Future Roadmap for Forest Landscape Restoration

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Abstract:

Forests provide chances to provide ecosystem services that are essential to biodiversity and human well-being as urban populations grow. Our goal is to deliberately increase urban forests so that everyone in our global communities—especially the most vulnerable—can have happier, healthier, and richer lives. Urban tree cover delivers an array of ecosystem services, including air pollutant reduction stormwater runoff reduction, building energy savings from reduced heating and cooling costs, and the associated avoided carbon emissions from reduced energy use and carbon dioxide sequestration. A benefit of providing these services with trees is the low energy cost due to solar radiation, via the process of photosynthesis, powering tree structure and function. The additional energy inputs needed for tree management are a real cost, but something that can be incorporated into green jobs, education, and outreach programs. Because of the negative consequences of ecosystem degradation, forest landscape restoration (FLR) should be incorporated into international sustainability agendas. Because FLR operates within complex socio-ecological systems, the path to successful FLR implementation faces various biophysical, socioeconomic, and governance hurdles. Globally, forest landscape restoration (FLR) is crucial to reducing a variety of social and environmental issues brought on by deforestation and landscape degradation. Although the urgent need to restore biodiversity and ecological functioning is widely acknowledged throughout many forest landscapes, there appears to be a disconnect between political promises and practical ground-level activities. Global trade and consumption trends continue to be significant contributors to land degradation. As an alternative, market dynamics might be changed to have a net positive impact on land use change as opposed to a negative one, providing creative methods to encourage and fund FLR. To develop best practices and efficient policies, it is crucial to comprehend the present market processes that fund FLR. We review and explore FLR problems in this paper's context of global environmental change. The roadmap provides an iterative and adaptive framework for evaluating and improving FLR techniques and outcomes over time.

Keywords: deforestation, runoff, restoration, photosynthesis, climate change, governance policies,

Highlights:

To address these issues, we proposed a five-step roadmap that includes:

I. Advancing ecological knowledge that supports FLR,

II. Adapting FLR management to environmental change by strengthening globally distributed experimental networks,

Modeling approaches,

IV. Improving socioeconomic and governance dimensions, and

V. Developing evidence-based knowledge platforms.

1. Introduction:

Large-scale deforestation, agricultural intensification, inappropriate land resource management, and climate change have all contributed to a considerable reduction in global biodiversity and ecosystem functions and services, with detrimental consequences for both nature and humankind. As part of the Bonn Challenge accords, the world community has committed to restoring 350 million hectares of degraded ecosystems by 2030 to address these challenges. The Bonn Challenge is based on the forest landscape restoration (FLR) concept, which strives to increase human well-being while restoring ecological integrity. FLR supports a triple-win scenario in terms of biodiversity protection, ecosystem service (ES) supply, and livelihood development by balancing both biophysical and socioeconomic benefits. While FLR offers a promising future for environmental sustainability, the path to achieving the ambitious targets of large-scale FLR remains unclear due to a lack of understanding of the biophysical, socioeconomic, and governance obstacles, as well as the complexity of balancing biodiversity, ESs, and livelihoods while integrating multiple benefits, scales, competing interests, and priorities. Global environmental changes, such as fast population increase, harsh climate events, and altered land-use patterns, intensify these issues, emphasizing the significance of rethinking how degraded ecosystems are restored. In a constantly changing world, achieving meaningful success in FLR necessitates a socioecological system (SES) framework that considers the challenges and opportunities posed by complex interactions between ecological things, processes, and humans.

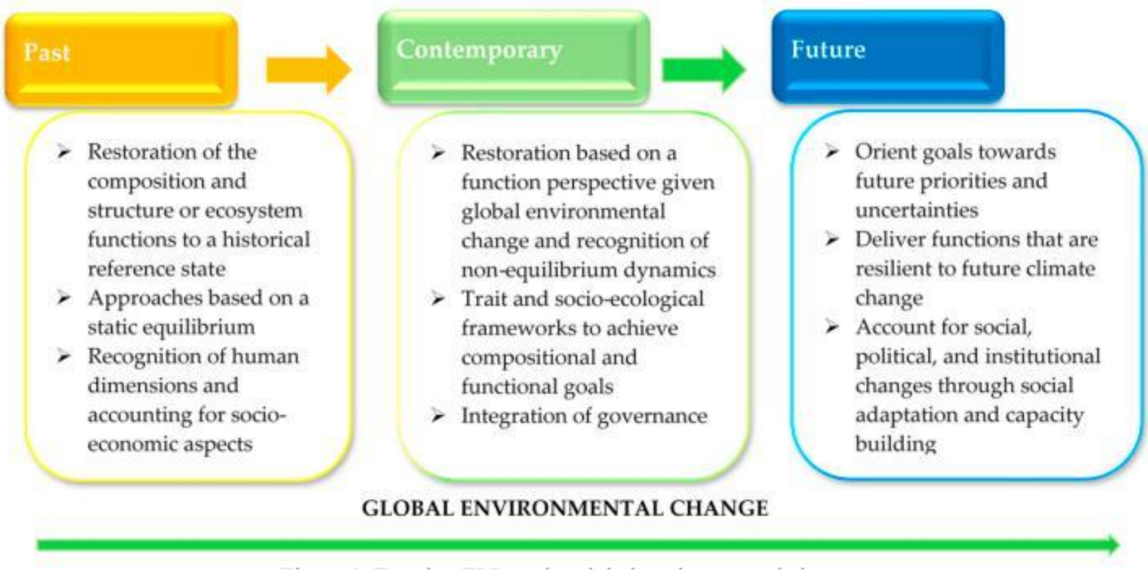


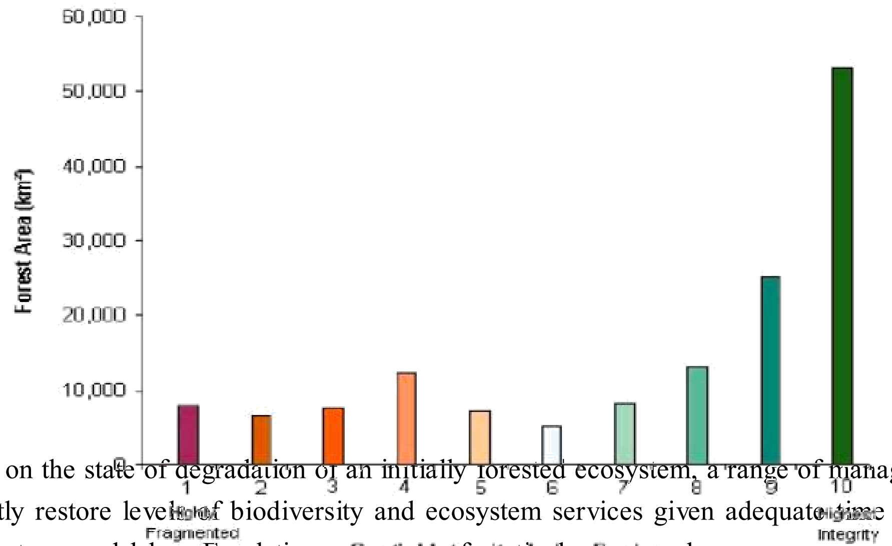
Figure 1. Framing FLR under global environmental changes

Even though there is no "one-size-fits-all" approach to successful FLR implementation, with a variety of strategies tailored to specific contexts needed to be considered, little guidance exists on how to design FLR strategies that will result in landscapes that are resilient to constantly changing natural, socioeconomic, and political environments and can sustain the provision of various goods and services. Indeed, failure to account for global environmental changes will limit the long-term viability of restored ecosystems. We summarize and discuss key challenges for FLR in the context of global environmental changes, and propose a roadmap to overcome these obstacles. We reflect on the extensive literature that has emerged in the last decade on the reasons for success and failure in FLR activities, the theories for and approaches to ecological restoration, current knowledge on the effects of global environmental changes on FLR implementation, the impacts of policies and other actions that have been adopted worldwide to ensure successful FLR and the context-dependency of FLR initiatives. We aim to assist FLR stakeholders including practitioners, researchers, engineers, landscape architects, and policymakers in the implementation of FLR by providing a framework that facilitates a systematic approach to efficient FLR.

2. Why Need for Forest Landscape Restoration?

The expression forest landscape restoration is used indiscriminately and it is difficult to define in a way that comprises all situations observed in the literature and practice, in different ecological and socio-cultural conditions. Initially used to express landscaping and planting to reclaim degraded sites, the forest restoration definition has developed to widen the more narrowly defined approach that has been tried in the past. Conceptually forest restoration has proceeded in step with the theories and principles of restoration ecology. Crucial to this concept is the focus on restoring the relationship between biodiversity and ecosystem functioning. An accredited definition of forest restoration is ‘‘to re-establish the presumed structure, productivity, and species diversity of the forest originally present at a site. The ecological processes and functions of the restored forest will closely match those of the original forest’’. Thus, forest restoration is an intentional activity that initiates, assists, or accelerates the recovery of an ecosystem concerning the presumed historical composition, structure, function, productivity, and species diversity of an ecosystem present at a site.

Restoration attempts to return an ecosystem to its historic trajectory. Historic conditions are therefore the ideal starting point for restoration design. If strictly applied, this definition makes forest restoration almost impracticable: wherever forest restoration intervention is implemented on the degraded and fragmented landscape, new forest emerging will not match the reference state, i.e. the original old-growth forest in species composition, monitoring changes in forest fragmentation that might result from restoration efforts. Some restoration ecologists are moving away from the ‘purist’ position, especially the more ideological views that set the goal of restoration to be an idealized pristine state, which also implies a static view of ecosystems. Various authors view forest restoration as in symmetry with forest degradation and deforestation and the restored ecosystem will not necessarily recover its former state, since contemporary constraints and conditions may cause it to develop along an altered trajectory. Simply as forest ecosystem processes decline in a stepwise manner with increasing anthropogenic or natural impacts, restoration approaches can lift a degraded or fragmented or completely altered forest to a higher level of the restoration staircase.



Depending on the state of degradation of an initially forested ecosystem, a range of management approaches can at least partly restore levels of biodiversity and ecosystem services given adequate time and investment of capital, infrastructure, and labor. Escalating outcomes of particular approaches are: recovery of soil fertility for agricultural or forestry use

i. Production of timber and non-timber forest products

ii. Restoration of biodiversity and ecosystem services

iii. It is open to discussion of the idea that natural regeneration will lead to the highest level of biodiversity and ecosystem services,

3. Benefits of FLR:

Forest landscape restoration can be achieved either through controlling pressures on forests, such as fires, invasive species, or unsustainable harvesting, or through techniques to accelerate forest recovery such as planting programs or attracting seed dispersers. These activities all have in common that they consist of active management interventions. Hence forest restoration has to be illustrious from natural forest succession, even though both processes lead to successional change: forest restoration is assisted, intentional, guided reconstruction of forests, whilst forest natural succession is regarded as unintended, nor prescribed or directed by humans.

3.1. FLR and climate change mitigation:

FLR has major potential as a climate mitigation mechanism through massive carbon storage. Achieving the goals set out by the Bonn Challenge will generate about US$ 170 billion per year in net benefits from watershed protection, improved crop yields, and forest products, and could sequester up to 1.7 giga_tonnes of carbon dioxide equivalent annually. If we reach the 350 million hectares of FLR milestone by 2030, an estimated 5.95 $GtCO_2$ could be sequestered. If we are to fully realize that potential, interventions must be designed to deliver against a basket of societal needs.

While it may appear counterintuitive, the temptation to maximize carbon benefits in any FLR intervention must be resisted. FLR implicitly involves carbon-intensive land stewardship but that seldom means that a successful FLR program will deliver the absolute maximum amount of carbon that an individual landscape could theoretically deliver. In other words, carbon should be treated as an important and abundant 'co-benefit' of FLR but not the sole objective.

3.2. FLR and Biodiversity:

FLR has the potential to generate significant biodiversity benefits. To maximize this potential, the following issues should be considered: The potential of restoration to re-establish connections between different habitats–In many ecosystems, some habitats have become fragmented as a result of degradation. Restoration can be used to recreate these connections thereby facilitating the movement of species (e.g. migration corridors).

i. The potential of restoration to increase habitat extent – In situations where very little of a given habitat remains or where habitat has been lost completely, restoration can be used to recreate a semblance of it.

ii. The potential of restoration to improve habitat quality – Restoration, by ensuring that a greater diversity of species is found in a given habitat, can be used to improve habitat quality.

In identifying possible areas for restoration, consideration should be given to opportunities to improve the extent, quality, and connectivity of high biodiversity areas, including areas rich in biodiversity or home to threatened or endangered species, as well as those that deliver important ecosystem services. Better accounting for the potential biodiversity benefits of restoration can help ensure that these biodiversity benefits are optimized. These impacts can include improved provision of ecosystem services (such as water supply, pollination, erosion control, or carbon sequestration) and more resilient ecosystems that are better able to cope with stresses and adapt to climate change. In addition, accounting for biodiversity in restoration activities can help countries meet their international commitments such as those associated with the CBD Strategic Plan for Biodiversity 2011-2020 and its Aichi Biodiversity Targets.

3.3. FLR and Human Well-Being:

Over 1.6 billion people depend on forests for at least part of their well-being. The vast majority are from more vulnerable groups such as poorer households, women, and those living in remote communities. Forests provide fuel wood, commodities, and products that sustain livelihoods;

To protect watersheds for agriculture and promote freshwater access, they provide immeasurable cultural and health benefits. In economic terms – the restoration of 150 million hectares of degraded and deforested lands in biomes around the world – in line with the forest landscape restoration (FLR) approach – will create approximately US$ 84 billion per year in net benefits that could bring direct additional income opportunities for rural communities.

4. Key FLR Challenges:

4.1. Relevance of Historical Knowledge:

Several studies have advocated the need to consider historical ecosystem conditions as a target and reference for FLR. This is because current forest conditions are often the result of past land use types and ecological processes that leave long-term legacies. Historical knowledge also provides a reference for defining compositional or functional end, points and for identifying future trajectories. However, concern about the impact of global environmental changes on ecosystems has led to a debate on the usefulness of history as a frame of reference because the most feasible future conditions are likely to strongly depart from past trends while being incrementally different from the current state. On the other hand, the dependence of the current state of an ecosystem on its history of anthropogenic disturbance, i.e., its hysteresis, may delay or prevent its recovery to its original or target state.

Thus, historical knowledge can serve only as a guide and not as a template for defining restoration targets and understanding long-term population dynamics under past climatic conditions. While looking to the past is easier than predicting the future, historical bias and uncertainty, the difficulty in choosing an appropriate historical period, and the paucity of information on long-term forest dynamics undermine the usefulness of historical knowledge for FLR. The decision to plant a certain species is based on the project's goals, the possibility of tree establishment, and the availability of high-quality genetic material. Because combining functionally dissimilar species allows for coexistence and complementary resource utilization, objectives frequently place a premium on desirable functional qualities (growth rate, wood density), as well as kinds (e.g., native vs. foreign), which influence candidate species selection. However, we still have a limited grasp of which features or combinations of qualities will ensure a successful establishment. While obtaining adequate high-quality seed and seedling stock is an essential initial step in the success of all planting procedures, knowledge of how and where to obtain regeneration material with the appropriate qualities for sites is also available under restoration and how to cost-effectively cultivate plants in nurseries.

4.2. Climate Change and Other Disturbances:

Trees at the heart of FLR are sensitive to natural and anthropogenic disturbances, and restored forest landscapes are no exception. Extreme weather events (e.g., severe drought) and novel climate-induced disturbances (e.g., pest and disease outbreaks) are likely to alter the ecological processes underlying the recovery of forest structure and functions, resulting in irreversible or undesirable changes (e.g., shifts in species distribution ranges), jeopardizing the long-term viability of restored landscapes. However, system complexity, limited knowledge of plant–soil–climate causal linkages, and the inability to reliably anticipate future climate make it difficult to predict forest growth and species-specific responses to changing climate.

While disturbances such as wind throw and forest fires are integral to forest structural dynamics, an increase in their frequency and/or range as a result of direct human activity or anthropogenic environmental changes may limit the structural elements of the forest and sources of microsite diversity, adding to the difficulty of restoration.

Ultimately, changes in drought and wildfire severity, frost-hardiness zones, flood events, pest and disease outbreaks, land use and land cover, and competitors' populations will affect species range distributions and adaptiveness in the future. However, our understanding of these critical issues, which may have long-lasting consequences for the success of FLR, is still in its infancy. Advanced methods such as modeling for navigating dynamic ecological functions and processes are constrained by errors and uncertainties in model predictions.

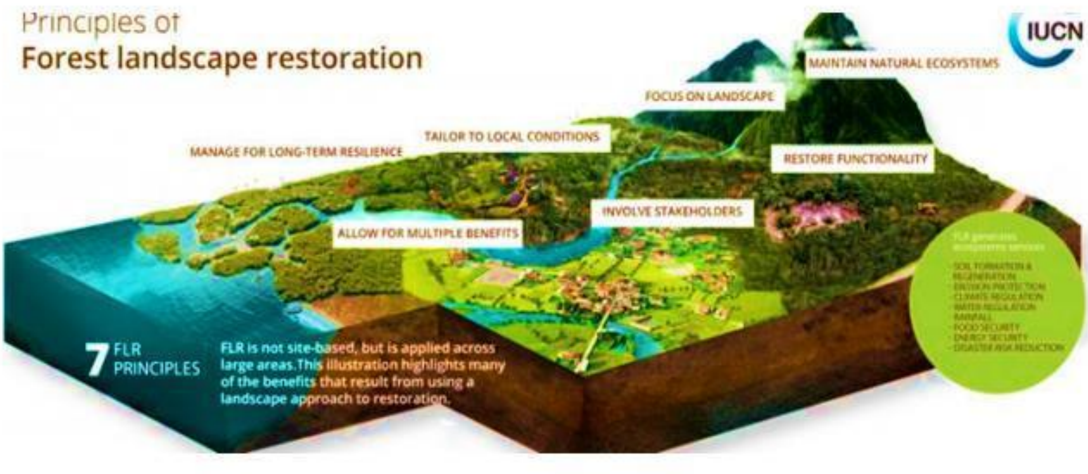
4.3. Governance and Socio-Economic Challenges:

The effectiveness of FLR, according to evidence, is dependent on the support, contribution, and cooperation of all stakeholders at all levels, as well as the governance framework in place. However, a fundamental obstacle to the successful implementation of FLR is a lack of meaningful stakeholder engagement. Furthermore, FLR is more likely to occur in settings with weak governance, a history of land tenure and rights conflict, a lack of policy coordination, and structural discrimination against women and indigenous peoples. As a result, it is critical to ensure that FLR efforts do not perpetuate past injustices or marginalized social groups, but rather promote equitable involvement for all stakeholders. The trans-boundary nature of landscapes means that FLR is shaped and influenced by diverse elements of governance (i.e., decision-making, policies, and institutions) including from other sectors (e.g., agriculture). However, the process of establishing strong and coherent policies that reconcile the conflicting interests of various actors, including state governance units, and that suit the multi-functionality of the target landscapes is hampered by the trans-boundary nature of landscapes (The trans-boundary nature of landscapes means Local and indigenous governance, including customary tenure and land-use decision-making, may not accord with national-level forest resource use and regulation, exacerbating these competing concerns.

The constantly changing legal and social contexts surrounding the restoration of a landscape, driven by population increase, globalization, land-use changes, and policy adjustments, can further sabotage FLR's success, necessitating FLR's adaptation to these changes. Other related issues such as poor planning and prioritization, a lack of conceptual clarity and clear guidelines for evaluating the efficacy of FLR interventions, insufficient and short-term funding, the risk of an "enthusiasm gap" arising from unmet expectations, and the "knowing–doing" gap may capsize FLR efforts in the long term.

5. How Forest Landscape Restoration is carried out?

There are a large variety of approaches that have been used to address FLR and many of these are considered in the chapters that follow. Some involve relatively informal techniques while others require considerable planning. However, the process of implementing FLR usually involves the consideration of four quite explicit questions:



I. How much restoration should be carried out in a particular landscape?
II. Where this should be carried out?
III. What type of restoration should be done at each location?
IV. How should the FLR process be managed?

6. Roadmap for Sustainable FLR:

To address the challenges identified above, we propose a roadmap consisting of five steps toward sustainable FLR. Key elements of each step of the roadmap are summarized here:

- Advancing Ecological Knowledge to Support FLR
- Adaptive FLR Management
- Modeling
- Social Improvements and Adaptations
- Evidence-Based Platforms

6.1. Step 1: Advancing Ecological Knowledge to Support FLR:

It is critical to establish knowledge of the biological processes underpinning the reintroduction or re-assemblage of plant communities to achieve successful FLR in the face of fast environmental change. Changing biotic and abiotic conditions have pushed ecosystems past certain thresholds, resulting in novel states with no historical precedent, implying that restoration targets and success criteria should be re-adjusted to reflect future priorities, with a focus on resilience to projected environmental changes and less reliance on historical reference frames. Because restoration may result in "new ecosystems" with innovative compositional structure and spatial distribution under changing circumstances. The goal of functional restoration is to maintain ecosystem function and develop multifunctional landscapes with a focus on multi-scale ecological processes' long-term viability.

6.2. Step 2: Adaptive FLR Management:

To test the effectiveness of concept-driven FLR, such field and large-scale experiments and observational research focusing on plant–environment relationships over gradients of environmental parameters and management activities are required. Multiple factors of the environment (e.g., light intensity, nutrient availability, temperature, and rainfall fluctuation) must be evaluated simultaneously in complex interactions that result in community responses (i.e., functions) and plant trait adaptations. In this aspect, attaining successful FLR in the face of environmental change will necessitate adaptive management, in which original conservation and management plans are updated when their limited success is revealed.

We suggest that experiments be conducted globally to test for the effects of current and projected environmental variability on functional traits and groups to generate new hypotheses for trait–function–environment relationships necessary for adaptive management, thus improving FLR approaches.

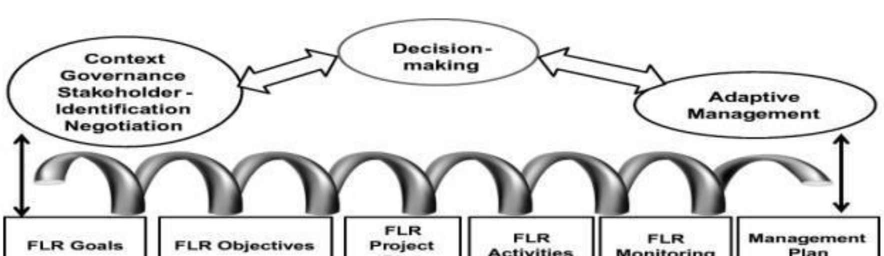


Fig: Key elements of each step of the roadmap for FLR

6.3. Step 3: Modelling:

Given the uncertainty in projecting, ensuring the survival of plant groups and maintaining the functioning of restored forests remains one of FLR's toughest difficulties changes in the future Nonetheless, attempts have been made to forecast future climate, with some promising results and opportunity to investigate the performance of plant communities in various climate scenarios. Models can be used to alter circumstances. Data is a requirement for landscape-scale modeling with adequate geographic coverage, which can be obtained through both experimental and observational methods research.

6.4. Step 4: Social Improvements and Adaptations:

The complexity of landscapes as socio-ecological systems calls for a greater focus on the sociopolitical dimensions of FLR. A conducive socioeconomic and political environment has generally been recognized as key to effective science-based FLR. Consequently, establishing institutional and regulatory frameworks that include integrative policies and consistently enforcing them would enhance the likelihood of FLR success.

6.5. Step 5: Evidence-Based Platforms:

Incorporating novel research and modeling findings, practical expertise, innovations, TEK, and experience with FLR into local and global evidence platforms or networks would be a useful avenue to pursue future FLR interventions. These platforms are necessary to understand context dependency and provide information on challenging questions related to where, when, and why FLR interventions are successful. The information would improve the ability of restoration practitioners to design an FLR that is resilient to future environmental changes. Standardized protocols for field and modeling approaches and generic indicators of FLR success could be made available for download.

The platform would also promote the exchange of information between FLR stakeholders (e.g., scientists, land managers, communities, government agencies, and the private sector), which in turn, would enhance communication, collaboration, and trans-disciplinary at the local, regional, and global levels and could bridge the “knowing–doing” gap. The new generation plantation (NGP) platform is a promising example of this, which can serve as the basis for developing more integrative and trans-disciplinary evidence-based platforms to support FLR.

7. Conclusions:

Because of the vast amount of deforestation and land that requires some type of restoration, it is necessary to find strategies to enhance the scale at which restoration is carried out. The issue is not merely to scale up an existing set of silvicultural practices tactics, but to figure out how to intervene in an already complicated landscape mosaic to increase both ecological and socioeconomic functionality. People who live in that landscape now and those who will live there in the future. FLR is a promising approach for meeting global restoration commitments. However, as a dynamic process occurring in complex SESs exposed to global environmental changes, FLR faces several challenges in design, prioritization of intended outcomes, management, stakeholder engagement, and other socioeconomic, and governance constraints. This study suggests a roadmap to tackle these challenges. The roadmap includes the building of sound ecological knowledge **(Step 1),** which can be continuously evaluated and updated through coordinated experiments **(Step 2)** and modeling approaches **(Step 3)**, and the improvement of socioeconomic and governance factors with an emphasis on participation, monitoring, and social adaptation **(Step 4).** Information from these four steps can be collected in evidence-based platforms **(Step 5)** to guide adaptive FLR. The roadmap thus promotes an iterative and adaptive process, aiming to continuously improve and adjust FLR interventions for changing environments.

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