refers to the knowledge, innovations and practices of indigenous and local communities around the world. Developed from experience gained over the centuries and adapted to the local culture and environment, traditional knowledge is transmitted orally from generation to generation (CBD).

Communities (plant or animal)

Refers to the assemblage of species in a given site at a given time and may include sets of species that co-exist with positive (mutualistic) or negative (competitive) interactions (Mudappa and Raman 2007).

Exotics/alien/non-indigenous species

Usually species from other countries. In the context of biotic homogenization, species indigenous to the country but from other habitats or geographical areas may represent local exotics (Mudappa and Raman 2007).

Invasives

Species, usually exotic/alien, that proliferate into natural or disturbed areas, often replacing and suppressing natural vegetation and the growth of indigenous species (Mudappa and Raman 2007).

Recovery

The process and rates of revival of defined attributes of forest ecosystems, usually by a natural process of succession (Mudappa & Raman 2007).

Secondary vegetation

Vegetation growing in disturbed or degraded sites, successional in nature (Mudappa & Raman 2007).

Succession

The dynamic process of establishment and maturation of an ecosystem in a newly exposed area, such as after a lava flow or landslide (primary succession), or in an ecosystem following a disturbance such as clear-felling (secondary succession) (Mudappa & Raman 2007).

Weed

Proliferating species (mostly plants in an agricultural context), that are usually exotic and often invasive, that establish and propagate widely (Mudappa & Raman 2007).

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