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# **Breathing Life into Nature Lost Lands: Ecological Restoration of Degraded Ecosystems**

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## ABSTRACT

Ecosystem degradation is the deterioration of the environment through depletion of resources which includes all the biotic and abiotic element that form our surrounding that is air, water, soil, pant animals, and all other living and non-living elements of the planet of earth. The major factor of environmental degradation is human (modern urbanization, industrialization, overpopulation growth, deforestation, etc.) and natural (flood, typhoons, droughts, rising temperatures, fires, etc.) cause. Today, ecological restoration of ecosystems is taken seriously as mitigations procedure and implementation have taken effect globally. Not to forget that there are still unresolved issues of ecological restoration of ecosystems globally and this further strengthening the difficulty in achieving successes in restoration of the ecosystem. This paper discusses the meaning of ecological restoration, challenges, merit, global governance policies and successes of ecological restoration of ecosystem degradation. The study found out the key principles and theories in restoration ecology to include: competition theory. food web theory, facilitation theory, hierarchical organization through, facilitation cascades, and metacommunity theory. It is hereby recommended that, there is a need to adopt a landscape approach thereby integrating restoration efforts into broader land-use planning, considering ecological, social, and economic factors.

**Keywords:** Ecological restoration, ecosystem degradation, environmental degradation, urbanization, industrialization, overpopulation, growth, deforestation, global governance.

## INTRODUCTION

Ecological restoration is seen as a distinct process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed (Society for Ecological Restoration International Science and Policy Working Group, 2004). Ecological restoration is required when the degraded ecosystem is unable to self-repair. The main aim of ecological restoration is to reinstate ecological processes and functions that are resilient, adaptable to change, and deliver important ecosystem services.

Ecosystem contributes to the maintenance of biodiversity and regional eco-balance; thus, the restoration of degraded forest ecosystem is crucial for regional sustainable development. On the other hand, we are all in the benefits of ecological restoration against the background of resource exhausted and increasing global change (Alcoze et al. 2000). Ecological restoration influences the environment through regulating the global carbon dynamic and biogeochemical cycling (Stone 2009). In view of this, ecological restoration becomes a global issue. Bowers, the chairman of the International Society for Ecological Restoration, proposed that ecological restoration in the changing world is to restore the world's future (Peng and Hou 2007).

The term degradation refers to deviations from the typical or ideal condition of an intact ecosystem. So, any action or process that eliminates or reduces the viability of ecosystem processes and consequently biodiversity, is generally referred to as ecosystem degradation (Dunster J & Dunster K, 1996).

An ecosystem driver is any natural or anthropogenic factor that directly or indirectly alters an ecosystem. Natural drivers such as earthquake, wildfires and volcanoes have a large but one way impact on ecosystem services since they do not receive the feedback from the ecological changes they cause.

Contrarily, anthropogenic drivers may produce a variety of changes to ecosystems, but because people live in or near the ecosystems they influence, they receive significant feedback from ecosystems (Muller K & Straub P, 2016). Over time, anthropogenic and natural drivers interact. For instance, local species extinctions may initially be the result of anthropogenic factors, but they may make an ecosystem more vulnerable to degradation in the face of significant catastrophes brought on by natural causes (Kinnaird MF & O'Brien TG, 1998).

### Statement of the Problem

Degraded ecosystems are widespread and escalating, resulting in unprecedented biodiversity loss, exacerbated climate change, and increasingly negative impacts on human livelihoods, particularly in vulnerable communities. Despite growing recognition of the importance of ecological restoration, efforts to revive degraded ecosystems often face significant challenges in achieving lasting ecological recovery. Key gaps remain in understanding the most effective restoration strategies, the complex interplay of

factors influencing restoration success, and how to scale up efforts to restore ecosystem health, resilience, and functionality. Without addressing these knowledge gaps, restoration initiatives risk failing to deliver meaningful ecological and socioeconomic benefits, undermining global efforts to conserve biodiversity and mitigate climate change.

### **Aim and Objectives of the Study**

The main aim of this study is to understand how ecological restoration of ecosystems efforts strives to restore the benefits that humans derive from ecosystems, such as clean water, fertile soil, pollination, climate regulation, and carbon sequestration. Specific objectives include:

1. Examine the key principles and theories in restoration ecology.
2. Investigate the drivers of ecosystem degradation.
3. Explore the restoration strategies and techniques of ecosystem degradation.
4. Assess various case studies from different ecosystems.
5. Examine challenges and success factors in ecological restoration.

### **Research Questions**

The following research questions guided the study:

1. What are the key principles and theories in restoration ecology?
2. What are the drives of ecosystem degradation?
3. What are the restoration strategies and techniques of ecosystem degradation?
4. What lessons can be learned from different case studies of ecosystem?
5. What are the challenges and success factors in ecological restoration?

### **Significance of the Study**

This study is significant because it aims to:

1. Inform effective conservation strategies for tropical ecosystems, which are critical for global biodiversity and climate regulation.
2. Guide policymakers and practitioners in designing and implementing successful reforestation projects.
3. Enhance understanding of the ecological processes driving biodiversity recovery in tropical ecosystems.
4. Support the achievement of international targets like the UN Sustainable Development Goals and the Convention on Biological Diversity.

### **Scope and Limitations of the Study**

Scope

The study will:

1. Focus on the key principles and theories in restoration ecology.
2. Evaluate the drivers of ecosystem degradation.
3. Consider the restoration strategies and techniques of ecosystem degradation.
4. Cover case studies from different ecosystems.
5. Success factors and challenges in ecological restoration.

Limitations:

1. The study may be limited by data availability and variability in reforestation project methodologies.
2. Results may not be generalizable to all tropical ecosystems due to regional differences.
3. The study focuses on biodiversity aspects; socioeconomic aspects of reforestation are not the primary focus.

### **Literature Review**

#### **Key Principles and Theories in Restoration Ecology**

Ecosystem restoration has been presented as an “acid test” for ecology, and restoration ecologists have been advocating for practices to be grounded in natural history and ecological theory for decades (Bradshaw, A.D, 1987). For example, restoration of degraded plant communities has long been bolstered

by successional theory and community assembly theory-based predictions on the progression and trajectory of restored communities, and by innovations in seed-mix design informed by coexistence theory (Palmer, M.A. 2016).

The application of other individual ecological theories has greatly improved restoration scale and success. Clear examples are facilitation theory in aquatic restoration, alternate stable state theory in herbaceous plant restoration, and landscape ecology theory for animal-based habitat restoration. Yet, meta-analysis shows that succession theory and community assembly theory continue to dominate in those limited circumstances where restoration practices have incorporated theory (Wainwright, C.E., et al, 2018). There are some key ecological restoration theories that will bolster restoration of degraded ecosystem;

- 1. Competition Theory:** Manipulating both the strength of competition (i.e., the process through which species vie for limited resources) and the likelihood of priority effects (i.e., when competitive outcomes depend on the timing of arrivals) can be a key strategy to bypass competitive hierarchies that would otherwise suppress establishment restoration-targeted basal species, such as trees or corals. Competition influences how communities form and function in all ecosystems and managing key competitive species interactions, like removing invasive or native competitors, has proven critical for promoting targeted species establishment. Thus, management to prevent early-arriving species from depleting resources and to deter invaders with similar niches (i.e., niche preemption or niche modification) can bolster ecological restorations (Shea, K., and Chesson, P. 2002).
- 2. Food Web Theory:** Because the connectivity, diversity, and evenness of local producers, consumers, and predators (i.e., food web structure) control wide-reaching processes in all ecosystems, incorporating food web theory into restoration will increase early success and stability in many habitats. All ecosystems have food webs, and the structure of these food webs have predictable bottom-up and top-down consequences for ecosystems. From the bottom-up, changes to the identity, diversity, and abundance of primary producers at the base of food webs control the density, diversity, connectivity, and/or trophic position of all other organisms in the ecosystem. In addition, both the number of trophic levels in a food web and overall biodiversity are positively affected by the continuous spatial extent of foundation species. Food web theory can be included in the planning stages of all restoration endeavors systematically (Borst, A.C.W., et al, 2018).
- 3. Facilitation Theory:** Facilitation theory-informed restoration can amplify beneficial interactions to improve establishment success and stability in stressful and high-disturbance habitats, a common ecosystem state for restorations. Positive interactions like facilitation or facultative and obligate mutualisms are pervasive in stressful habitats like alpine and prairie grasslands 48–50, the rocky intertidal 51,52 and salt marshes 53,54. Indeed, the stress gradient hypothesis 55 predicts that stress amelioration by intra-or inter-specific neighbors is more common and more important in physically and biologically harsh habitats. Additionally, associational defenses among species are more common and important in habitats with high consumer pressure. The success of primary and secondary pioneer species in stressful habitats depends on either facilitators (e.g., microbes or habitat ameliorating neighbors) or on consumers (e.g., apex predator consumer control) (Harris, J., 2009).
- 4. Hierarchical Organization Through Facilitation Cascades:** As an expansion of facilitation theory, the concept of hierarchical organization through facilitation cascades predicts greater gains in restoration of foundation species, and in related diversity and function, if secondary foundation species are incorporated into restoration plans. By combining facilitation, priority effects, and food web theory to predict patterns of biodiversity in harsh environments (Altieri, A.H., et al, 2007), this integrated approach posits that physically-tolerant primary foundation species (e.g., salt marsh cordgrass, trees) initiate a hierarchical community structure by ameliorating biotic and abiotic stress upon establishment, thereby setting the stage for establishment of other species and community interactions. By increasing biodiversity and spatial

resource heterogeneity (see: Facilitation), they also have wider-reaching, larger-scale positive effects by creating the conditions that promote secondary foundation species establishment (Angelini, C., et al, 2011).

- 5. Metacommunity Theory:** For restoration of highly fragmented and/or naturally patchy habitats, metacommunity theory informs how dispersal dynamics will affect the initial establishment and long-term persistence of restored populations. Metacommunity theory explains trajectories of communities by incorporating both the dispersal limitation and spatial processes that control extinctions and recolonization across local, regional, and global scales (Leibold, M.A., et al, 2017). According to this theory, connections between local communities by dispersal can play a fundamental role in species population establishment and persistence, including the maintenance of within-and across-patch genetic diversity which may enhance resilience to disturbance or environmental fluctuations. Restoration projects could incorporate metacommunity theory in their plans to simultaneously achieve recovery of populations that are resilient to disturbance and resistant to environmental changes across landscapes (Driscoll, D.A., et al, 2014).

### Drivers of Ecosystem Degradation

An ecosystem driver is any natural or anthropogenic factor that directly or indirectly alters an ecosystem. Natural drivers such as earthquake, wildfires and volcanoes have a large but one way impact on ecosystem services since they do not receive the feedback from the ecological changes they cause. Contrarily, anthropogenic drivers may produce a variety of changes to ecosystems, but because people live in or near the ecosystems they influence, they receive significant feedback from ecosystems (Muller K & Straub P, 2016). Over time, anthropogenic and natural drivers interact. For instance, local species extinctions may initially be the result of anthropogenic factors, but they may make an ecosystem more vulnerable to degradation in the face of significant catastrophes brought on by natural causes (Kinnaird MF & O'Brien TG, 1998).

**Natural:** Natural disasters have profound impacts on ecosystems. Natural forces such as avalanches, earthquakes, wildfires, erosion and volcanoes can completely destroy local animal and plant populations to the point where they are unable to thrive in certain locations. This may happen physically as a result of a singular calamity, or it may result in long term asset degradation due to an introduction of invasive foreign species into the ecosystem (Fraver S., et al, 2017).

- 1. Erosion:** In general, soil erosion refers to the depletion of soil caused by a combination of natural (such as water, wind and snow) and man- made (such as intensive and extensive agriculture) forces. Erosion can be categorized as either a natural or an accelerated process, depending on its severity. It negatively affects agricultural output, source water quality and the health of ecosystems in both the aquatic and terrestrial environments (Fayas CM., et al, 2019). Erosion impacts ecosystem in following ways such as loss of crop land, clogged and polluted streams, increased flooding and reef water quality etc. (Hobbs RJ & Huenneke LF., 1992).
- 2. Earthquake:** One of the natural calamities that degrades ecosystems is an earthquake, a major natural disturbance. Due to increased mortality and altered habitat quality, such disturbances may seriously jeopardize the survival and competition of plant species (Hobbs RJ & Huenneke LF., 1992).
- 3. Avalanche:** When a massive area, or slab, of snow descends the mountain with high force and speed, it causes an avalanche. An avalanche is a powerfully destructive natural phenomenon that kills plants, animals, insects and tragically, occasionally people as it flattens trees on the hillside (Muller K & Straub P., 2016).
- 4. Wildfires:** Forest fires have many implications on ecosystems. At the global level, these fires are a significant source of carbon emissions, contributing to global warming which could result in biodiversity changes. At the regional and local level, they lead to change in biomass stocks, alter the hydrological cycle leaving negative impacts on marine systems such as coral reefs, as well as the functioning of plant and animal species (Kinnaird MF & O'Brien TG., 1998).

**Anthropogenic:** Human activities endanger the ecosystem by causing habitat loss, biodiversity loss and the spread of exotic species.

1. **Pollution:** Emissions of both Sulphur dioxide and nitrogen oxides deposit in water, on vegetation and on soils as “acid rain”, thereby increasing their acidity with adverse effects on flora and fauna. Increased ground-level ozone also causes damage to cell membranes on plants inhibiting key processes required for their growth and development (Davies SJ & Unam L., 1997).
2. **Climate change:** The ecosystem continues to be destroyed by in large part as a result of climate change. Increased temperatures, rising sea levels, and ocean acidification brought on by global warming have upset the natural balance of ecosystems (IPCC & Settele J, et al, 2014).
3. **Resource exploitation:** Fossil fuels, forests, nutrient rich soil, and water are just a few examples of the abundant natural resources found in many ecosystems. Excessive resource exploitation practices like deforestation and mining damage ecosystems (Zeilhofer P., et al, 2014).
4. **Population decline/overpopulation:** Animals play an important role in population management and as food sources. Due to overfishing and killing, many animal populations are under decline. Animals are frequently hunted for their expensive skins, feathers, horns and meat. On the other hand, rapid population growth puts pressure on natural resources, which results in the degradation of our environment. Mortality rate has gone down due to better medical facilities, which has resulted in an increased lifespan (Dixo M., et al 2009).
5. **Land use change/land degradation:** Land degradation is a process in which the value of the biophysical environment is affected by direct or indirect human-induced processes including anthropogenic climate change (Shao X, et al, 2017).
6. **Urbanization:** Urbanization is a significant anthropogenic factor affecting urban ecosystems as it can influence interactions among the atmosphere, hydrosphere, and biosphere. Several ecological problems have emerged with rapid urbanization, including:
  - Global warming.
  - Contamination of soil, air and water.
  - Biodiversity loss (Alberti M., 2005).
7. **Industrialization:** Developmental activities such as construction of roads, highways, bridges and industries must be carried out in order to keep up the pace of economic growth but various adverse effects in the form of socio-economic and cultural disruption are faced during this process. People and wildlife have to go through the complete resocialization and adjustment process in an unfamiliar environment (Bhandari D & Garg R.K., 2015).

## **Restoration Strategies and Techniques of Ecosystem Degradation**

### **Passive vs. Active Restoration**

Ecosystem restoration encompasses a diverse continuum of restoration endeavors and aspirations, spanning from mitigating societal impacts to rectifying environmental degradation (remediation), rejuvenating ecosystem functionality (rehabilitation), and ultimately reinstating native ecosystems in their entirety (ecological restoration) (Gann et al., 2019). Ecosystem restoration represents a pragmatic strategy for reversing the detrimental effects of ecosystem degradation.

Restoration of damaged sites commonly involves active interventions to initiate, accelerate, or direct recovery of a damaged ecosystem towards a stage that is structurally and functionally similar to that which previously occurred. However, restoration ecologists continue to debate whether damaged ecosystems can recover spontaneously in a reasonable time without external supplementary intervention (van Andel & Aronson, 2012).

### **Passive Restoration**

Passive or spontaneous restoration depends solely on natural processes such as colonization and regeneration to produce a desired result, that is, to approach a restoration target. Passive restoration forms one end of a continuum of restoration activities and is in unambiguous contrast to technical reclamation approaches at the other extreme of this continuum. Technical strategies are normally applied to heavily

disturbed sites. They include recontouring landforms, importing topsoil and planting or sowing all or most target species etc. (Chazdon, 2014). Globally, passive restoration is more widespread than active restoration, and has been found to be more successful than passive restoration in restoring habitat structure and biodiversity in tropical forest habitats (Crouzeilles et al., 2017).

### **Active Restoration**

Active ecological interventions are designed to drive succession and increase the pace of restoration, often promoting yields of a limited number of ecosystem services (e.g. timber production). Examples of the most active restoration methods include: preparing land, producing saplings in nurseries, planting and follow-up care for saplings, manually restoring meanders in river systems or transplanting cultivated corals to degraded reefs.

Such active restoration measures are often beneficial in highly degraded ecosystems, particularly those that have entered alternative stable states (e.g. where soils have been compacted, hard pans have formed, topsoil has been lost or invasive species dominate) (Holl and Aide, 2011).

### **Restoration Techniques**

**Invasive Species Removal:** Invasive species removal focuses on controlling or eradicating non-native plants and animals that negatively impact native ecosystems. Non-native species refers to any plants, animals and microorganisms that have been accidentally or deliberately introduced into areas beyond their normal range (van Andel & Aronson, 2012). For example, below are the ways to control/ remove invasive plants;

- PULL invasive seedlings and small or shallow-rooted plants when soil is moist. Dig out larger plants, including the root systems. Use a forked spade or weed wrench for trees or shrubs.
- DEADHEAD to prevent spread of seeds of invasive plants. Cut off seeds or fruits before they ripen. Bag, and burn or send to a landfill.
- MOW or CUTTING at least 4 times a season to deplete plants' store of nutrients and carbohydrates, reduce seed formation, and kill or minimize spread of plants. If necessary, repeat each year.
- CONTROLLED BURNING during the spring, repeated over several years, allows native vegetation to compete more effectively with the invasive species. This requires a permit. Spot treatment with glyphosate in late fall can be used to make this method more effective.
- Use a CORN-BASED PRE-EMERGENCE HERBICIDE on annual weeds. This product is also an organic fertilizer, i.e., it can stimulate growth of existing plants, including weeds, so it is appropriate for lawns and gardens but may not be appropriate in woodlands.
- In lawns, SPOT TREAT with BROAD-LEAF WEEDKILLER. Good lawn-care practices (test soil; use lime and fertilizer only when soil test shows a need; mow high and frequently; leave clippings on lawn) reduce weed infestations.
- CUT DOWN the tree. Grind out the stump, or clip off re-growth.
- GIRDLE tree: cut through the bark and growing layer (cambium) all around the trunk, about 6" above the ground. Girdling is most effective in spring when the sap is rising, and from middle to late summer when the tree is sending down food to the roots. Clip off sucker sprouts.
- FRILL: Using a machete, hatchet or similar device, hack scars (several holes in larger trees) downward into the cambium layer, and squirt in glyphosate (or triclopyr if recommended in text above). Follow label directions for Injection and Frill Applications. This is most effective from middle to late summer. Clip off any sucker sprouts or treat with glyphosate.
- CUT STEM / CUT STUMP WITH GLYPHOSATE (or triclopyr if specified above). Follow label directions for Cut Stump Application. Clip off sucker sprouts or paint with glyphosate. See Note on Herbicides.
- FOLIAR SPRAY WITH GLYPHOSATE herbicide (see Note on Herbicides). Use a backpack or garden sprayer or mist blower, following label directions. Avoid overspray and/or dripping onto non-target plants, because glyphosate kills most plants except moss (Gann et al., 2019).

### **Forest restoration**

Process of establishing a forest and its benefits in a place where a forest formation naturally occurred in the past. Practitioners frequently prioritize the recovery of ecosystem services for benefiting people and nature. Restoring forest ecosystems and effectively conserving remnants is vital to face the global outbreak of deforestation, forest degradation, climate change, social injustice, and the biodiversity crisis. Besides scaling up forest restoration, setting reasonable goals can guide to more successful plantings that provide more ecosystem services that deliver different benefits and potential trade-offs. Forest restoration is urgent for conserving and recovering biodiversity. Human-caused deforestation and forest degradation have devastated our world, leading entire ecosystems to tipping points. Increasing forest cover in originally forested ecosystems is paramount (Shao X, et al, 2017).

**Reforestation:** Planned establishment of a forest on an area that was previously naturally forested; the conditions for planting a new forest do not need to seek for replicating the previous one. It can be composed of native or exotic species, combining one or more species (van Andel & Aronson, 2012).

### **Forest restoration methods include;**

- 1. Natural Regeneration:** Whether it is possible to use natural regeneration, assisted or not, it is the best choice for its low cost and no need for complex planning and deep ecological knowledge. In this sense, the area's first actions to be promoted aim to activate its full potential for ecological recovery. Isolating the area to avoid animal grazing and trampling and controlling competition, combined with the removal of other degradation factors, such as soil erosion, fire, and herbivory, enable the (re)colonization of native species. In conditions where the target area has no serious degradation factors, it is possible to use a non-assisted passive regeneration, the lowest-cost forest restoration method (Alberti M., 2005)..
- 2. Assisted Natural Restoration:** This intermediary method is based on directly assisting some of the regenerating seedlings and planting additional trees in empty spaces. In such cases, it is possible to adopt techniques to drive good-quality natural regeneration. Some techniques are used for this end, such as nucleation and the transplant of the soil seed bank, described in the 'techniques' session (Gann et al., 2019)..
- 3. Active Forest Restoration:** Sometimes, it is impossible to assist natural regeneration in the target area due to the loss of natural resilience. In that case, the alternative is to introduce an initial tree community, creating the biophysical conditions required to start the ecological succession. In addition, active restoration can benefit from agricultural species to initiate the process by planting agroforestry systems (Alberti M., 2005).

### **Role of Native Species and Biodiversity Recovery**

Ecosystem restoration heavily relies on the reintroduction and flourishing of native species to recover biodiversity and ecosystem functions. Native species, adapted to local conditions, are crucial for restoring genetic diversity, which enhances ecosystem resilience against disturbances like climate change and disease. This, in turn, supports the provision of essential ecosystem services (Raymakers, C. 2006). The role of native species in ecosystem restoration include:

- 1. Genetic Diversity:** Native species possess unique genetic traits that enable them to thrive in specific environments and adapt to changing conditions. Reintroducing them helps restore lost genetic diversity, making ecosystems more resilient to future threats (Alberti M., 2005).
- 2. Ecosystem Function:** Native species play vital roles in nutrient cycling, pollination, water purification, and other essential ecosystem processes. Their presence is critical for maintaining a healthy and functioning ecosystem (Holl and Aide, 2011).
- 3. Biodiversity Conservation:** Restoration efforts that focus on native species contribute to the conservation of biodiversity, including rare and endangered species that may depend on specific habitats and ecological conditions (Hancock L. 2022).
- 4. Ecosystem Stability:** A diverse community of native species is more likely to be stable and resilient to disturbances, as different species can fill similar ecological roles and adapt to changing conditions.

### **Biodiversity Recovery:**

1. **Species Richness and Composition:** Restoration aims to increase the variety and abundance of native species, leading to a more diverse and complex ecosystem (Hancock L. 2022).
2. **Habitat Restoration:** Creating or restoring diverse habitats through the use of native plants and other species is essential for supporting a wide range of life forms (Rodrigues, R. R., 2009).
3. **Ecosystem Services:** Biodiversity recovery enhances the provision of vital ecosystem services, such as clean water, pollination, and climate regulation, which benefit both the environment and human populations (Pereira, H. M., & Navarro, L. M. 2015).

### **Case Studies from Different Ecosystems**

#### **Case 1: The Great Barrier Reef: A Race Against Time**

The Great Barrier Reef, a UNESCO World Heritage site, is the world's largest coral reef system and one of the most biodiverse ecosystems on the planet. However, it has faced severe threats from climate change, pollution, and overfishing, leading to widespread coral bleaching and the decline of marine life. The restoration of the Great Barrier Reef is a complex and ongoing challenge that requires a multifaceted approach (UNDRR. 2024).

#### **Efforts to restore the reef have focused on several key strategies:**

1. **Pollution Reduction:** One of the primary sources of pollution affecting the reef is agricultural runoff, which carries nutrients and sediments that damage coral. Initiatives to reduce this pollution include improving land management practices and promoting sustainable agriculture (Vignola, R., et al. 2015).
2. **Coral Restoration:** Scientists are developing innovative techniques to restore damaged coral reefs, such as coral gardening and the use of heat-resistant coral strains. These methods involve growing coral in nurseries and then transplanting them onto the reef, where they can help regenerate damaged areas (Pangilinan M.J.M. et al. 2015).
3. **Marine Protected Areas:** Expanding and enforcing marine protected areas around the reef is crucial for reducing the impact of overfishing and allowing marine populations to recover.

While these efforts are still in the early stages, there have been encouraging signs of recovery in certain areas of the reef. However, the long-term success of these initiatives depends on global efforts to mitigate climate change, which remains the most significant threat to the reef's future (Harris, J. (2009).

#### **Case 2: Urban Ecosystem Renewal: The Bronx River in New York City**

Urban ecosystems are often overlooked in discussions of environmental restoration, yet they are critically important for the health and well-being of city residents. The Bronx River, which flows through one of New York City's most densely populated boroughs, was once a symbol of urban decay. Polluted by industrial waste and neglected for decades, the river had become a hazardous eyesore (Aronson et al. 2010).

The restoration of the Bronx River is a powerful example of how community engagement and government support can transform an urban environment. Local organizations, including the Bronx River Alliance, played a key role in mobilizing residents and securing funding for cleanup efforts. These initiatives included removing pollutants, restoring native vegetation, and creating green spaces along the riverbanks (Pangilinan M.J.M. et al. 2015).

One of the most significant achievements of the Bronx River restoration is the return of wildlife to the area. Species that had not been seen in the river for decades, such as the alewife (a type of herring), have returned, indicating a significant improvement in water quality. The revitalized river now serves as a valuable recreational resource for the community, offering opportunities for boating, fishing, and nature observation (Januchowski-Hartley et al. 2012).

## **Success Factors and Challenges in Ecological Restoration**

### **Estimating the restoration benefits**

The restoration of damaged or degraded ecosystems is often the primary objective of ecological restoration projects. In many cases, focusing restoration project outcomes purely on ecological benefits is well-justified, for example, in the case of a statutory requirement to conserve or restore an ecosystem or species (Wortley et al. 2013). However, one concern is that in many cases, restoration practitioners are failing to demonstrate the links between ecological restoration, society and policy and are underselling the evidence of benefits of restoration as a worthwhile investment for society (Aronson et al. 2010).

A number of studies have found that private landholders are more likely to participate in restoration projects where there is a clear benefit, financial or non-financial (i.e., social goals), to their participation (Januchowski-Hartley et al. 2012). Therefore, consideration of broader social and economic benefits of restoration could help advocates and practitioners in restoration activities to tailor their programs to promote better engagement (Aronson & Alexander 2013).

### **Estimating the cost of ecological restoration**

When public funding for biodiversity conservation is limited, information on cost is important for ecological restoration planning because it allows decisions to be made about whether to conserve or to restore, which restoration projects to select, and which restoration methods to use. Inappropriate accounting for costs during the planning phase of restoration projects could result in wastage of public funds, selection of wrong projects, and failure to achieve restoration targets. This is especially important when multiple methods with varying costs could be used to achieve the desired restoration outcome. However, restoration costs are rarely reported by ecological restoration studies and published cost data are often collected using different approaches, making them hard to compare (Bullock et al. 2011).

### **Equitable and Effective Stakeholder Engagement for Landscape Restoration**

The socio-ecological context, variety of land uses, and spatial interactions that define landscapes make stakeholder engagement especially critical but also complex. A key barrier is the difficulty of finding common ground among highly diverse stakeholders with varying backgrounds, needs, and priorities (Cortina-Segarra et al. 2021). The very definition of “landscape”, including its boundaries, spatial flows, and baseline conditions, is often complicated due to its inherently dynamic and socially constructed nature. Poor communication and siloed approaches can create misunderstandings and conflicts (Mañas-Navarro et al. 2023), especially in multi-sectoral landscapes, where concerns about loss of economic stability and livelihoods may weigh against restoration efforts. Landscape restoration projects frequently operate within diverse political and administrative systems that may not align with restoration goals. Additionally, governments can be slow to address community needs, and legal and technical constraints can hinder collaboration (Bell-James et al. 2023).

### **Prioritizing restoration projects**

Project funding in many countries worldwide follows a democratic process, where a project analyst provides information on each project option so that the actual decision-maker is sufficiently informed to make their own well-founded judgments about a projects’ social desirability. Benefit cost analysis, provides information on the efficiency and social welfare of a project. It informs decision makers in the political process about the projects or investments that will lead to the greatest net benefits to the community as a whole. The next step in efficient project prioritization relies on the accurate identification and estimation of benefits and costs (Nyborg 2012).

### **Indicators of Success**

Indicators of success in ecosystem restoration can be categorized into ecological, physical, and socio-economic factors. Key ecological indicators include biodiversity (species richness, diversity, and composition), ecosystem functions (nutrient cycling, carbon sequestration), and vegetation structure. Physical indicators often involve soil health (nutrients, stability), water quality, and habitat structure. Socio-economic indicators, although less frequently used, can include community engagement, economic benefits, and social acceptance of the restoration project (Vignola, R., et al. 2015).

## **Ecological Indicators:**

### **Biodiversity:**

- Species Richness: The number of different species present in the restored area.
- Species Diversity: A measure of both the number of species and the relative abundance of each species.
- Species Composition: The specific types of species present, reflecting the recovery of a community.
- Vegetation Cover and Structure: The amount of ground covered by vegetation and the complexity of the vegetation layers (Mangelsdorf, M. et al. 2015).

### **Ecosystem Functions:**

- Nutrient Cycling: The rate and efficiency of nutrient movement within the ecosystem.
- Carbon Sequestration: The ability of the ecosystem to absorb and store carbon from the atmosphere.
- Water Quality: Improvements in water clarity, oxygen levels, and reduction in pollutants (Pangilinan M.J.M. et al. 2015).

### **Biotic Integrity:**

- Colonization by native species: The successful establishment and reproduction of native plants and animals.
- Presence of key functional groups: The return of essential species like pollinators, decomposers, and predators.
- Soil invertebrates: The abundance and diversity of soil organisms, which are vital for nutrient cycling and decomposition (McCarthy J. J., et al. 2001).

## **Physical Indicators:**

### **Soil Health:**

- Nutrient levels: The availability of essential nutrients like nitrogen, phosphorus, and potassium.
- Soil stability: Resistance to erosion and compaction.
- Water infiltration: The rate at which water can penetrate the soil (Hazarika OB & Dutta D. 2017).

### **Habitat Structure:**

- Presence of different habitat types: The re-establishment of diverse habitats like wetlands, forests, or grasslands.
- Structural complexity: The presence of varied vegetation layers and other structural elements that provide shelter and resources (Vignola, R., et al. 2015).

## **Hydrological Function:**

- Water flow patterns: The restoration of natural water flow regimes in rivers, streams, and wetlands.
- Floodplain connectivity: The re-establishment of connections between rivers and their floodplains.

## **Socio-Economic Indicators:**

### **Community Engagement:**

- Public participation in restoration: The level of involvement and support from local communities.
- Social acceptance: The degree to which the restored ecosystem is valued and utilized by the local population (Harris, J. (2009).

### **Economic Benefits:**

- Increased tourism: Restoration can enhance recreational opportunities and attract visitors.
- Ecosystem services: The restored ecosystem can provide valuable services like clean water, flood control, and carbon sequestration, which have economic value.
- Reduced costs for natural disasters: Restored coastal areas, wetlands, and floodplains can reduce the impact of natural disasters, leading to economic savings (TEEB.2009).

## **Monitoring and Evaluation:**

- Reference sites: Comparing the restored site to a similar, healthy ecosystem to assess progress.

- Trajectory of recovery: Tracking changes in indicator values over time to understand the restoration trajectory.
- Adaptive management: Using monitoring data to adjust restoration strategies and ensure success (Franklin, J. 2011).

### **Community Involvement and Policy Support**

Local communities are recognized as essential partners in restoration projects. The merits of community involvement include;

- Increased Trust and Social Acceptance: Meaningful dialogue and opportunities for community members to influence processes and outcomes can foster trust and mitigate resistance.
- Enhanced Sustainability: Incorporating local knowledge and input ensures restoration projects are effective and sustainable in the long term.
- Improved Problem-Solving: Community involvement can lead to a better understanding of the issues and the development of more effective solutions.
- Sense of Ownership: When communities are involved in the planning and decision-making, they develop a sense of ownership over the project and are more likely to support and participate in its success (Dhakal B.N. 2023).

### **Challenges:**

- Neglecting Social Factors: Many projects focus on ecological manipulation while neglecting the social aspects, which can lead to project failure.
- Traditional Worldviews: Restoration efforts must consider and integrate local values and beliefs for successful implementation (Gann, G. D. et al. 2019).

### **Policy Support:**

Supportive policies are essential for creating an enabling environment for restoration.

Mechanisms:

- Funding: Policies can unlock funding for restoration projects through various mechanisms, such as livelihood security programs like India's MGNREGA.
- Incentives: Policies can incentivize restoration efforts by providing financial or other benefits to individuals and communities who participate in restoration activities.
- Legal Frameworks: Policies can establish legal frameworks that support restoration efforts, such as those related to land management, water resources, and biodiversity conservation (TNC. 2009).

### **Summary of the Findings**

Based on the documents analyzed, the findings of the study are summarized as indicated below:

1. The study found the key principles and theories in restoration ecology to include: competition theory, food web theory, facilitation theory, hierarchical organization through, facilitation cascades, and metacommunity theory.
2. The study revealed the ecosystem driver to include: Natural drivers such as earthquake, erosion, avalanche, wildfires and volcanoes. While the Anthropogenic drivers include: pollution, climate change, resource exploitation, population decline/overpopulation, land use change/land degradation, urbanization, and industrialization.
3. The study found out the restoration strategies and techniques of ecosystem degradation. They restoration strategies include: Passive or spontaneous restoration, and Active restoration. While the techniques for ecosystem degradation include: Invasive species removal, Forest restoration, and Reforestation.
4. It was discovered from the study that, the case study of the Great Barrier Reef, a UNESCO World Heritage site, is the world's largest coral reef system and one of the most biodiverse ecosystems on the planet. While the case of the Bronx River restoration is one of the most significant achievements as it leads to the return of wildlife to the area.
5. The study showed the challenges inhibiting ecological restoration to include: Neglect of social factors which can lead to project failure, and inability of restoration effort to consider local values and beliefs. On the other hand the success indicators are categorized into ecological, physical, and

socio-economic factors. The ecological indicators include biodiversity (species richness, diversity, and composition), ecosystem functions (nutrient cycling, carbon sequestration), and vegetation structure. While the physical indicators include soil health (nutrients, stability), water quality, and habitat structure. Socio-economic indicators, include community engagement, economic benefits, and social acceptance of the restoration project (Vignola, R., et al. 2015).

## CONCLUSION

The effectiveness of ecological restoration is largely attributed to the resilience capacity of an ecosystem, to the restoration actions and to the monitoring of recovery indicators. In this sense, the focus on ecological restoration should take into account that the areas are part of an integrated system, requiring the knowledge of its structure and functions for its sustainability, as well as the individual role of each species, especially those that play a fundamental role in strong interactions and in the resumption of ecological succession.

It is essential to take into consideration the performance of key species and the arrangements of functional species, because they keep the ecosystem balanced on several levels, both biotic and abiotic. This fact prevents exotic species from becoming invasive by occupying an ecological emptiness (absence of natural predators and competitors) and from settling in areas under the restoration process.

## RECOMMENDATIONS

Based on the findings of the study, it is hereby recommended that:

1. Adopt a landscape approach: Integrate restoration efforts into broader land-use planning, considering ecological, social, and economic factors.
2. Engage local communities: Involve local people in restoration planning and implementation to ensure sustainable outcomes and benefits for communities.
3. Use native species: Prioritize native species in reforestation and restoration efforts to support biodiversity and ecosystem function.
4. Monitor and adapt: Implement long-term monitoring and adjust restoration strategies based on outcomes and changing conditions.
5. Support policy frameworks: Advocate for policies that promote ecological restoration, provide incentives, and integrate restoration into development plans.

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