Chapter 1
Ecological Restoration: An Overview of Science and Policy Regime

Vijay Jain, Kuldeep Singh Rautela, and Manish Kumar Goyal

Abstract Ecological restoration projects require science-based assessment in association with policy development for making a strategic framework and prioritizing the intervening actions. It will ensure the long-term future health and stability of the ecosystems. Ecological restoration science aims to provide ecosystems in pre-disturbance conditions. It will give an approach to improve the regional biodiversity and structural and functional integrity with surroundings and diminish the regional climatic and economic value degradation. The futuristic tasks associated with ecological restoration across different regions worldwide can be classified into social, ecological, economic, and political categories. Here, we have discussed several aspects of ecological restoration plans for urban, wetlands, and Himalayan ecosystems and their associated ecological and socioeconomic impacts. Therefore, through proper implementation of restoration principles, guidelines, and maximum involvement of stakeholders, we can achieve maximum ecological and sustainable aims during the 2021–2030 decade of ecosystem restoration.

Keywords Restoration science · Policy · Cities · Wetlands and Himalayan ecosystem

1.1 Introduction

The World Environment Day on 5 June 2021 marked the beginning of the United Nation decade for ecosystem restoration from 2021 to 2030 to discontinue and invert the deterioration of the natural world. The initiative of this decade begins with the

V. Jain (✉) · K. S. Rautela
Department of Civil Engineering, Indian Institute of Technology Indore, Indore, Madhya Pradesh, India
e-mail: phd2101104008@iiti.ac.in

M. K. Goyal
Department of Civil Engineering, Indian Institute of Technology Indore, Indore, Madhya Pradesh, India

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observance of the climatic emergency conditions due to losses of natural ecosystems and higher levels of pollution, which threatens the existence of millions of species on our planet. This initiative leads to science and policy discussions among all the United Nations member country for focusing on future ecological restoration programs (UNEP 2021a). The key objective of this program is to restore at least 0.35 billion hectares of degraded ecosystems across the globe by 2030. Its projected cost will be 1 trillion US dollars, equivalent to 0.1% of worldwide financial gains between 2020 and 2030. The above restoration plan creates 9 trillion US dollars in natural ecosystem services and will decrease society's poverty (United Nations 2022). Ecological restoration projects require science-based assessment in association with policy development for making a strategic framework and prioritizing the intervening actions. It will ensure the long-term future health and stability of the ecosystems. Scientific research groups have to assess the prioritization of the regions for restoration in association with national and local policymakers for making sustainable landscapes to sustain biodiversity and ecosystem services. Several studies estimated that restoring 15% of transformed land in critical priority areas would avert at least 60% of future decline in biodiversity and the severity of climate change. For the achievement of this aim, wetlands and forests are significant landscapes. However, if the objective is to achieve restoration with minimum economic inputs, then arid ecosystems and grasslands are the regions of interest (Crossman 2017; Csákvári et al. 2022).

Furthermore, cost-benefit and cost reduction methods will be used to optimize the monetary and resource allocation for restoration techniques during spatial development. For example, in Europe, steppe habitats have community significance for the drier part of the aridity gradient. These habitats were included in the Eurasian forest-steppe areas, with great species and functional diversity. The grassland's presence in the region offers additional societal and financial significance, which has been utilized as extensive pastures and meadows since earlier times. Despite this, residual semi-natural habitats face risk due to anthropogenic activities like enormous land degradation and habitat fragmentation. Therefore, it is a massive task for the scientific community, policymakers, practitioners, and activists to keep and restore the lasting semi-natural steppe regions. It should be simplified by executing restoration primacies and assessing the optimum restoration techniques locally and countrywide. The historical and futuristic data science assessment for all the ecological and economic factors is required to make an optimized restoration action plan. Ecological restoration plans are of two types, i.e., passive and active. The passive restoration plan strategy focused on allowing natural processes with minimal external interference. It applies to locations with minimum abiotic stress and low to reasonable disturbances in landscapes due to humans.

In contrast, the active restoration strategy's key objective is to enhance the landscape's abiotic and biotic factors. It is worth mentioning that the interference cost in an active restoration plan is higher than passive restoration. The prioritization of ecosystem restoration will be based on the consideration of an optimized ecological and economical passive or active restoration plan through the regeneration capacity of regional habitats, neighboring vegetation covers, and long-standing fields. Restoration of the ecological system comprised a wide range of approaches. It will vary with geographical, topographical, hydrological and type of ecosystem. It is mentioned as a go-to technique for resolving upcoming environmental changes (Csákvári et al. 2022).

There are three types of restoration science practices followed presently worldwide, which are as follows:

- **Rapid environmental, ecological, and cultural changes:** It will focus on providing climate change mitigation and adaptation solutions, minimizing the regional flora and fauna invasive species, and increasing the ecosystem benefits and valuation compared to traditional restoration practices.
- **Innovation in combination with ecological and engineering design:** It will provide a newly designed ecosystem through green infrastructures in urban regions and the making of agro-ecosystems and natural landscapes in peri-urban and rural regions.
- **International and national agreements for restoration investments:** This will focus on providing transboundary restoration projects and achieving common sustainable goals through cooperation at different levels for the betterment of humankind and nature.

Therefore, ecological restoration science aims to provide ecosystems in pre-disturbance conditions. It will give an approach to improve the regional biodiversity and structural and functional integrity with surroundings and diminish the regional climatic and economic value degradation. The United Nations governance flow chart for ecosystem restoration is shown in Fig. 1.1.

1.2 Need for the Ecological Restoration

The understanding of ecological restoration in our day-to-day life requires an understanding of ecological terms and their significance. Therefore, we have to understand first the word ecology, derived from the Greek word *Oekologie.* It can be separated into *Oikos (home)* and *logos (to study).* Therefore, ecology is defined as the study of life at home with an emphasis on the interrelations between organisms and their environment. The German biologist "Ernst Haeckel" defined ecology in 1866 as "the complete knowledge of all the relations of organisms and its surrounding outer world in the presence of certain organic and inorganic conditions of existence." Ecology studies interactions at organisms, populations, communities, ecosystems, biomes, and the biosphere levels. Thus, ecological restoration for any region and species will improve its, directly and indirectly, associated surrounding conditions and complex interrelationships with different biotic and abiotic components.

The subset of ecology is an ecosystem, and usually, the terms "ecological restoration" and "ecosystem restoration" are used identically despite certain distinctions. Ecologically regions comprised of several ecosystems like forests and rivers,

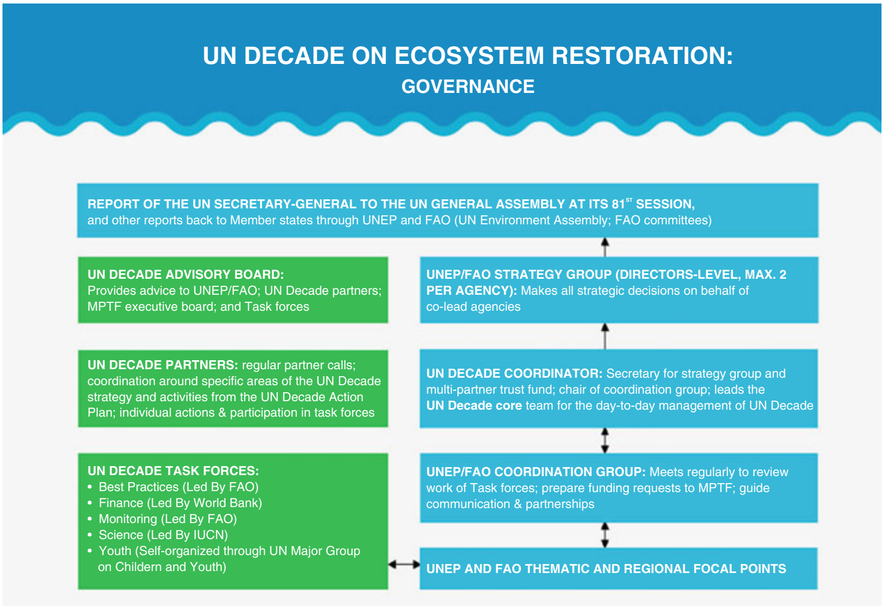

Fig. 1.1 UN decade on ecosystem restoration governance (United Nations 2022). (*Source:* https://www.decadeonrestoration.org/about-un-decade)

which are two distinct ecosystems in a region. Ecologically they can be studied in a combined/isolated manner to understand the interrelations between them. The ecological restoration of any region is usually subdivided into various ecosystem restorations present in the region for proper management and monitoring for more extended periods. The ecosystem is a vital subunit of the ecology that contains various essential interactions between different life forms on Earth. It associates all the living organism interactions within themselves and their surroundings. It has variable scales ranging from small soil grains to the entire Earth planet (United Nations 2021a).

The broader categories of ecosystem types include natural and artificial or man-made ecosystems. Natural ecosystems function naturally with minimum or no anthropogenic interference. The natural ecosystems will be further classified as terrestrial (forests, deserts, grasslands) and aquatic ecosystems (oceans, rivers, lakes). Artificial ecosystems were operated and managed entirely through anthropogenic activities like crop cultivation fields, aquariums, cities, etc. Ecosystem stability in a region determines the structural and rate functions. Structure signifies the composition of living organisms and their distribution and amount, the distribution of non-living materials like nutrients, water, and the range of physical conditions like temperature and light time, while rate refers to the energy flow in the community, rate of nutrient cycles, and biological and ecological regulations for biotic and abiotic components combined. Therefore, ecological restoration is necessary to make a sustainable relationship with our ecosystems. It will provide sustainability through climate change mitigation, assuring food availability for rising populations, and minimizing the decline in biodiversity. To achieve the target of keeping the mean temperature of our planet below 2 °C, ecological restoration will be required in combination with renewable energy systems. In this manner, it will benefit the present and future generations by conserving and preserving natural resources (UNEP 2021a; United Nations 2021b).

Ecological restoration is "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed." It is the international agreement for accelerating the process of ecosystem recovery in terms of structure, functional utility, and its exchanges with surrounding landscapes and seascapes. It will enhance ecological integrity and ecosystem resilience to climate change (SER 2022).

There are various reasons for explaining the requirements of ecological restoration at a large scale globally; some of them are presented below:

- It is estimated that there will be 10 trillion US dollars in economic loss globally by 2050 if the ecosystems continuously decline at the present rate.
- Restoration of 15% of converted land will prevent 60% of biodiversity loss on the Earth.
- Globally, 81% of urban regions would prevent water pollution through efficient water management practices for their population, in combination with forest protection and better agricultural practices (UNEP 2021b).

Ecological restoration can be used to reduce pressure on natural resources with significant interventions like afforestation, removal of invasive flora and fauna species, and re-establishment of locally extinct species. Thus, ecological restoration works will benefit us by providing physical and mental health benefits and long-term food and water security, enhancing biodiversity and economy, reducing future war and migration conflicts for natural resources, and providing climate change mitigation and adaptation solutions (Fischer et al. 2021; Howell et al. 2013).

1.3 Restoration Ecology

Restoration ecology is the scientific discipline for applying the ecological restoration concept in the field. Thus, restoration ecology is distinguished through ecological restoration in terms of research and development applications for on-site ecological restoration projects. The concept of restoration has been in practice through earlier centuries, but in the present time, the development of restoration ecology began in the twentieth century through the Aldo Leopold conservationist movement. It has been grown at different scales with more minor scales like afforestation to large-scale projects like Louisiana wetlands. The success of the ecological restoration projects depends on the initiation from the regional population and implementation through community members voluntarily. As restoration is a complex process in terms of collaborations with a wide range of participation of people from diverse fields, therefore, social science will be an integral part of the restoration at each development level.

The restoration ecology primarily focused on community and ecosystem ecology specific to vegetation development in the region. Recently, it has been utilizing the concept of conservational biology to increase certain animals' presence in the region. In the latter part of the twentieth century, restoration ecology was recognized as a scientific field and studied by several organizations worldwide. The widespread applicability of restoration ecology began with the establishment of the International Society for Ecological Restoration in 1988. Research work in association with journals like *Ecological Restoration* (1981) and *Restoration Ecology* (1993) increases the popularity of the restoration ecology concept among the scientific community and policymakers.

There are certain concepts associated with restoration science that have widespread applicability, which are detailed below:

Disturbance Disturbance events can occur at various scales in severity and with variable temporal resolution. These disturbances cause the alteration in the species, nutrient cycles, soil, and water properties. These disturbances can be classified as natural or anthropogenic. Natural disturbances are extreme weather events, such as wildfires, volcanic eruptions, etc., while anthropogenic disturbances cause alteration through habitat destruction and fragmentation through converting land for agricultural usage or dam reservoir construction across the water bodies. Anthropogenic activities influence climate change and extreme weather events' severity and temporal variability. The restoration project aims to initiate ecosystem recovery after the disturbances and recreate the natural cycles of the pre-disturbance.

Genetics The long-term sustainability of the restoration plan considers the genetic diversity of the ecosystem**.** Regional flora and fauna, with lots of consideration, are used in vast numbers for a successful establishment to enhance genetic diversity in the re-established ecosystem. It is a decisive factor in ecological restoration as it will decide the evolving and recovering ability from disturbances for extended periods.

Succession It is the process through which the community structure varies in terms of numbers and proportions of the wide range of species found in the ecosystem due to the recovery time post-disturbance event. Passive restoration will allow succession to naturally occur in the ecosystem after eliminating all the disturbing sources. For example, the rise of deciduous forests in the Eastern United States was a successful restoration after finishing all the agricultural practices in the region. In contrast, active restoration increases the restoration process with changes in the natural succession path. For example, like mine tailings, the passive restoration will take a considerable time; thus, active restoration is the appropriate choice.

Community Assembly Theory It is the concept involved in developing sites like pre-disturbed events. It will depend on the initial arrival of the wide range of species in the region and their mutual biological interactions. This is a challenging task in restoration projects as each site does not develop ideally to the pre-disturbed event with desired species composition or ecosystem utility. It will depend on the seed mixes, the planting order, and the time when there is a requirement for redeveloping specific ecological communities with the plans to prevent them from invasion by pests.

Landscape Ecology Landscape ecology involves several concepts for restoration. The restored regions are usually divided into smaller parts, making them sensitive to several disturbance events due to habitat fragmentation. A smaller habitat region will support a lesser number and proportion of species due to the high risk associated with interbreeding and regional extinction. Biogeography island theory estimates that diverse species populations will develop in huge landscapes with better connectivity to the people in the surrounding patches. This theory presumes that the area between habitat patches is uniform and hostile. These patches decided for restoration are less hostile to the targeted restoration species and desired ecosystem utilities. The restoration projects will improve the connectivity among the fragmented habitat regions for restoring paths. These paths can be termed in different forms based on the requirement like wildlife corridors and stepping stones for allowing better movement across the region. Corridors are defined as thin linear strips between isolated habitat regions, while stepping stone is having low connectivity with allowable movement paths across different patches.

Application The restoration application has a large number of steps that consider all or specific points described below:

Site Assessment Complete appraisal of the restoring site's present conditions and determine all necessary activities. It is the initial step for assessing all the disturbance events and techniques required for halting or reversing them.

Assessing the Aims of the Restoration Project This will be based on the requirements of the restored community. The decision of the aims will be based on the literature review for a similar environment, assessing the historical datasets for detailing the pre-disturbance region and its biological interactions. It will identify the best species to sustain present and future climatic changes.

Removing Sources of Disturbance Initiation of the restoration project will be based on the prior removal of all the disturbance-inducing factors in the region, for example, halting all mining and farming practices, restricting cattle entry, and removing the area's toxicity and invasive species.

Restoring Processes/Disturbance Cycles There are specific restoring processes like natural flooding or fires that can restore regional ecological integrity, as these will provide the ability for native species to evolve and tolerate natural disturbances and return to the initial state without actions by restoration people.

Substrate Rehabilitation It will involve improving the local environmental conditions, like soil, water, and air quality, for pre-disturbed events.

Vegetation Restoration These seem to be a simple solution but require an assessment to identify native species in the region, as invasive species plantation in the region may cause a complete failure of the restoration project. It can be done in the form of seeds or seedlings.

Monitoring and Maintenance The continuous monitoring of the restoration site till the achievement of the restoration target is a critical task that can be useful for futuristic restoration strategy and management. The ideal restoration projects achieve self-sustainability for the ecosystem without anthropogenic interference. Still, in some cases, like periodic removal of pests have to be carried out until the planted saplings are not fully developed for making restoration efficient for longer-term (Howell et al. 2013; Palmer et al. 2016).

Restoration efforts are required for each ecosystem, but critical attention has been given to severely impacted ecosystems by anthropogenic actions like forests, wetlands, and key biodiversity areas worldwide (Vaughn et al. 2010).

1.4 Ecological Theory

The restoration ecology is a complicated conservation process and can't be considered a substitute for conserving or preserving the present natural resources and ecosystems. The primary objective of ecological restoration is to establish the native species on the restoration site in the pre-disturbed environment according to the community model. The community or the ecosystem model concept is based on the prior understanding of the ecological theory and the nature of earlier communities in the restoration site. Thus, the concept of ecological theory will be considered the heart of each restoration project in the mind of the restorationists. The ecological theory utilizes for understanding human actions during the restoration process. The restoration team, scientific community, and policymaker members' combined activities and interactions will decide restoration efficiency for more extended periods.

1.5 Restoration Science: Principles, Strategy, and Guidelines

In a general manner, each ecological restoration plan for any site has three principles to be followed, which are described in detail below:

Get Everyone on Board Identify each stakeholder associated with the restoration project. Provide complete information on the restoration plan to each person impacted or affected by this directly or indirectly. Acknowledge all the diverse views from different backgrounds of the population on nature to achieve maximum benefits with the restoration plan. Get maximum involvement from various persons who can contribute through their knowledge and skills to get valuable support to the

Fig. 1.2 Restoration principles (UNEP 2022b). (***Source:*** https://www.unep.org/news-and-stories/story/panel-unveils-10-guiding-principles-campaign-revive-earth)

restoration project, minimize the opposing points, or overcome the upcoming challenges.

Setting Goals and Measuring Progress Through prior assessment of the restoration site and learning on ecosystems, we have to establish a protected and self-sustainable restoration site. It will be based on continuous monitoring of the time-based achievement of mid-term and ultimate goals. Determine all the measurable indicators for monitoring the progress and regulating the project's completion time.

Help Nature Help Itself It is a wholly known fact that we can't be able to restore the degraded or destroyed ecosystem to its original state. However, we can enhance its ecological and functional integrity naturally and sustainably. Therefore, the efficient restoration project plan should consider all the natural processes like introducing all the native species, improving the nutrient cycling regimes in different environmental components, etc.

The broad principles as decided by the UNEP (2022b) are shown in Fig. 1.2 and described below:

Principle 1 Global Contribution Successful ecosystem restoration requires global contribution, which can assist us in adaptation to climate change, the decline in biodiversity loss, and land degradation.

Principle 2 Broad Engagement Individuals are the core of the restoration plan. It is estimated that more than 40% of the Earth's population is impacted by ecological degradation. Thus, we have to engage all the marginalized people in restoration plans, like indigenous people, minorities, women, etc.

Principle 3 Continuum of Activities No single approach can be followed for all the restoration tasks, as it is decided based on the severity of degradation and its self-sustainability for restoration on its own.

Principle 4 Benefits to Nature and People Restoration should be carried out in such a manner that under any scenario it should not lead to further degradation of regional environment and people who depend on it.

Principle 5 Addressing Causes of Degradation Restoration is not a substitute for conservation. Thus, we required a proper assessment of degradation's natural and anthropogenic drivers.

Principle 6 Knowledge Integration Integrate all the forms of knowledge, i.e., scientific sources and traditional and local community information, for making an efficient restoration plan.

Principle 7 Measurable Goals Ecological, economic, and social aims of the restoration plan with a timeline should be decided before the initiation of the restoration plan.

Principle 8 Local and Land/Seascape Contexts The restoration plan's impact varies from place to place. Thus, it should be made in the context of the local site and its surrounding population.

Principle 9 Monitoring and Management Restoration is a complex process; thus, continuous monitoring with proper management is required regularly for long-term sustainability. Ecological theory and adaptive restoration will be valuable approaches.

Principle 10 Policy Integration Regional- and national-level government cooperation is needed for policymaking and supporting the ecosystem's restoration plan for extended periods.

The strategy adopted for the worldwide greater utilization of ecosystem restoration will focus on the following points, which are shown in Fig. 1.3.

Restoration guideline preparation will follow the approach for making restoration plan-associated principles and strategies effective in re-establishing the site, engaging all the stakeholders with maximum participation, and producing maximum benefits with minimum resources, time, costs, and efforts (IUCN 2012; UNEP 2021a).

Fig. 1.3 Strategy points for ecosystem restoration (SER 2022). (*Source:* https://www.ser.org/page/DecadeonRestoration)

1.6 Adaptive Restoration

An adaptive approach to ecological restoration will provide several tasks for reorganizing and redesigning the aims, strategies, and technologies involved at each stage of the restoration project. This approach in restoration provides steps to the restoration team for daily evaluation of the project progress and identifying the corrections scientifically for modifying our expectations in achieving the ecological restoration objectives. In supplement to this, we can determine the impact of any special disturbance event or the involvement of any new innovative techniques for preparation to meet the upcoming challenges. This approach has certain limitations; it is time-consuming and requires extensive documentation of each day and activity during the completion of the restoration project. However, project documentation with continuous collection and assessment of information for planning, implementation, and management is crucial for assisting in long-term sustainable success for the restoration project and adopted practices in it. The research work involved in developing restoring practices will contribute to the ecological theory. Therefore, scientific experiments and on-site trials were the main components of adaptive restoration used to determine the critical information for site designing and selecting restoration implementation and management strategies.

1.7 Case Studies of Ecological Restoration

This section discusses case studies of ecological restoration for wetlands, Himalayan, and urban (artificial) ecosystems in detail below.

1.7.1 Urban Ecological Restoration

Urban regions are classified as artificial ecosystems with the maximum anthropogenic influence in their creation and regulation. The urban regions occupy less than 1% of the Earth's land surface but provide household facilities to more than half of the world's inhabitants. These regions are created after replacing the natural ecosystems and are generally observed as having high degradation due to informal planning, less vegetation, huge waste, and greenhouse gas emissions. These phenomena lead to the degradation of more natural ecosystems and fertile land in surrounding urban regions (UNEP 2021a). In this context, Varanasi, the oldest city in India, has recently observed several changes in urban design to restore urban ecology. The city has a population of 1.3 million and generates about 445 tons of municipal waste per day, which is collected and transported along with different forms of waste. Thus, to improve the city's waste management, Varanasi Nagar Nigam prepared a "holistic waste management strategy" with support from United Nations Environment Programme, ICLEI – Local Governments for Sustainability, South Asia, and International Environmental Technology Centre (IETC). The primary objective of this waste management planning is to make the Varanasi city "*Nirmal Kashi*" by enhancing integrated solid waste management practices that are self-sustainable, benefit society, and enhance the quality of life. It will target waste reduction, reuse, and complete city coverage with street sweeping, waste collection, transportation, and scientific disposal. Thus, this waste management practice will provide a clean city and its surrounding ghats for religious pilgrimages (UNEP 2018). Several developments were initiated to implement a waste management plan in the city. The construction of three transfer stations for the whole city is to provide better collection and segregation of waste, as shown in Fig. 1.4.

This waste management approach will lead to maximum resource utilization and increase waste treatment and disposal efficiency, leading to a circular economy's creation. Similarly, cities have a high population density and built-up regions, which provide very little vegetation in the urban region. Varanasi city is estimated to have less than 5% vegetation, which is relatively less than the 20% requirement for better living standards. The region's urban forest or green belts will minimize the urban heat island effect and air, noise, and soil pollution, increase microclimate regulation, etc. (Das et al. 2020; Hinge et al. 2018; Poonia et al. 2021a). Therefore, several plantation programs are presently initiated with the integration of the Indian smart cities mission and through several NGOs to increase the vegetation in the city (Goswami and Kumar 2020). The city is located on the west side of the Ganga

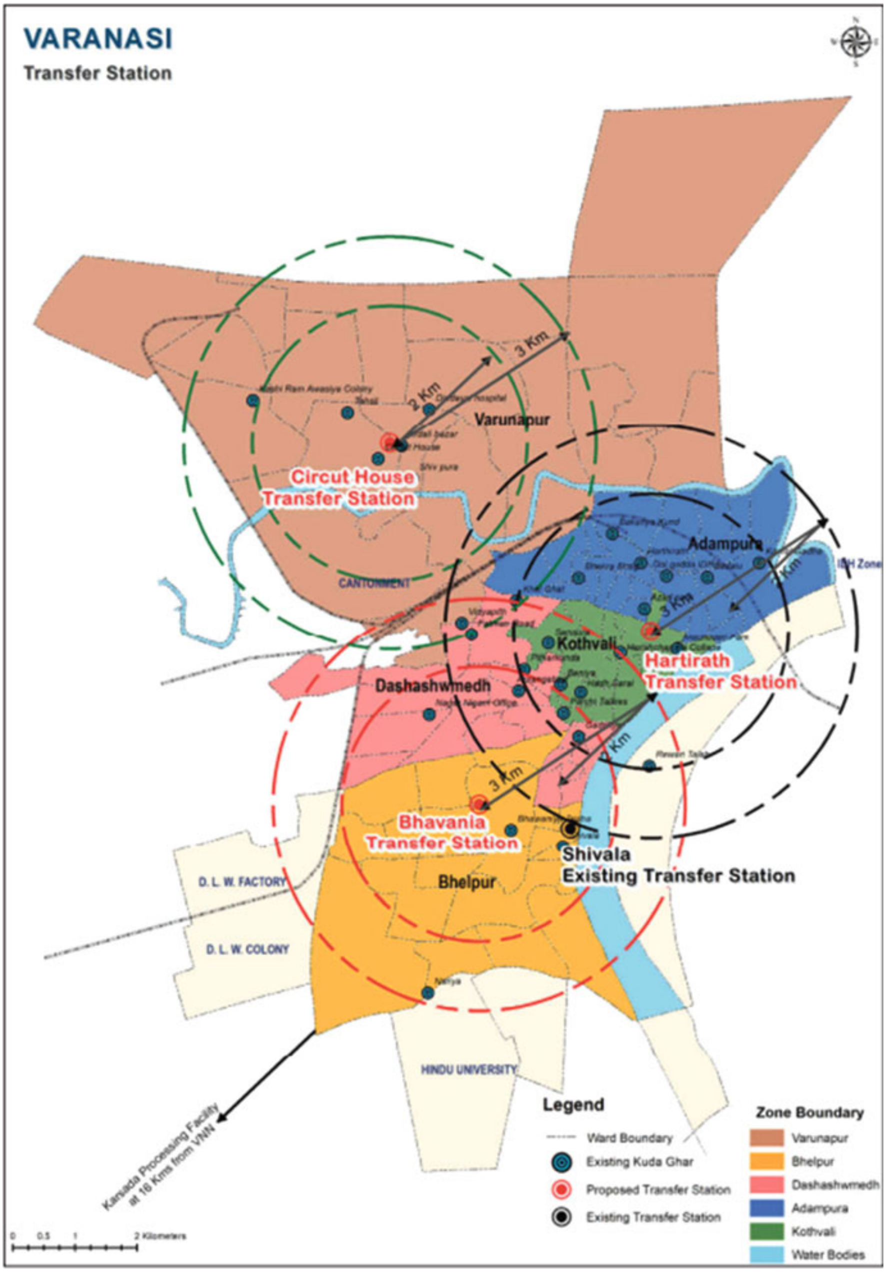

Fig. 1.4 Three proposed transfer stations and their buffer zones (UNEP 2018)

river. Due to the presence of the Ganga river, the city has religious significance, and many rituals occur across its banks over several ghats daily. Regular use and improper management will lead to the degradation of water quality, kunds, ghats, and its ecosystem across the city. “Kunds and talav” are small water bodies developed due to natural significance and will face threats of extinction due to the continuous degradation of water quality. One of the talavs, i.e., “Pushkar Talav,” faces severe threats due to the continuous dumping of solid and liquid waste. Thus, the rejuvenation of water bodies like “kunds and talav” and the restoration of community open spaces over ghats under several policy programs through local public involvement for improving the city’s living conditions have been carried out (Bansal et al. 2020; Praharaj 2014).

1.7.2 Wetland Ecological Restoration

These are classified as natural aquatic ecosystems that sustain unique biodiversity and play a vital part in climate change variability. This section discusses ecological restoration case studies for floodplain, coastal, and saline wetlands. Floodplain wetlands are highly ecologically sensitive ecosystems that provide structural and functional integrity to their surroundings. Wetlands occupy 6% of the land surface and consume 12% of the Earth’s carbon emissions. The floodplain wetland restoration presented by Sarkar et al. (2021) is in two districts of West Bengal, i.e., Mathura and Chandania in North 24 Parganas and Bhomra in Nadia. Ecological degradation, encroachment, and shrinkage are causing ecological value, biodiversity, and fish production to decline. It is estimated through spatiotemporal assessment of these three wetlands from 2000 to 2017 by GIS tools and field assessment. The significant outcomes of the evaluation provide that all the wetlands are alkaline, with a pH ranging from 7 to 9.5, with increased macrophyte invasion. All the wetlands shrinking at the effective rate, i.e., Bhomra at 57.68%, Mathura 37.20%, and Chandania 44.07%, respectively. Bhomra and Mathura wetlands are showing a decline in fish production. All these three wetlands have lost their connection with the parent river channel. Therefore, all these factors combined cause fisheries and diversity decline of wetlands. Probable threats to wetland diversity are water pressure (95%), sedimentation (85%), macrophyte invasion (70%), and the absence of river linkage (65%). Apart from these, climate change significantly impacts the wetlands due to variability in temperature, rainfall patterns, and extreme weather events. Thus, to make an ecological restoration plan for these wetlands, we have to monitor land use changes, aquatic weed invasion, industrial runoff, solid waste, and climatic variability in temperature and rainfall (Sarkar et al. 2021; Sharma and Goyal 2020).

Climate change is estimated to significantly impact 84% of coastal wetlands and 13% of saline wetlands due to a rise in the 1 m sea level. Sea level rise and storm surge will significantly impact the coastal wetlands (Sarkar et al. 2021; Wetlands International 2022). Here we discuss the case study of assessing the restoration practices for Ashtamudi lake Ramsar site coastal wetland in Kerala. Major threats to these wetlands are a decline in water quality, mangrove vegetation, and fisheries production. The risk of rising population, urbanization, over-exploitation of natural resources, and less environmental management is causing significant threats to wetlands (Goyal et al. 2022). Therefore, restoration economic feasibility is determined through the assessment of ecosystem services of wetlands in market values, determining the marginal willingness to pay (WTP) for the wetland attributes by the local population, and comparing WTP with restoration costs and benefits. Based on this assessment, it is determined that WTP for the restoration project is comparable to the average weekly wages of Kerala people in 2019. These cost evaluations can be minimized through financial support from the government in subsidies and NGOs, involvement of corporate industries through corporate social responsibility, etc. (Poonia et al. 2021b; Sinclair et al. 2021).

The Sambhar Salt Lake wetland is the playa wetland, i.e., shallow circular-shaped wetlands. The salinity in this wetland contributed due to the presence of ions like calcium, sodium, potassium, carbonates, bicarbonates, etc. This is declared a Ramsar site due to its importance in reference to migratory birds, as nearly 0.1 million flamingos come to these wetlands in winter annually. It is determined that due to illegal saltpan encroachment, wetlands' water level and quality are declining. This leads to a falling migratory bird population in the winter season. Thus, this site's restoration will require a complete stoppage of all salt mining in the region and providing systems for raising the water level in the wetland during fewer rainfall seasons (Goyal et al. 2018; Goyal and Ojha 2010, 2012; Naik and Sharma 2022).

1.7.3 Himalayan Ecological Restoration

These are classified as a natural terrestrial ecosystem that spread in several Asian nations, contains the highest mountain peaks, and is a source of many freshwater perennial rivers in the region. In this study, we discuss in detail the central Himalayan ecosystem restoration project carried out in the Uttarakhand region of India.

The Himalayan region (HR), with a geographical covering of 5.95 square km, stretches over 2500 km between the Indus and Brahmaputra River systems (Rautela et al. 2022). The HR physio-graphically stretches from the southern foothills (Siwaliks) to the northern Tibetan plateau. The three significant geographical groupings of the Himalayan regions are greater (Himadri), lesser (Himachal), and outer (Siwaliks), which are continuous throughout their length and are divided by critical geological fault lines. Excessive usage of resources, substantial land modification, and climate change affect mountain ecosystems across the Himalayas (Goswami et al. 2018; Yadav et al. 2021). Mountain ecosystems are essential for their natural beauty, as places of serenity and spiritual refuge, and for the ecosystem products and services, which they supply to almost half of the worldwide population. The Himalayan ecosystems are stressed by environmental factors such as climate fluctuation, altitude, and soil. The winter pastures are transferred to higher elevations

Fig. 1.5 Ecological restoration by mixed forest approach used by Pandey et al. (2017)

every year and gradually recede. Various ecological impacts in the Himalayan environment include the conservation of flora and fauna, restoration and recharging of groundwater and surface streams, land restoration and soil enrichment, mitigation of geohazards and forest fires, and so on.

A study was carried out by Pandey et al. (2017) in Kot Malla village, Rudraprayag district, Uttarakhand state of India. They studied ecological restoration and livelihood sustainability through mixed forestry in a man-made forest called JUNGALEE, made by Jagat Singh. Through the surge in demographic evolution of the anthropogenic presence, the mid-Himalayan region observes an increase in the pressure on forest ecosystems. The probable impacts due to this approach are shown in Fig. 1.5.

1.7.4 Ecological Impact

The forest offers many resources today that support many ecological services and functions. Because there are more than 75 different types of trees, plants, and herbs in this jungle, flora and animals may thrive there. A wide diversity of trees has accelerated carbon sequestration and filtered filthy air, allowing the entire world to breathe easier. A few years ago, the mountainside was wholly desolate and had a rocky surface. However, Jagat's strenuous efforts have covered the mountain with greenery. The forest's abundant vegetation has drawn local fauna. Wild cocks can be seen hanging out in the forest during the day and running through it, as well as birds chirping from the branches and jackals howling at night. A rich floral unit may naturally develop into a rich hydrological unit, as Jagat Singh Jungalee's hard work has demonstrated. A forest is thought of as a possible supply of water since it aids in processes like evapotranspiration, infiltration, and percolation that are either directly or indirectly connected to rainfall. The village of Kot Malla, which had previously had sparse vegetation and a bare stony surface insert, had almost all its streams dry up, and the groundwater table had been falling yearly. However, Jagat's persistence had recharged the streams surrounding his forest, and today the streams flow for 6–8 months of the year.

To restore soil and land, Jagat created terraces that sloped inward, allowing water to be retained for a while and also providing nutrients to early-planted tiny plants. Allowing the community animals to graze on his newly planted grasses makes their feces available and improves the soil's nutritional content. He also ensured that bushes degraded and that the ground eventually sprouted new life with compost, manure, and trash. This voyage is distinguished by a significant investment in soil improvement and land restoration. It was essential to plant a variety of trees and to reject monocropping to meet the nutrient demands of trees without misbalancing soil composition by excessive pressure on a few nutrients. Several pits with litter and decomposed materials were dug within the jungle to prepare compost and spread it throughout. The mid-Himalayan region is susceptible to geohazards like landslides, rockslides, rock falls, etc., because of their fragile ecosystem. A steep mountain slope with little to no vegetation is particularly vulnerable to landslides and rock falls, which can seriously harm people and property. Due to the variety of plants in Jagat's forest, his jungle has proven essential in preventing landslides. While a single tree variety may partially cause a landslide, many tree varieties have unique root networks intertwined together that hold soil in their way and prevent it from loosening up.

In contrast to mixed forests, mono-plantations typically have loose roots. The massive monoculture of pine trees, one of the leading causes of forest fires, has been significantly reduced by diversified forestry. Pine, an oily pine, burns fast, but the diversified characteristic of mixed forestry controls forest fires and makes them burn slowly. The mixed forest provides enough time to put out fires with human effort and can help to avoid serious risks.

1.7.5 Socioeconomic Impact

Jagat Singh was the one who originally planted the seeds of this forest, prioritizing socioeconomic issues over everything else. He created this forest using his traditional knowledge and scientific technologies that may be used in mixed forestry to address the local problems. For solving several ecological and socioeconomic issues, a global solution has emerged. Without assistance from any governmental or non-governmental organization, a local-level solution to the problems of fuel, feed, and water has been found. The inhabitants have easy access to the very nutritious fodder grasses produced in this area. Now, women in this region do not have to walk tens of kilometers with bundles of fodder on their backs through the dangerous, untamed forest. The Jagat's forest model has been applied throughout the neighborhood, where residents who previously had little interest in growing trees on their agricultural property willingly do so. The cultivation of feed and medicinal plants has begun. Although milk sales are still uncommon in this region, they may be promoted, and a source of income is created because fodder is now readily accessible and will help the local economy. People are economically prosperous and growing increasingly independent.

On the other hand, a study of ecological restoration in the higher-altitude ecosystems of the Himalayan region was conducted by Kuniyal et al. (2021). As these regions are affected by global warming and climate change activities, their rational management has been a matter of excessive concern (Trant et al. 2020). Many eco-services are provided by Himalayan alpine pastures, like carbon sequestration, water availability, biodiversity preservation, and food security. Several factors contribute to degradation, including the emergence of invasive species, poor management and development strategies, soil erosion, overgrazing, and the harvesting of medicinal plants. Therefore, these regions require both the preservation of natural vegetation and, when needed, their restoration. In addition to increasing native vegetation coverage and connectivity, eco-restoration also provides a range of socioeconomic benefits, as well as increasing ecosystem goods and services and promoting socioeconomic development. Still, there are no clear guidelines or orders for restoration initiatives in high-altitude degraded grasslands. To overcome this, Kuniyal et al. (2021) completed an on-site assessment of eco-restoration in high-elevation grassland ecosystems in Dayara alpine pasture (Bugyal) (3501 m), Uttarkashi district, Uttarakhand state of India. The case study tries to assess how the project will affect, among other things, the amount of grazing space available; the number of tourists in the area that can be supported; the general stability of soil erosion; the vegetation profile, mainly plant development; and the availability of soil nutrients. The ecosystem restoration evaluation involved computing the restoration success index while seeing 3 classes, including direct management measure (M), environmental desirability (E), and socioeconomic feasibility (SE), while considering 22 different factors. Both biotic and abiotic stresses were included in “M.”

In alpine regions, soil erosion was considered an abiotic pressure due to topographic fragility, while grazing and tourism were seen as biotic pressures. The degradation factors considered for the current investigation were discovered to be consistent with other Himalayan region impacted locations. According to reports, overgrazing has occurred in high-altitude meadows of Himalayan areas (Byers 2005; Cao et al. 2013; Khan et al. 2019; Nautiyal et al. 2004). In the instance of the Dayara Bugyal, it was discovered that local livestock populations were growing at a rate of 33 CU annually and were also thought to be the maximum at fault for overgrazing. After the rehabilitation phase, it was discovered that the migratory livestock unit was under control. Significant processes and deterioration characteristics in alpine ecosystems, such as soil cracking and plant disturbance, are significantly correlated with overgrazing. Ecosystem restoration will promote tourism and is predicted to be the primary source of future development in the Himalayan region. Several factors hinder sustainable tourism growth in Uttarakhand, including a lack of thoughtful plans, an outdated legislative framework, and an influx of visitors. Ecotourism may now be encouraged in the region, which may induce changes in the socioeconomic status of two nearby rural regions because of the low tourism activity in the area.

Homestays are recommended for visitors, tour guides are trained, and birdwatching is encouraged.

Consequently, eco-restoration techniques and their assessment model may have a role in making restoration practices more effective in the future. Other erodible high-altitude locations can also be restored with geo-coir mats and pirul (leaves of pine trees) check dams. Several of the recommendations made by the case study, including grazing pattern and herb establishment prevention, tourism management strategies, and other recommendations, are also applicable to other degraded pastures in the Indian Himalayan and other mountain alpine and subalpine ecosystems.

1.8 Policy Planning and Implementation for Ecological Restoration

The concept of ecological restoration has gained more attention on the public policy agenda. The implementation of ecological restoration typically takes place at the more minor levels. However, several political actors, both nationally and internationally, have declared they intend to engage in it (Corcoran 2010). Restoration has many benefits, one of which is that it helps combat global environmental change. Reforestation plans for carbon sequestration and wetland restoration for flood safety are two examples of climate protection and adaptation policies increasingly relying on restoration. In addition, it is used to protect the delivery of ecosystem services. The European Union, among others, emphasizes restoration as a strategy to achieve the 2020 biodiversity goals, also known as the Aichi goals. As an implementing tool for various resource-specific policies, such as the EU Water Framework Directive, which aims to restore surface water and groundwater to an "ecological good state" (ECD EC2000/60), it is also becoming increasingly crucial in agricultural policy frameworks and for enhancing the food security. Likewise, restoration is also used as a planning technique to compensate for disturbances to the aesthetic or cultural values of the landscape, often including elements of traditional methods and local culture (European Commission 2011, 2022).

Promoting ecological restoration activities, including vegetation, water, wildfires, wildlife, and recreation management, will be the responsibility of policymakers and related parties. Some examples of possible actions are monitoring the health of resources; maintaining, repairing, or improving terrestrial and marine ecosystems; or controlling human use. The following initiatives will be supported: the eradication of invasive species; restoration of grasslands and riparian areas to improve river basin functionality; practicing environmentally and ecologically friendly fire management; and prescribed burning and thinning of forests to reduce fuel load and increase forest heterogeneity and enhance the habitat of wildlife and fish. The focus will be on growth and building partnerships to build organizational capacity and utilize large-scale management contracts at the landscape level and improving and developing consulting work with tribal governments to leverage their conventional expertise in land management. Partnerships with stakeholders, communities, local authorities, volunteers, and residents will be prioritized to promote communication and reduce conflict when developing and implementing ecological restoration activities.

Restoration initiatives can be carried out in cities and rural regions, focusing on various ecological systems or landscapes. Such activities can take place at multiple scales, ranging from small-scale, vastly localized experiments and tentative trials to remediation of industrial or mining locations to what is referred to as "megaprojects," like the Kissimmee River restoration in Central Florida (Whalen et al. 2002), prairie restoration in the United States (Ryan 2005), or current water preservation practices in the Netherlands (Drenthen 2009). Projects may also entail the purposeful restoration of desired species that have been eradicated or rendered extinct locally due to pressures from other development pressures and changes in land usage. For instance, wolf reintroduction programs have generated controversy both in Scandinavia and North America, not least because of local worries about the possibility of livestock loss (Gross 2008). Another project priority is river restoration, which may involve the removal of dams, re-routing and re-bouldering of rivers (as was done, for instance, in Sweden; see Lejon et al. 2009), "daylighting" of culverted rivers, or biological restoration of city riverbanks (e.g., in the United Kingdom; see Eden and Tunstall 2006).

1.8.1 Policy Planning and Implementation for Ecological Restoration in India

The natural resources and ecosystems have been protected and conserved in India by various acts and interventions held by the government. On the other hand, local conservation initiatives have been successful thanks to grassroots community movements such as the Chipko movement in Uttarakhand, Silent Valley Movement in Kerala, etc. However, India's main ecological issues include 96 million hectares of degraded land, an unparalleled decline in biodiversity, and catastrophic weather occurrences. Through greenhouse gas emissions and biodiversity decline, this ecosystem degradation accelerates the degradation of natural ecosystems (Bellard et al. 2012). India can significantly contribute through its policy framework to attaining socioeconomic and environmental sustainability by viewing restoration and conservation as the primary objective and long-term funding (Fleischman et al. 2020). For instance, the MGNREGA program helps jobless migrant workers and other rural people find employment while working on damaged land to establish different forests, wetlands, botanical gardens, and economic models through environmental restoration. Rural regions can promote ecological and rural tourism by creating new ecosystems based on biodiversity on degraded soil. The innovation in biodiversity-based ecosystems can promote ecological and rural tourism on degraded soils in rural regions. This will provide local communities with new small-business options and advance conservation via the care of these individuals. It is anticipated that India's rural or nature tourist industries will expand in the post-COVID future (Roy et al. 2020). Furthermore, using community and wastelands accessible to various regional and nationwide departments, like the forest, revenue, and railway departments, to progress, for example, specialized biomass production facilities can help with carbon sequestration and bioenergy and benefit laborers and other stakeholders financially.

1.9 Future Challenges

The futuristic tasks associated with ecological restoration across different regions worldwide can be classified into social, ecological, economic, and political categories. Here we discuss specific challenges in detail as follows:

1.9.1 Ecological Challenges

In a recent assessment, the Space Applications Centre (SAC) of the Indian Space Research Organisation (ISRO) found that 96.3 Mha of land, or 29.32% of the country's total geographic area, has been degraded or turned into desert. However, deforestation (29.3 Mha), wind erosion (18.23 Mha), and salinity are the leading causes of ecosystem degradation (3.67 Mha). According to Díaz et al. (2006), habitat loss is a significant cause of the decline in biodiversity, food insecurity, climate variability, and unemployment in rural regions. Protected or not, most of India's forest ecosystems are degraded and suffer from biodiversity decline caused by biological encroachment, anthropogenic influence, and excessive logging (Bawa et al. 2020; Pandey 2008). India has contributed 6255 animal and 2235 plant species to the IUCN's revised red list (IUCN 2020). One hundred fifty-nine vulnerable, 197 endangered, and 93 severely endangered floral species are among the 449 that have been classified as threatened, with varying conservation statuses. Five plant species in all have already vanished. A total of 722 species of animals, including 398 vulnerable, 230 endangered, and 94 severely endangered species, face threats (see IUCN 2020). Ecosystem degradation has sped up the rate at which wild species disappear from the environment, in addition to tiny population sizes and restricted ranges. The extinction of different indigenous species in the Himalayas (a biodiversity hotspot) has been seriously threatened by habitat degradation for various development schemes (Pandit 2020).

1.9.2 Social Challenges

India has historically struggled to include rural residents in development efforts because they lack access to necessities like health care, education, and transportation to urban regions (Bhattacharya 2020). The most difficult facing India in its severe economic downturn is delivering livelihood options for mobile workforces who come back to their areas in state-wide lockdown (Bhagat et al. 2020). According to a survey on employment in rural regions of India, more than 25 million families demanded effort in August 2020, which is a 66% increase over the demand levels in August 2019 (Ministry of Law and Justice 2005; MoEFCC 2022). Maximum time, these minor farmers work as laborers in the fields of progressive farmers or adjacent towns since they lack land (Singh et al. 2020). But because of land use policies (1950–1972), these backward, poorer, and minor farmers have been awarded a tiny plot of typically deteriorated or fertile land (Nielsen and Oskarsson 2016). Therefore, they rely entirely on the government's nutritional aid distribution policies or definite work initiatives, especially women and the elderly.

1.9.3 Political Challenges

Politicians believe pledges, planning, and planting will solve all problems (Fleischman et al. 2020). This is being implemented as a political ruse in several states of India, where in a day, he plants millions or 500 million seedlings in a year (Adlakha 2022). These plantation activities are essential to the country's efforts to sequester carbon. However, restoring degraded ecosystems by increasing vegetation cover instead of following conventional thinking will accelerate biodiversity loss and lead to near-term deterioration. It may deteriorate further in the coming time (Holl and Brancalion 2020). The IPCC Panel has cautioned against creating more than a few million square kilometers of a single species-based landscape, even for bioenergy production (Stokstad 2019). This leads to easier land use changes for ecosystem services (Dong et al. 2020). Recent scientific advances in restoration and conservation indicate that floral diversity is the goal and should be seen as the main force behind restoration plans (Palmer et al. 2016). Restoring a destroyed ecosystem or creating a new ecosystem in a degraded area takes time and effort. As defined by restoration experts, conventional ecological concepts and practices should be used to conserve biodiversity and restore degraded ecosystems (IUCN 2018). We cannot combat land degradation and protect biodiversity unless the actions of policymakers are grounded in the restoration science and the functioning of ecosystems (Palmer et al. 2016).

1.9.4 Opportunities

Restoring the ecosystem could be a practical, affordable, and lasting solution to India's ecological problems. In addition, it provides an opportunity for economies to recover from the COVID-19 epidemic and for humanity to be protected from expected future more deadly pandemics (Tollefson 2020). The United Nations Environment Programme calculates that for every $1 invested in ecosystem restoration, $9 is supported in a range of ecosystem services. India has great potential to make restoration and conservation programs one of its top priorities and incorporate these activities into its current socioeconomic policies. In addition, India's degraded land represents approximately 27.5% of the world's degraded land area. The United Nations Decade of Ecosystem Restoration could greatly benefit from India's improved access to foreign funding for biodiversity and ecosystem restoration projects.

1.10 Conclusion

The ecological restoration approach provides the path for restoring the site to its pre-disturbed conditions, which usually depends on several climatic, ecological, and anthropogenic factors. Ideally, each restoration plan can never restore the site's ecosystem in its initial state with the same species assemblage. Thus, restoration plans for low to moderately degraded sites will provide maximum benefits with minimum costs rather than a wholly degraded ecosystem. Ecological restorations act as supplementary paths rather than thinking as a complete substitute for the conservation approach. It has high uncertainty in providing its outcomes which need continuous monitoring and management throughout its implementation with the integration of knowledge, adaptive restoration, ecological theory, etc. However, it has the enormous ability to provide the foundational changes in our surrounding natural environment (Fischer et al. 2021; Vaughn et al. 2010). The United Nations' strategy for ecosystem restoration involves leadership and a shift in the behaviors toward restoration, requiring involvement from social, political, corporate, and spiritual leaders. Their combined action will help to involve a vast population through social responsibility, faith belief, and financial benefits by governments and corporates (UNEP 2022a). Ecological restoration for each site in this decade from 2021 to 2030 may allow us to prevent the severity of climate change and extreme weather events and achieve sustainable goals for future generations (United Nations 2022). The severity and impact on the population due to ecological degradation are variable with the type of ecosystem. For example, the urban ecosystems are observing severe changes due to an increase in population, and its impact is observed instantly by humans, while wetlands are shrinking annually, which impacts the migratory bird's population and fish production for local people. Thus, species consideration for restoration is the critical point for a restoration plan to provide maximum benefits for highly impacted species populations. Therefore, through restoration principles, guidelines, and maximum involvement of stakeholders, we can achieve maximum ecological and sustainable aims during the decade of ecosystem restoration (UNEP 2022c).

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