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ECOLOGICAL RESTORATION OF EARTH'S ECOSYSTEM AND THE DECADE OF ECOSYSTEM RESTORATION

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ABSTRACT

Restoration ecology has demonstrated an astounding growth as a new discipline of applied science, since its emergence in the past decades. Future-aimed restoration should acknowledge the changing and unpredictable environment of the future, assume the dynamic nature of ecological communities with multiple trajectories, and connect landscape elements for improving ecosystem functions and structures. Ecosystem loss is depriving the world of carbon sinks, like forests and wetlands, at a time when humanity can least afford it. Ecosystem restoration aims to repair some damage done to the environment and regain ecological functionality. The United Nations (UN) recently declared 2021 to 2030 the Decade on Ecosystem Restoration- a global mission to revive billions of hectares, from forests to farmlands, from the top of mountains to the depth of the sea. The path to a more sustainable use of ecosystems must begin with the development of inclusive wealth measures which capture natural, social, human and manufactured capital and are thus more accurate ways to measure economic progress.

Keywords: Ecosystem Restoration, United Nations Environment Programme, Indian Forest, Sustainable Development Goals, Ecology.

ABBREVIATIONS: CBD-Convention on Biological Diversity, FAO-Food and Agriculture Organization, FES-Foundation for Ecological Security, FRA-Global Forest Resources Assessment, GHG-Greenhouse gases, HUL-Hindustan Unilever Limited, ISER-India State of Forest Report, JFMC-Joint Forest Management Committee, NCF-Nature Conservation Foundation, SDG-Sustainable Development Goals, SEEAEA-System of Environmental Economic Accounting Ecosystem Accounting, NTFPs-Non-timber forest products, UN-United Nations, UNCCD-United Nations Convention to Combat Desertification, UNEP-United Nations Environment Programme, UNESCO-United Nations Educational, Scientific and Cultural Organization, UNFCCC-United Nations Framework Convention on Climate Change.

INTRODUCTION

Ecological restoration aims to initiate the recovery of an ecosystem following damage, degradation, or destruction. Restoration practitioners create the conditions needed for recovery so the plants, animals, and microorganisms can carry out the work of recovery themselves. The ecosystem may not necessarily recover to its former state since contemporary ecological realities, including global climate change, may cause it to develop along an altered trajectory, just as these same realities may have changed the trajectory of nearby undisturbed ecosystems.

Ecological restoration aims to re-establish or recreate a self-organizing ecosystem on a trajectory to reach full recovery. While restoration activities can often place a degraded

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ecosystem on an initial trajectory of recovery relatively quickly, full recovery of the ecosystem can take years, decades, or even hundreds of years. For example, while we can initiate a forest restoration process by planting trees, for full recovery to be achieved, the site should be a fully functioning forest with mature trees in the age-classes representative of a mature native forest. If there were 500-year-old trees in the forest that was destroyed, then the restoration should logically take hundreds of years to achieve full recovery. During that recovery period, unforeseen barriers to recovery may be encountered, or additional restoration activities may become possible at later stages of development.

Ecosystem Restoration is defined as "a process of the reversing the degradation of ecosystems, such as landscapes, lakes and oceans to region their ecological functionality; in other words, to improve the productivity and capacity of ecosystems to meet the needs of society. This can be done band capacity of ecosystems to meet the needs of society. This can be done by allowing the natural regeneration of overexploited ecosystems or by planting trees and others plants" (UNEP, 2019).

The restoration of ecosystem aims at the preservation and sustainable utilization of biodiversity. Such establishment of a healthy and connected ecosystem targets the degraded state of the environment, improves people's livelihood, increases food and water security, which are vital for the well-being of human beings and social, economic and environmental development (CBD, 2019). If ecosystems are considered as socio-ecological areas that are beneficial to various stakeholders and give multiple returns, it will become easier to detect the causes of ecosystem degradation and manage the losses and work for their sustainable development (IUCN, 2008).

Ecosystem restoration is "any intentional activity that initiates or accelerates the recovery of an ecosystem from a degraded state"; the deliberate act of renewal, recovery and reestablishment of damaged or destroyed ecosystems and the restoration processes or treatments entirely depend on the types of the ecosystem. To restore an ecosystem having functional benefits, the approach must include strategies with proper knowledge regarding the landscape level, local conditions etc. (IPBES, 2018; CBD, 2019).

The Restoration Principles given by CBD (CBD, 2019)

- It provides complementation but conservation activities cannot be substitute instead.
- It should correspond to CBD rules and regulations following ecosystem principles.
- It should be measured in multiple scales and according implemented in preferred to science vision.

On 1 March 2019, the United Nations General Assembly proclaimed 2021–2030 to be the United Nations Decade on Ecosystem Restoration. All initiatives within the UN Decade will consequently have a dual focus on protecting as well as restoring ecosystems. Integrated land-use planning, undertaken in a rights-based manner, where all stakeholders are informed of the full range of benefits to be gained through conservation, restoration and sustainable use of natural resources in their local ecosystems, assists in achieving this balance. The United Nations Environment Programme (UNEP) and Food and Agriculture Organization (FAO) along with their partners will provide leadership, coordination and technical support throughout the UN Decade.

Healthy, stable and biodiverse ecosystems are the foundation of our health and well-being, as well as that of our fellow species. They help to regulate our climate and control extreme events, pests and diseases, as well as to provide us with water, food, raw materials and spaces for recreation. They absorb our wastes, sustain economic sectors and the livelihoods of millions of people, and they nurture our health, culture and spiritual fulfillment (IPBES, 2019).

However, we have been over exploiting and degrading the world's ecosystems and wild species, causing the erosion of the very services we depend on (UNEP, 2021). Driving this degradation are the ways we produce food and alter our landscapes and oceans, along with climate change, pollution and invasive species (IPBES, 2019; Benton et al., 2021).

All selected ecosystems – farmlands; forests; freshwater; grasslands, shrublands and savannahs; mountains; oceans and coasts; peatlands; and urban areas – are being degraded, often at an accelerating rate. We are fast approaching a tipping point for the

climate and are close to overshooting some of our other 'planetary boundaries' (IPCC, 2018).

Degradation is undermining hard-won development gains and threatening the well-being of today's youth and future generations, while making national commitments increasingly more difficult and costly to reach. None of the agreed global goals for the protection of life on Earth and for halting the degradation of land and oceans have been fully met and only 6 of the 20 Aichi Biodiversity Targets have been partially achieved (CBD, 2020; UNEP, 2021). We need to re-create a balanced relationship with nature, not only by conserving ecosystems that are still healthy, but also by urgently and sustainably restoring degraded ones.

Much has been done already, and we can build on the lessons learned from existing restoration approaches and initiatives. Commitments by 115 governments to restore a total of nearly 1 billion hectares of land as a contribution to achieving the objectives of the CBD, UNCCD, UNFCCC and the Bonn Challenge are a good start. The UN Decade on Ecosystem Restoration aims to prevent, halt and reverse the degradation of all kinds of ecosystems, contributing to reductions in global poverty and ensuring that no one is left behind. Running from 2021 until 2030, the UN Decade launches a global movement to restore ecosystems worldwide. This will help to achieve multiple global goals, including the Post-2020 Global Biodiversity Framework under the CBD, the Paris Agreement under the UNFCCC, the Sustainable Development Goals (SDGs) under 2030 Agenda and the Land Degradation Neutrality targets under the UNCCD. There are also clear complementarities with the efforts being developed in both the UN Decade of Ocean Science for Sustainable Development (2021–2030) and the UN Decade of Family Farming (2019–2028). The UN Food Systems Summit 2021 provides an opportunity to promote scaled up action on restoring farmlands and other food-producing systems. It also presents the overall strategy for the UN Decade and the way forward.

The impacts of the COVID-19 pandemic will be felt for generations. Yet this crisis has also demonstrated the power of international cooperation and provided us with an opportunity to steer away from our current destructive trajectory (UNEP 2021). To put countries on a path that is green, sustainable and fair, national governments must include ecosystem restoration in their pandemic recovery plans. This Decade can serve as a launch pad to accelerate the transformative changes we need to combat the climate crisis, prevent mass extinctions and build social and economic resilience.

The Aims for the UN Decade

The UN Decade has the overarching goal to prevent, halt and reverse the degradation of ecosystems around the world. The vision for the UN Decade is a world where – for the health and well-being of all life on Earth and that of future generations – the relationship between humans and nature has been restored, where the area of healthy ecosystems is increasing and where ecosystem loss, fragmentation and degradation has been ended. This is an endeavor that no single entity can undertake alone. It requires political will, innovation and collaboration. The UN Decade aims to catalyze the delivery of existing restoration goals, targets and initiatives, as well as the development of new ambitions for impact (Fig 1).

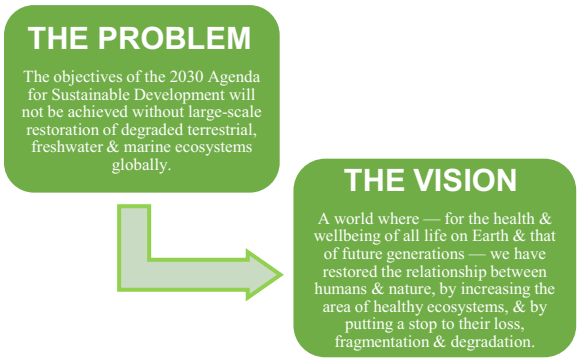


Fig 1. Plan for UN Decade Ecosystem Restoration.

The UN Decade programme also supports the implementation of 17 Sustainable Development Goals (SDGs), and other conventions and targets related to climate change, desertification, biodiversity as well as other landscape restoration projects (Fig 2).

Fig 2. The 17 Sustainable Development Goals (SDGs).

- Eliminate Poverty
- Erase Hunger
- Establish Good Health and Well-Being
- Provide Quality Education
- Enforce Gender Equality
- Improve Clean Water and Sanitation
- Grow Affordable and Clean Energy
- Create Decent Work and Economic Growth
- Increase Industry, Innovation, and Infrastructure
- Reduce Inequality
- Mobilize Sustainable Cities and Communities
- Influence Responsible Consumption and Production
- Organize Climate Action
- Develop Life Below Water
- Advance Life On Land
- Guarantee Peace, Justice, and Strong Institutions
- Build Partnerships for the Goals

TYPES OF WORLD'S ECOSYSTEM

The programme has categorized eight vital earth's ecosystem for restoration, they are: farmlands, forests, freshwaters, grasslands, shrublands and savannahs, mountains, oceans and coasts, peatlands and urban areas.

❖ **Farmlands**

Farmlands endure human life imparts with food, fiber and other essential products and supplement of biodiversity habitat, economic opportunities and spiritual and cultural benefits (UNCCD, 2017). At least two billion people depend on the agricultural sector for their livelihoods, particularly poor and rural populations, and over 90% of calories and protein originate on farmland degradation is reducing crop and livestock yields (Searchinger et al., 2019; Abraham and Pingali, 2020; FAOSTAT, 2021). While farmland degradation typically involves harm to soils, it can also result from the loss of wild species that provide pest control and crop pollination (FAO and ITPS, 2015; Dainese et al., 2019). Roughly 80% of global arable land is impacted by at least one form of degradation, such as aridity, vegetation decline, soil salinization and loss of soil carbon which affects roughly one-fifth of farmlands worldwide.

❖ **Forests**

Forests helps in the regulation of climate and absorption of carbon from the atmosphere; which provide habitats for 80%, 75% and 68% of all amphibian, bird and mammal species, respectively (Vie et al., 2009; Harris et al. 2021). They contribute to precipitation, regulate stream flow and foster groundwater recharge, providing drinking water to one-third of the world's largest cities (HLPE, 2017). Food, shelter, energy, medicines and around associated jobs come from forest products (FAO, 2014; 2018). Nearly 100 million hectares of tropical forests were converted to farmland. Apart from fragmentation, hunting it also accelerated the loss of biodiversity from these ecosystems. Although deforestation has slowed in recent years, the world lost around 10 million hectares of forests per year between 2015 and 2020 (FAO and UNEP, 2020). Each year on an average of 122 million hectares of forests are affected by fires, pests, diseases, invasive species, drought and adverse weather events. Degradation could affect up to 1.75 billion people who live in or near forests, including indigenous and local communities, small holders and people who work in formal or informal forest-based enterprises by the increase of the risk of flooding and, along with fragmentation of ecosystems, increases human-wildlife conflicts (Gibb et al., 2020). It has been linked to outbreaks of vector-borne diseases like malaria (Morand and Lajaunie, 2021) and animal-borne diseases, such as COVID-19 (UNEP and ILRI, 2020) and Ebola (Olivero, 2017). According to FRA 2020, forests currently cover 30.8% of the global land area where more than half of the world's forests are found in only five countries (the Russian Federation, Brazil, Canada, the United States of America and China) and two-thirds (66 %) of forests are found in ten countries.

❖ **Freshwater**

Freshwater bodies are home to around one-third of vertebrate species and 10 % of all described species on Earth with many more in the world's wetlands. Freshwater ecosystems provide food through inland fisheries, water for drinking, agriculture and industry, and transportation of goods (Funge-Smith and Bennet 2019; CBD, 2020b). They help in the regulation of water quality and regional climate and provide flood protection. Forests and water are interlinked, with an estimated 75% of the world's accessible freshwater coming from forested watersheds (FAO, 2019).

Approximately 1.4 billion livelihoods worldwide are directly reliant on water, including jobs related to the food and beverage, energy and water industries (UN, 2018). The integrity of freshwater ecosystems – and their capacity to provide ecosystem services – is increasingly under threat. Use of freshwater for power generation and irrigation provides economic benefits, but it can also cause environmental and socioeconomic impacts downstream (Snoussi et al. 2007). Agriculture accounts for 92% of the global freshwater foot print, and 29% of the water in agriculture is directly or indirectly used for animal production (Hoekstra and Mekonnen, 2012). Freshwater ecosystem degradation and over-abstraction are contributing to water scarcity; half a billion people worldwide face severe water scarcity year round (Mekonnen and Hoekstra, 2016).

❖ **Grasslands, Shrublands and Savannahs**

Most grasslands, shrublands and savannahs are found in drylands, although some are cool and wet, occurring in continent but most extensively in Africa and Asia, drylands also include hyper-arid deserts ((Prăvălie, 2016; UNCCD, 2017). Drylands generally have a low productivity, yet they support the livelihoods of over 1.75 billion people, including many poor populations (Safriel et al., 2005; Mortimore, 2009). Over 250 million people depend on drylands for their livelihoods in East Africa. Collectively they store substantial soil organic carbon, helping to mitigate climate change (Mbaabu et al., 2020). They also provide water storage and regulation, wood fuel, timber and charcoal, as well as forage for livestock. Agriculture has globally cleared and/or transformed an estimated 70% of grasslands; and 50% of savannahs (Foley, 2011). Degradation of grasslands and savannahs threatens the culture and livelihoods of indigenous and ethnic minority communities (Dudley et al., 2020).

❖ **Mountains**

Mountain ecosystems host roughly half of the world's biodiversity hotspots and support the livelihoods of people living in mountain regions and provide critical ecosystem services to inhabitants of lower lands, including freshwater, timber and recreation opportunities (CBD, 2007). Known as the 'water towers of the world', mountain ecosystems fulfill the freshwater needs of half the global population (CBD, 2007; UNEP, Grid-Arendal, GMBA, 2020). Mountains are also a source of food: of the 20 plant species that supply 80% of the world's food, six-maize, potatoes, barley, sorghum, tomatoes and apples – originated from and have been diversified in mountains (UN, 2020b). Degradation of mountain ecosystems is endangering crop production, animal husbandry and overall food security (Romeo et al., 2020). Globally, 311 million people, approximately half of the mountain population in developing countries, live in areas exposed to progressive land degradation. Of these, 178 million are considered vulnerable to food insecurity. Changes in snow and glaciers affect run-off in some river basins, in turn impacting local water resources and agriculture (Hock et al., 2019).

❖ **Oceans and coasts**

The ocean sustains all life on Earth and provides the world's life-supporting space and oxygen in the atmosphere. It regulates our weather and climate, provides food and medicine and holds sacred and intrinsic value for many indigenous and local communities. Salt marshes, coral reefs, sea grass beds and mangroves protect coastlines by slowing floodwater release and reducing wave heights (Das and Vincent, 2009; Shepard et al., 2011; Ferrario et al., 2014; UNEP, 2016).Yet a third of our oceans' commercial fish stocks are now overfished (FAO, 2016b; 2020b). This threatens the livelihoods of fishers, of which there are 60 million globally (FAO, 2020b). Plastic pollution is estimated to reduce marine ecosystem services (Beaumont et al. 2019). Microplastics, and their toxic chemicals, are present in seafood and drinking water (UNEP 2019a). Over the last 50 years, the open ocean has lost 77 billion metric tonnes of oxygen, expanding 'dead zones' by 4.5 million km^2 – similar in size to the European Union (Stramma et al., 2010; Schmidtko et al., 2017). Rising water temperatures and acidification (caused by rising CO2 levels) are affecting the productivity and the distribution of marine fish stocks (FAO, 2020b). Unless we make drastic cuts to greenhouse gas (GHG) emissions, all coral reefs worldwide are expected to disappear due to bleaching and acidification by the end of this century (UNEP, 2017). Coastal development and conversion to aquaculture have led to the loss of 20 % of the world's mangroves, along with their protective services (Friess et al., 2019; UNEP, 2014). Almost 30% of all seagrass has been lost since the late 19th century (UNEP, 2020a).

❖ **Peatlands**

Peatlands store nearly 30% of global soil carbon despite covering only 3% of the world's land area

(Joosten, 2009; Scharlemann et al., 2014). They purify and supply water, offer a natural haven for culture and recreation, and provide biomass, food and other livelihoods to millions of people (Crump 2017). Many European countries have drained the majority of their peatlands, including Germany (98%), The Netherlands (95%), Denmark (93%), and Ireland (82%) (Tanneberger et al., 2017). Drainage, which affects nearly 15 % of all peatlands, leads to subsidence (sinking), land loss, vulnerability to toxic haze-producing fires and, in coastal peatlands, salinization (Crump 2017; FAO 2020a). It also contributes to peatland degradation, which accounts for 3–4% of all global GHG emissions each year (IPCC, 2014; Leifeld and Menichetti, 2018; Olivier and Peters, 2019). In the tropics, drainage is mainly associated with commodity plantations, such as oil palm cultivation, as well as acacia (IPBES, 2018; Evans et al., 2019). Restoring peatlands could avoid GHG emissions equivalent to 12–41% of the remaining GHG budget for keeping global warming below 2°C (Leifeld et al., 2019).

❖ **Urban areas**

Urbanization is the process through which cities grow and higher and higher percentages of the population comes to live in the city. Cities can play a key role in increasing standards of living and decreasing poverty and, if well-managed, provide good homes, opportunities for social interaction, clean air and water, food and climate regulation. In addition to climate regulation, green and blue infrastructure contributes to water regulation and pollution reduction, as well as enhancing human well-being (Elmqvist et al., 2015). Cities can also harbour significant biodiversity in urban parks, gardens and restored landscapes such as industrial parks, railway tracks and residential areas (CBD, 2021). However, ineffective urban planning and management have contributed to socioeconomic inequality and deteriorating environmental quality. Although access to water and sanitation is usually better in urban areas than rural ones, the number of city inhabitants without access to safely managed drinking water has increased by more than 50% since 2000 (UN Water, 2021). According to estimates, cities generate 70% of global carbon emissions and consume two-thirds of the world's energy (UN Habitat, 2020). Air pollution is a major health risk: more than 80% of people living in urban areas that monitor air pollution are exposed to air quality levels exceeding World Health Organization guidelines (UN, 2016).

ECOSYSTEM RESTORATION IN INDIA

India is one of the mega biodiverse countries with only 2.4% of the world's land area where 7-8% of all species are recorded including 45,000 species of plants and 91,000 species of animals. India hosts 8.6% of all mammalian, 13.7% of all avian, 7.9% of all reptilian, 6% of all amphibian, 12.2% of all piscine, and 6% of all flowering plant species. Approximately 28% of the total Indian flora is endemic.

India is holding four of the world's biodiversity hotspots: The Himalayas, The Western Ghats, The North-East, The Andaman-Nicobar Islands. Between these, lie the moist deciduous Sal forest of eastern India, the dry deciduous Teak forest of central and southern India, and the Babul dominated thorn forest of the central Deccan and western Gangetic plain. Approximately 24.16% of the country's geographical area is under green cover.

However, India is also the second most populous country in the world and a sizeable portion of the country's population is heavily dependent on resources and services provided by the natural ecosystems. The country's forests, grasslands, coasts and other ecosystems are now increasingly threatened with deforestation, degradation, fragmentation and other anthropogenic habitat modifications. Addressing and reversing the negative impacts of unplanned growth and development can be achieved by adopting the forest landscape restoration approach. An area of approximately 108 million hectares would need to be brought under green cover. Presently, the forest and tree cover of India is 24.16% or 79.42 million hectares according to the India State of Forest Report (ISFR) 2015. This further classifies the forests into 2.61% Very Dense forest (more than 70% canopy cover), 9.59% Moderately Dense forest (40-70% Canopy cover), and 9.14% Open forest (10-40% canopy density) (Fig 3).

Fig 3: Geographical distribution of Indian Forest (Source: Binod et al., 2018),

❖ **Focus on Ecosystem Restoration beyond conservation**

Ecological restoration is still a developing discipline in India, with a limited number of practitioners and projects. Most initiatives are small and site-specific. On the other hand, the need for restoration is considerable and urgent.

More importantly, restoration has the capacity to generate substantial rural livelihoods and reduce human-wildlife conflicts. India has an ambitious target of restoring 26 million hectares of degraded lands by 2030. Reaching this target will require certain key enablers to be in place.

1) Restoration ecology has a rather low presence in academic curriculum in India at present and this needs attention. Separate processes will also be required for the training of field-level staff who will conduct implementation and monitoring programmes.

2) To make sure that projects adhere to the core principles of restoration. The international standards can help in this regard, with suitable adaptation for Indian conditions.

3) A typical restoration project lasts well over five-six years, and calls for sustained funding and focus. These enablers will make the difference between successful restoration and otherwise.

SOME OF THE LEARNINGS OF RESTORATION INITIATIVES:

➢ **In Jim Corbett National Park, Uttarakhand:** Lantana *(Lantana camara),* one of the world's most troublesome invasive weeds, has become a menace in most of the protected areas located in tropical and subtropical belt of India. The lantana-infested landscapes not only are impoverished as habitats of wildlife but also contribute to human-wildlife conflicts owing to diminished ecosystem services. It is a small case of study of successful eradication and restoration of two lantana-invaded sites in Jim Corbett National Park, India. The idea of eradicating lantana developed using knowledge about its ecology. Subsequently weed free landscapes were restored to productive grasslands and mixed woodlands using native species. It has enhanced the habitat quality for herbivores whose populations are vital for the survival of top carnivores such as tiger (*Panthera tigris corbetti*). The restoration of these areas to grassland communities has successfully prevented secondary invasions by lantana and other weeds.

❖ **In Old Jalukie, Nagaland:** Old Jalukie is located in the north-eastern part of the country, Old Jalukie is a village in Nagaland, India. The village falls within an important watershed area. In the absence of schemes that provide alternate livelihood opportunities, farming is performed by slashing and burning the forests, an old technique called *jhum*, where the land is often left fallow for its recovery. The village council declared an area of 370hectares as Community Biodiversity Reserve and agreed to impose a total ban on *jhum* cultivation, hunting, logging and tree felling within the declared area. Fallow lands were afforested using locally available species that can be used in construction and are commercially viable. A total of 291 hectares was planted using saplings that were germinated from seeds collected from the nearby forests. The combined efforts of the local community along with JFMC have had a positive impact on the ecosystems of Old Jalukie. Abiotic properties of the area like soil quality and water availability have also seen considerable improvement. Old Jalukie, having won the India Biodiversity Award 2014 and Governor's Award 2014, serves as a model JFMC.

➢ **In Lonavala, Maharashtra:** Lonavala, situated in Maharashtra, India is part of the global "biodiversity hotspot", the Western Ghats. Lonavala's growing popularity as a site for both tourism and developmental projects such as construction of roads, railways, industries supplemented by an ever increasing population has negatively impacted surrounding forest landscape. The company targeted to achieve a minimum of 33% forest cover in all project sites through plantation of native trees by employing local villagers. Special efforts were made to protect the endangered Golden Mahseer fish in the local lakes and rivers. To make the restoration process sustainable and community driven, Tata Power also organized awareness campaigns among villagers. However, only 30% of the planted saplings survived in the unprotected areas due to cattle grazing and uncontrolled fire, while thesurvival rate in the protected areas was around 80%. Wildlife habitats were restored gradually and corridors were created to assist their move. The increased productivity of the forests meant the villagers now had more fodder, fuel wood and other forest products. Tata Power's

restoration activities in Lonavala, owing to increased community involvement, have proven to ecologically and socially effective.

➢ **In Valparai, Tamil Nadu:** Valparai, a hill station in the southern State of Tamil Nadu, is part of the Anaimalai Hill range of the Western Ghats. The rainforest restoration programme was started by Nature Conservation Foundation in collaboration with Hindustan Unilever Limited (HUL) to conserve the biodiversity in the forest fragments present in the company owned land within the landscape. NCF carried out the restoration process meticulously, following scientific methods. After plots were chosen, a reference system based on the intact forests in the landscape was selected. The removal of *Lantana camara* and other invasive species contributed towards a high survival rate of native saplings. NCF reported that 70% of the planted saplings survive. Active intervention measures such as weeding out invasive species helped protect the native species. It will create corridors for wildlife movement and habitat patches for vulnerable species, increase carbon sequestration, improve soil and water conservation (Fig 4).

Fig 4: In the Anaimalai hills, preparation for restoration planting in 2004 (Left) and some recovery shows of rainforest trees in 2018 (Right)
[Source: https://www.conservationindia.org/articles/rainforest-fragments]

➢ **In Andhra Pradesh; Odisha; Madhya Pradesh:** Restoration initiatives by Foundation for Ecological Security (FES) spanning thirty years across three Indian States were selected as best practices. These included the following sites: Thamballapalle and Peddamandyam in Andhra Pradesh; Angul, Dhenkanal, Koraput and Keonjhar in Odisha; Indravan, Mandla and Agar in Madhya Pradesh. All sites in Madhya Pradesh reported invasion by *Lantana camara*, an exotic species that thrives well under disturbances, and causes changes to local soil and moisture properties apart from altering native plant communities. Sites in Andhra Pradesh reported higher frequencies of fires that damage wild vegetation and planted crops. Thus, forest degradation in these areas triggered a complex series of reactions, impacting biodiversity, ecological processes and the local people. In total; 1,002,446 hectares of forest land was restored of which 30,856 hectares belonged to sites from Madhya Pradesh, 632,413 hectares were from Odisha and 339,197 hectares belonged to sites from Andhra Pradesh. Sites were regularly monitored with the aid of local villagers. Survival rate of saplings from all sites across three States was reported to be nearly 70%. As forest productivity improved and villagers gained more access to fodder, fuel wood and NTFPs, their livelihood was enhanced. These economic benefits managed to bring about a change in the perception towards restoration activities. FES advocates the consultation of local bodies to ensure that restoration efforts help to regain productivity, revive ecological

processes and ensure the wellbeing of both man and biodiversity.

➢ **In Banni, Gujarat:** In India, 24% of the geographical area is covered by grasslands. Grasslands support a wide variety of browsers and grazers, and the predators that depend on them. Declared a protected forest in 1995, Banni grassland covers about 11.71% of the mainland area of Kutch district in Gujarat. It is a dry savannah type grassland interspersed with wetlands in low lying areas, with vegetation dominated by grass species and a rich community of flora and fauna. Apart from changing vegetation composition, it has led to the loss of many wetlands as well as the disappearance of winter migrating wetland birds. The livestock is now concentrated in small pockets, causing additional pressure on the grassland. Banni by including members from the local communities in all aspects of restoration. GUIDE along with the Forest Department, held meetings to discuss restoration plans with village heads and other local villagers. To understand the success rate of the restorative efforts, monitoring was undertaken for the developed grass plots and areas under restoration. For Banni grasslands to recover from the damages caused in the past, restoration practices must continue to be implemented with a community centric approach.

➢ **In Sundarbans, West Bengal:** A new technology developed by Indian scientists for ecological restoration is helping in revival of mangroves degraded due to rising sea levels, climate change and human intrusion in the Sundarbans in West Bengal. Ecological restoration refers process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed as a means of sustaining ecosystem resilience and conversing biodiversity. The restoration technology, developed by Krishna Ray (West Bengal State University, Kolkata) and Sandip Kumar Basak (Sarat Centenary College, Dhaniakhali), involves plantation of native salt-tolerant grasses and a diverse set of carefully identified mangrove species in different zones of degraded mangrove patches. The Sundarbans is a protected wetland under the Ramsar Convention and is also a UNESCO World Heritage site. Small coastal patches of mangroves are highly vulnerable and fragmentation of the ecosystem is creating barriers to species movement and dispersal. The restoration method has been tested on a two-hectare degraded patch of mangroves in Ramganga village over the past five years and has been found more effective than monoculture of mangrove plantations as usually practiced. The project was initiated with help from the Department of Biotechnology in 2013 and is now likely to be extended to 100 acres. The transplantation started in November 2014, initially at a moderately degraded patch and was then extended to severely degraded zones (Fig 5). The restoration process begins with stabilizing entire site of restoration by planting native salt tolerant grasses. An onsite mangrove nursery was developed to propagate mangroves for transplantation. Besides local mangroves and associate species, the nursery also grew threatened, endangered and vulnerable species. In all, 22 species of mangroves and associate plants were grown so as to maintain native diversity.

Fig 5. Ecological restorations in coastal Sundarbans, West Bengal. *Photo credit*: S. K. Basu

➢ **In Western Ghats:** The effectiveness of forest restoration in the Western Ghats, shows significant recovery of tree cover and plant biodiversity. Controlled active restoration, performed by planting native species and eliminating weeds, can also aid carbon sequestration, the study has found. The researchers conducted their study on the Valparai Plateau, a 22,000-hectare section of the Anamalai Hills, which they describe as a "human-modified landscape"**.** The region has witnessed extensive deforestation between 1890 and 1940 for tea, coffee, cardamom, and eucalyptus plantation by the British. Remnants of the rainforest were used for selective timber felling in the past. Since 2000, three plantation companies have conducted restoration activities on the plateau. The sites were carefully chosen after ensuring they were degraded rainforests alone and didn't include the famously misunderstood native grasslands of the Western Ghats. The active restoration process included steps to prevent cutting of wood, preventing the growth of weeds, and planting a diverse variety of native species. Researchers studied an average of 1,099 plants, spanning 106 species, per hectare and 50 plots of land in the region, half of which underwent 'active restoration', while the other half underwent 'natural regeneration' where nature took over with no human intervention. Before and after photographs helped compare tree cover, and the sites were studied in pairs. A key strength and distinguishing feature of the study is the examination of multiple components of ecosystem recovery, from canopy closure and the diversity of tree species, to the amount of carbon sequestered, in restored forest. The team discovered that active restoration came closer to the natural ecosystem and healthy growth of the benchmark areas. Compared to natural regeneration, these plots also showed more consistent and prominent results.

➢ **In Nilgiri Biosphere Reserve:** To cite a simple example, over 50% of protected areas in the Nilgiri Biosphere are invaded by alien plant species, severely impairing biodiversity and availability of fodder for herbivores. And accentuating human-wildlife conflict. Dry and moist deciduous forests have been degraded by species like *Lantana camara*, *Chromolaena odorata* and *Parthenium hysterophorus*. New threats like *Senna spectabilis* are expanding aggressively. Shola-grassland ecosystems in the upper Nilgiris that form crucial watersheds have been impacted by species like *Acacia mearnsii* (Black Wattle) amongst others. At a back of the envelope calculation, this means over 2500 sq. kms of degraded area in NBR alone. This would need restoration action at a very large scale for the next thirty to forty years. If implemented well, this could significantly increase the carrying capacity of our ecosystems for wildlife.

SOME OF THE ECOLOGICAL RESTORATION PROJECTS AIMING TO HEAL THE WORLD

➢ **Bamboo and Agroforestry for land restoration:**

i. Planting bamboo both enhances land vitality and supplements the income of local people. These benefits were documented in Anji, China, where bamboo shoots were valued at approximately USD 2 billion per year (INBAR, 2018). In Tanzania, bamboo-related enterprises generated an estimated extra USD 200 every month for each household and created jobs for nearly 1000 villagers (FAO and INBAR 2018). China, Ethiopia, Cameroon, Viet Nam, India, Madagascar, Ghana, the Philippines and Kenya are other countries that have successfully incorporated the use of bamboo for land restoration (FAO and INBAR, 2018). Peprah et al. (2014) demonstrated the ability of bamboo to restore degraded lands in Ghana, reporting overall survival rates of 95 \% and rapid foliage growth converting degraded sites into green landscapes.

ii. Another successful example of plant-based land restoration is agroforestry. Agroforestry is often suitable for landscape restoration, it can improve soil properties, resulting in increased soil fertility and erosion and improved water availability to plants. Agro-forestry can improve rural livelihoods by providing a variety of products, including food, fodder, fibre and wood. Selecting appropriate species for the local soil and climate conditions is critical for the success of agro-forestry systems. For example, Lu et al. (2017) and Bohre and Chaubey (2014) recommend very differ sets of species for subtropical forest restoration in Southwest China, and land restoration of Northern Coalfield Limited in Singrauli, Uttar Pradesh, India, respectively. The use of bioenergy plants for degraded land restoration is gaining worldwide attention as it provides multiple benefits in the form of firewood, biodiesel, bioethanol, charcoal, plywood, paper, pulp, and so on (Tripathi et al., 2017). Commercial utilization of these end products also helps in fostering a bio-based economy and reducing poverty by providing a market for products that can often be produced on both degraded and restored land.

➢ **In Costa Rica Water Fund**

Agua Tica is the first public-private water fund initiative in Costa Rica. Its target is to restore and conserve forests in a critical watershed near the Greater Metropolitan Area of the capital city, San Jose, in order to achieve water security by maintaining high quality water for downstream users. This area is key to the country's water supply with nearly 60 % of its population (2.6 million inhabitants) and 70 % of its industry located in the watershed. As a consequence, demand for water is high as a result of population growth, historic scarcity and changing land use. Before watershed protection, deforestation to establish agriculture and grazing was rapid, and was causing increased erosion and degraded water quality. The water fund project operated by The Nature Conservancy (a Costa Rican NGO) and other partners; offer protection to the inland riverine forest areas and native cloud mountain forests. Agua Tica is based on the premise that preserving water quality and quantity will provide economic, environmental and social benefits. In the 1970s and 80s, this region of Costa Rica had one of the highest rates of deforestation globally (the Natural Capital Project), which led to soil erosion, nutrient run-off and unhealthy water quality. In a payment for ecosystem services scheme, landowners in the watersheds that are the source of water supplies are paid to plant trees, build fences to keep cattle out of riverbeds, and sustainably manage their forests. The anticipated benefits of the project include erosion control to maintain the quality of drinking water supplies, the protection of reservoirs, improved ground water recharge, and improved dry season flows to secure reliable water supplies. Specific activities that contribute to reaching these goals include investment in forest protection, adoption of agricultural best practices, environmental education, and establishment of agro-forestry systems, embankment control, and reforestation. The programme is also tracking the mitigation of greenhouse gas releases and biodiversity conservation.

➢ **Mexico's National Forestry Commission**

Mexico's National Forestry Commission **(**CONAFOR) successfully restored 1 million hectares of forest land throughout the country, between 2014 and 2018, according to Initiative20x20. CONAFOR worked with local landowners and communities to help them implement restoration projects, and the plant survival rate in the region has nearly doubled. The World Resources Institute has praised CONAFOR's work, calling it “exactly the right way to show leadership on restoration in Latin America.” The program remains active, and is continuing to work with residents on planting trees that will provide economic benefits as well as improving the country's resilience to climate change.

➢ **Coastal development and coral reef degradation**

Waikiki, Hawaii, demonstrates how land-use change and degradation can impinge on coral ecosystems. The image shows how terrestrial habitats that would contribute to the resilience of coral reefs have been replaced by urban and tourism infrastructure. It also shows how areas of reef have been removed entirely and replaced by recreational marinas, including a channel cut through the reef to enable boats to reach the shore. Although opportunities for coastal habitat and reef restoration appear limited, efforts are being made to reduce the stressors affecting Hawaii's reefs from land-based activities. For example, in May 2018, Hawaii became the first state of the United States of America to pass a law (which will come into effect in January 2021) to ban sunscreens containing oxybenzone and octinoxate, which have been found to be harmful to coral reefs (Coldwell 2018).

➢ **Dune restoration for protecting urban area**

In 2012, after a major coastal storm which destroyed beach-dune support infrastructure, Almada municipality decided to undertake sand fore-dune restoration with the ReDuna project. Along 1 km of the Atlantic coast, support structures and native species were used to restore the ecosystem. The facilities installed, such as overhanging walkways and signage, have enhanced the possibilities of the local population and tourists for interacting with sand dunes and getting to know their value and importance, while reducing trampling. This project is praised by the local population and tourists for providing added aesthetic values and by beach support-structure owners, who were able to keep the economic revenue from the facilities. Over time, native vegetation and animals have returned, increasing biodiversity and providing resilience to the restored ecosystem.

➢ **In Brazil land restoration**

The semi-arid region of Brazil located in the Caatingaand Minas Gerais (about 858,000 km^2) is susceptible to land degradation and is home to 29% of

the country's population, including the poorest of the region, with quality of life below the national average. Land degradation intensified by drought is one of the most serious environmental problems of this region, causing significant economic and social damages. The National Policy to Combat Desertification and Mitigate the Effects of Drought (adopted in 2015) recommends that states and municipalities mainstream actions into their public policy to address this problem. To this end, the Department of Sustainable Rural Development and Combating Desertification is working with municipalities of the region in the planning and implementation of the URAD project (Recovery Units of Degraded Areas and Reduction of Climate Vulnerability) through environmental, social, and productivity initiatives underpinned by the mix of six activities: training and capacity building of rural smallholder farmers; rehabilitation and conservation of soils; water and biodiversity; water harvesting; basic sanitation; and energy efficiency. The programme anticipates engaging families living in the recovery units in the implementation of actions such as the construction of dams, ecological stoves, beekeeping, and the rehabilitation of riparian forest, so that the community takes ownership of technology to improve quality of life, increase employment and income and food security.

➢ **Maiden Island Reef**

The reefs around Maiden Island in the Caribbean were the subject of what the Society for Ecological Restoration refers to as the "the world's largest total marine ecosystem restoration, which included both coral reef and mangrove habitats." Part of the reef had been destroyed by Hurricane Luis in 1995, and the reef had also been degraded by urbanization and industrialization. The restoration used thousands of Reef Balls, an "artificial reef module which mimics the structure and function of a natural reef." Corals were attached to the reef balls, ultimately resulting in 5,000 new coral colonies consisting of more than 30 species.

ABOUT RESTORING ECOSYSTEMS

One hundred and fifteen governments have committed to restoring a total of around 1 billion hectares on land, as a contribution to achieving the objectives of the CBD, UNCCD, UNFCCC or the Bonn Challenge on forest landscape restoration (Keeble, 2015; Sewell et al., 2020). The roots of degradation lie within our economic and political systems; the solution will be neither quick nor easy. It outlines insights from a growing body of research that is establishing the principles of successful restoration, as well as technical and scientific innovations to facilitate the work.

A. Approaches and Principles for Restoration Programmes

Ecosystem restoration encompasses a wide variety of approaches that contribute to conserving and repairing damaged ecosystems (UNEP and FAO, 2020). This may involve active restoration or the removal of drivers of degradation to 'passively' promote natural regeneration. Whatever the approach, restoration requires time, resources, knowledge, enabling policies and governance if it is to contribute to human well-being, economic development, climate stability and biodiversity conservation.

❖ **Restoration approaches**

➢ **ECOLOGICAL RESTORATION**

1) Process - Assisting the recovery of a terrestrial, freshwater or marine ecosystem that has been degraded, damaged, or destroyed.

2) Intended end point - Transition from degraded ecosystem to a reference ecosystem, which may be a natural or a cultural one.

➢ **FOREST AND LANDSCAPE RESTORATION**

1) Process - Reversing the degradation of soils, agricultural areas, forests and watersheds thereby regaining their ecological functionality

2) Intended end point - Restoring multiple ecological, social and economic functions across a landscape and generating a range of ecosystem goods and services that benefit multiple stakeholder groups.

➢ **RESTORATION OF AQUATIC PRODUCTION ECOSYSTEMS**

1) Process - Maintaining ecosystem structure and function to support food provisioning, while minimizing impacts, rather than restoring ecosystems to an initial state before production activity started.

2) Intended end point – Large oceanic marine ecosystems supporting or affected by direct and indirect impacts of fishing gears and fisheries

production; recovery through changes in fishing methods and gear modification to rebuild fish stocks and reduce adverse impacts on the environment. Specificities shown for both freshwater ecosystems and coastal ones with linkages to fisheries and aquaculture.

➢ **REGENERATIVE AGRICULTURE**

1) **Process -** Farming that uses soil conservation as the entry point to regenerate and contribute to multiple provisioning, regulating and supporting services.
2) **Intended end point -** Enhancing environmental, social and economic dimensions of sustainable food production. Soil carbon, soil health and on-farm biodiversity are restored.

➢ **REWILDING**

1) **Process** - Rebuilding, following major human disturbance, a natural ecosystem by restoring natural processes and the complete or near complete food-web at all trophic levels as a self-sustaining and resilient ecosystem using biota that would have been present had the disturbance not occurred.

2) **Intended end point -** No pre-defined end point. Functioning native ecosystems complete with fully occupied trophic levels that are nature-led across a range of landscape scales.

❖ **Restoration principles**

The Strategy of the UN Decade on Restoration calls for the development and implementation of gender-responsive methods for empowering women and girls in dialogue, planning, decision-making and implementation of ecosystem restoration (UNEP and FAO, 2020).

International Principles: Present a robust framework to guide restoration project toward achieving intended goals. It highlights the role of ecological restoration project is connecting, productivity and sustainability goals. It recommends performance measures for restoration activities for industries, communities and governments to consider. The Standards support development of ecological restoration plans, contracts, consent conditions, and monitoring and auditing criteria. Generic in nature, in standards framework can be adapted to particular ecosystems, biomes or landscapes; or traditional cultures. The standards provide a blueprint for ensuring ecological restoration achieves its full potential in delivering social and, ultimately, long-lasting economic benefits and outcomes. Such principles can help to address challenges in restoration, including effective design and implementation, accounting for complex ecosystem dynamics in the context of climate change and navigating trade-offs associated with land management priorities and decisions (Gann et al., 2019) (Fig 6).

Fig 6: Eight principles underpinning Ecological Restoration (Gann and McDonal, 2019).

Key principles to guide Ecological restoration

PRINCIPLE 1

- **ENGAGES STAKEHOLDERS**
  The interests and contributions of multiple stakeholders, especially of the local ones are identified, regarded and directly involved by the Ecological Revival projects to render advantages to both human beings and nature (Fig 7).

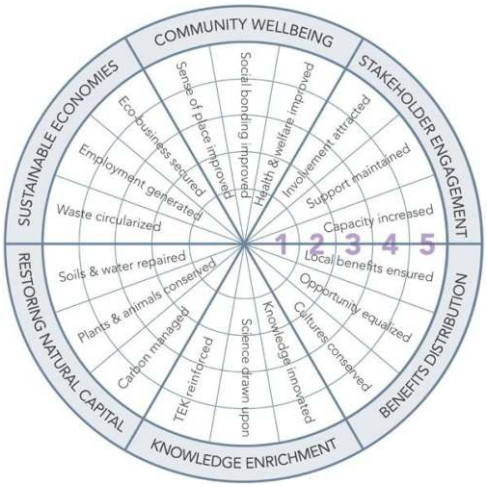


Fig 7: A Social Benefits Wheel (Gann and McDonald, 2019).

PRINCIPLE 2

- **DRAWS ON MANY TYPES OF KNOWLEDGE**
  The amalgamation of obtained practitioner knowledge, conventional ecological knowledge, local ecological comprehension and scientific unearthing always proves to be advantageous to the practice of ecological rejuvenation.

PRINCIPLE 3

- **IS INFORMED BY NATIVE REFERENCE ECOSYSTEMS, WHILE CONSIDERING ENVIRONMENTAL CHANG**
  The potential of the indigenous species and communities to recuperate, redevelop, adjust and progress with the environmental changes are escalated by the reference models.

PRINCIPLE 4

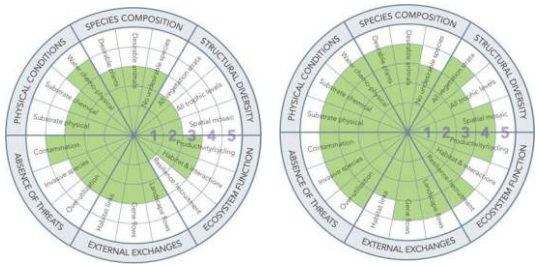
- **SUPPORTS ECOSYSTEM RECOVERY PROCESSES**
  Specialists try to escalate or enrich the natural revival conducted by the plants and animals by interacting with each other and through their shared natural habitat and surroundings.

PRINCIPLE 5

- **IS ASSESSED AGAINST CLEAR GOALS AND OBJECTIVES USING MEASURABLE INDICATORS**
  In their preliminary phase, the vision, purposes of the restoration projects are certainly discovered, along with the identification of particular indicators useful for the measurement of their advancement.

PRINCIPLE 6

- **SEEKS THE HIGHEST LEVEL OF ECOSYSTEM RECOVERY POSSIBLE**
  Ecological restoration focuses on rate of feasible amelioration befitting all the conditions (Fig 8).



Baseline **10 years later**

Fig 8: Ecological Recovery Wheel (Gann and McDonald, 2019).

PRINCIPLE 7

- **GAIN CUMULATIVE VALUE WHEN APPLIED AT LARGE SCALES**
  Despite their spatial scale, ecosystem restoration projects show propitious end results efficiently. However, numerous restoration processes are exercised at a larger spatial scale such as the watershed or basin level. Also, to come to grips with the ecological sustainability requirements, the scaling-up of restoration actions is a desideratum.

PRINCIPLE 8

- **IS PART OF A CONTINUUM OF RESTORATIVE ACTIVITIES**
  Like many other schemes, ecological restoration is also one with great potentiality. To a significant extent, it can contribute to biodiversity

preservation and management, hike up carbon sequestration and various benefits of a healthy ecosystem; bring about progression in human life that includes good health and livelihood; and also result in the enhancement of the relation between man and nature in a positive way (Fig 9).

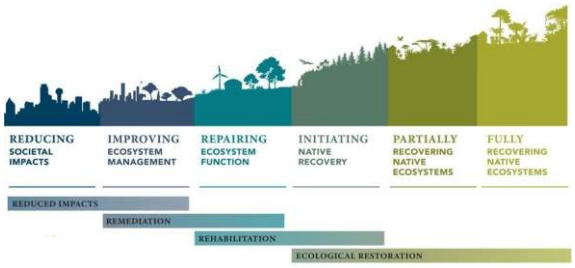


Fig 9. Restorative Continuum (Gann and McDonald, 2019).

B. MAJOR CONDITIONS REQUIRED FOR ECOSYSTEM RESTORATION

Highlighting the inter linkages between restoring ecosystem health and economic sustainability will be key to moving restoration forward in the context of the build-back better recovery plans, as well as to ensuring the equitable delivery of benefits (Aronson et al., 2020). Initiatives to raise awareness of the risks posed by ecosystem degradation will also be crucial for raising restoration finance.

Investing in ecosystem restoration will be fundamental to transitioning to sustainable economic development that works in balance with nature. Directing financial flows towards such investment requires better integration of information on ecosystems into economic planning tools. It also requires financial systems that channel investments towards economic activities that enhance, rather than degrade, ecosystems.

Despite the economic imperatives, over-exploitation of natural resources is embedded in our economies and governance systems. Breaking this habit requires recognizing the environmental externalities – the unaccounted-for consequences for nature and future generations – of our current approaches to planning economic development. Fundamental to this will be addressing perverse subsidies and other economic incentives that drive ecosystem degradation.

The path to a more sustainable use of ecosystems must begin with the development of inclusive wealth measures – which capture natural, social, human and manufactured capital and are thus more accurate ways to measure economic progress – and natural capital accounting.- The recent adoption of the System of Environmental Economic Accounting Ecosystem Accounting (SEEA EA) framework by the international statistical community is a major step towards the integration of ecosystems into national accounts and macroeconomic planning. It is a key part of the tool kit for reflecting the value of ecosystems in public policies, plans and economic systems.

Communities and civil society need to be engaged and supported to secure ecosystem restoration across scales. Public and private funds can help communities secure land tenure and support local investment in ecosystem restoration. Education is also vital to ensure that future generations benefit from a greater understanding of nature and an appreciation of its value.

CONCLUSION

Humans have been responsible for putting deep footprints on our natural environment bringing great destruction to our forests, ecosystems, wildlife and biodiversity. Several anthropogenic factors are responsible for this including habitat degradation and fragmentation, illegal human settlements in highly sensitive ecosystems and their dependence on local ecosystems for their daily sustenance, infringement into forests, anthropogenic wildfires, and changes in the land use patterns, conversion of forested areas into industrial sites and agricultural farmlands, infrastructure development projects to mention only a handful. The exponential rise in global human populations across the planet has been putting pressure on the local ecosystems beyond their individual threshold of their carrying capacity.

Hence, under the United Nations ecological restoration decade has been proposed and launched with an overall target of fulfilling 17 SDGs. In this major review work we have investigated the policies, strategies, success and failures of ecological restoration both across India as well as the world to get an unbiased local, regional and global perspective at various levels. Several successes and challenges have been identified and investigated. This has provided us with a grand opportunity to review and tackle the challenges associated with successful ecological restoration at the ground level. It is important to realize

that this huge initiative is not just linked to environmental protection; but also with local and international economic developments. The COVID-19 pandemic has certainly slowed down the progress of ecological restoration due to several safety guidelines, protocols abs changed time line and schedule of work; but in spite of all odds some progress has been made. This is a mammoth task and several countries, government and non-government agencies, field experts and ordinary citizens participating in these initiatives need to understand the long term objectives of ecological restoration and need work together on a common platform to achieve deck success on the ground.

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