Shaping the future of ecological restoration: Integrating predictability and adaptive insights

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Authors contribution

RMA, EC conceived the concept; RMA, EC developed the framework; TOGT, RMA conducted case studies desk research; RMA, EC drafted the manuscript; IRA, KS, FCMPR, EC revised and edited; EC supervised.

Abstract

Introduction: Ecological restoration must move beyond fixed historical baselines to face the realities of climate change, biodiversity loss, and complex socioecological dynamics.

Framework for restoration: We propose the Future-Based Approach (FaBRestor), a novel framework that reframes restoration as a forward-looking, adaptive process. FaBRestor integrates multitemporal lenses—past legacies, present conditions, and future projections to design interventions that are ecologically sound and socially inclusive, better coping with global change. This article outlines the framework's core principles, including adaptive management, transdisciplinary collaboration, and the use of predictive tools, demonstrating how they are put together in a holistic and interconnected way.

Implications for practice: FaBRestor provides essential strategic support for practitioners and decision-makers, offering forward-looking strategies to cope with global change and dynamic ecosystems. Its novelty lies in the systematic integration of emerging best practices into a single, coherent framework. While individual components may exist in the literature, they are rarely combined into an actionable strategy. FaBRestor provides interconnection among the elements, better equipping restoration efforts for an uncertain future by promoting more flexible, adaptive, and resilient outcomes.

Key-words Ecological restoration; Climate resilience; Adaptive Management; Transdisciplinary approaches; Future-based planning

Reframing ecological restoration for the future

In an era marked by rapid ecosystem evolution and global changes, ecological restoration became a central tool to reverse degradation and mitigate climate change. Yet, many efforts still rely on rigid historical reference conditions and short-term goals. Conventional approaches have faced significant challenges and often fail to address climate impacts, species adaptability, and socioeconomic integration by overlooking ecological dynamics, climate projections, and social realities (Dudney et al. 2022; Puettmann 2014). To address the challenges of global change, ecological restoration must be dynamic, adaptable, and forward-looking. Contributing to this necessary shift, we introduce the Future-based Restoration (FaBRestor) framework, which acknowledges and incorporates ongoing ecosystem changes. It provides a coherent, adaptive, and actionable framework that integrates past legacies, present conditions, and future scenarios. To achieve it, FaBRestor employs ecological memory, augmented by real-time data and projections of future changes, to situate ecological restoration within a broader temporal continuum, thus guiding more resilient restoration decisions.

The FaBRestor framework

FaBRestor framework moves beyond reactive restoration strategies, equipping practitioners to design adaptive and proactive solutions that remain effective under future uncertainty. To do so, FaBRestor is built on five interconnected principles: multitemporal lenses, transdisciplinary, socioeconomic inclusion, technology and models, and smart adaptive management (Figure 1).

Multitemporal lenses

The FaBRestor recognizes that understanding and addressing the causes of only current restoration challenges is not enough. Instead, it advocates and addresses restoration processes and functions in different time scales. It encompasses a holistic and perspective that integrates the past, present, and future to achieve resilient and adaptable restoration projects. Historical knowledge, real-time monitoring, and climate modeling together inform strategies that are both grounded and adaptive. Anticipating change allows practitioners to design restoration that is viable in future climates, rather than replicating past conditions (Harris et al. 2006).

Practical examples of using long-term data aligned with future modeling to support current management decisions can be found in the Cape Floristic Region of South Africa. Severely impacted since European settlement in the 19th century, the vegetation in this area is now different compared to its long-term history. By simulating past changes through paleoecology and participatory system dynamics modeling, researchers established a basis for assessing how future fire and grazing management might affect plant biodiversity outcomes. Looking though the multitemporal lenses when targeting successful restoration is therefore crucial for understanding the landscape's history, changes and future trajectories, ultimate supporting adapted decisions (Kirsten et al. 2024).

Transdisciplinarity

Ecology and biology alone cannot fully address the complexity of ecological restoration. Tackling these challenges requires integrating diverse knowledge, methods, and perspectives across disciplines, while recognizing their interconnections (Riggs et al. 2023). FaBRestor places transdisciplinarity at its core, promoting a holistic, science-based approach that enables practical and sustainable solutions beyond the limits of any single field.

The experimental study by Bailey et al. 2021 is a good example of transdisciplinarity being crucial in supporting large-scale restoration efforts in the arid and highly modified agricultural Midlands region of Tasmania, Australia (Davidson et al. 2021). Given that a species' climate-linked local adaptation varies significantly with environmental conditions, the integration of disciplines such as genetics, ecology, botany, paleoecology and ethnoecology, where key for species selection and for creating seed-sourcing strategies tailored to climate change, (Alberto et al. 2013; Costa e Silva et al. 2020). Expertise of entomology and zoology were also essential for understanding how biotic enemies affects species and genetic composition of revegetation sites, which can compromise community composition and climate adaptation.

Transdisciplinarity, as a key element of the FaBRestor, offers solid methods for understanding the intricate interactions that drive ecosystem dynamics, aiding in their effective restoration. As a result, it opens new ways for identification, comprehension, and analysis of hidden current and future restoration challenges.

Socioeconomic inclusion

Ecological restoration requires recognizing people as agents and sources of knowledge, not just beneficiaries. Historically, restoration efforts have predominantly focused on advancing technical and ecological knowledge, often neglecting the intricate and essential connections between ecosystems and human societies (Aronson et al. 2010; Wortley et al. 2013). As a result, restoration actions have often prioritized maximizing biological values while undervaluing the critical role that society and traditional communities play in the restoration process. This oversight can hinder the long-term sustainability and social acceptance of restoration efforts (Choksi et al. 2023). Wortley et al. 2013 reviewed 301 articles on restoration projects' assessment from 1984 to 2012, revealing that only 1% of them covered social-economic attributes among the ecological ones, while 94% used only measures of ecological attributes. This trend has led to a disproportionate allocation of resources, tools, and actions, limiting the overall effectiveness of restoration efforts and potentially costing their success.

In the FaBRestor, socioeconomic factors are integrated to address the complex interplay between social and ecological systems. This requires implementing strategies that identify and incorporate local people's interests, knowledge, and needs where communities are actively involved in decision-making processes, from setting objectives and prioritizing actions to monitoring projects, ensuring a more inclusive and sustainable restoration effort (Erbaugh et al. 2020; Fleischman et al. 2022).

Technology and models

Using technology in forestry has significantly improved the understanding of forest complexities, interacting factors and changes, facilitating restoration activities and decision-making. Embracing multi-temporality and adaptability requires a better and deeper understanding of the dynamic nature of forests and the interaction of multiple factors across various spatial and temporal scales (Koch and Kaplan 2022; Seidl and Turner 2022). To manage this complexity, the development and use of emerging technologies, such as remote sensing, ecological modeling, and artificial intelligence, are essential for enhancing data collection, processing, and analysis (Nikinmaa et al. 2020; Seidl et al. 2016).

The potential for alternative technologies in forest restoration is increasing, particularly with advancements in drone technologies. Drones are versatile throughout restoration, offering high-resolution insights into vegetation dynamics over time, providing baseline data on ecological and geophysical conditions across broad areas, therefore contributing to improved restoration decision-making (Almeida et al. 2019; Ancin-Murguzur et al. 2020; Fernández-Guisuraga et al. 2018). The development of ecological models is also valuable for dealing with uncertainties under climate change. For example, species distribution models (SDM) can be powerful, especially in selecting species, a crucial step in ecological restoration (Fremout et al. 2021; Nunes et al. 2020). By forecasting potential future species distributions under climate change, SDMs can guide species selection and inform proactive strategies for adaptation and mitigation (Simonson et al. 2021; Thuiller et al. 2015). However, the actual use of new technologies and models is still theoretical and remains within academic circles, rarely translated into actionable guidance for policymakers, forest managers, or practitioners. Bridging this gap requires tools that translate complex scientific data into user-friendly guidance, improving real-world restoration outcomes (Elith et al. 2006; Yousefpour et al. 2017). In alignment with FaBRestor, leveraging technology, models, and AI as decision-support tools is essential for effectively address restoration challenges and fostering more sustainable, resilient, and functional forest ecosystems.

Smart adaptive management

Traditional restoration often aims to re-establish historical conditions by restoring specific structures and functions, based on the assumption that ecosystems follow linear, predictable trajectories (Harris et al. 2006; Suding and Gross 2006). Yet, with climate change, land-use pressures, and ecological disturbances increasing, restoration must adapt to shifting baselines, feedbacks, and uncertainty (Suding et al. 2015).

To advance in restoration efforts, FaBRestor reframes adaptive management as a core strategy, not a corrective measure. It treats restoration as a dynamic experiment, guided by learning loops, robust monitoring, and flexible goals. The FaBRestor recognizes that events do not follow a predetermined path or guide the restored area toward a singular climax. Instead, they create numerous potential trajectories, each leading communities to distinct levels of organization, structure, and function in a dynamic equilibrium (Aronson and Andel 2006; Parnell 2016). Therefore, requiring restoration actions to evolve alongside the trajectories.

Promising examples already exist. In Australia, Broadhurst et al. 2017 embedded experimental designs into seed sourcing strategies to improve planting resilience under climate stress. In Florida and Nepal, adaptive monitoring and local engagement reshaped priorities, reduced uncertainties, and improved both ecological outcomes and livelihoods (Reid et al. 2005). The iterative nature of adaptive methods underscores a continuous learning process wherein information from cycles of planning, monitoring, assessment, and implementation informs decision-making, enhances progress evaluation, and increases resilience against unforeseen challenges (Council et al. 2004).

FaBRestor builds on these principles by proactively integrating change into planning, embracing uncertainty, and aligning restoration activities with evolving conditions. In doing so, it enhances both the ecological robustness and long-term sustainability of restoration actions.

Implication for practice

FaBRestor is not a prescriptive protocol but a flexible guide. It can inform restoration at different scales, from plot-level experiments to national policies. By integrating diverse values and perspectives, recognizing the role of society in shaping ecological outcomes, and committing to sustainable and equitable restoration initiatives, restoration efforts can become more effective and enduring. The approach spotlights key elements that are essential to inform decisions, addressing current and future ecological restoration challenges (Figure 2).

FaBRestor identifies key actions that can be identified and implemented to ensure the effectiveness of this strategy, as outlined in the recommendations below (Table 1):

This approach also complements emerging trends in restoration finance, including carbon markets and biodiversity credits, which require robust forecasting and monitoring to ensure credibility. By aligning ecological function, social engagement, and predictive planning, FaBRestor supports durable restoration success.

FaBRestor: From concept to practice

The framework contribution lies in its systematic approach to translate emerging best practices into a cohesive strategy for effective restoration. While existing literature may contain individual best practices, such as technology-driven planning, they are rarely unified into an actionable, coherent strategy. FaBRestor provides the connection of these disparate elements, offering a holistic framing for practitioners and decision-makers. Therefore better equipping restoration efforts to promote flexible, adaptive, and resilient outcomes suited for an uncertain future. This strategic support moves beyond traditional, reactive restoration by enabling a proactive, comprehensive approach to dynamic ecosystems.

This is how FaBRestor is effectively used on-the ground projects (Figure 3):

Outcome

The outcome of applying FaBRestor is a site-specific restoration strategy that yields tangible ecological, social, and long-term collaborative benefits. The holistic strategy results in ecosystems that are more resilient to current and projected climate conditions. A key outcome is the development of local capacities and strengthened livelihoods through social inclusion and collaborative frameworks. Instead of treating restoration as a static endpoint, the framework's use of continuous learning and monitoring ensures the outcome is a dynamic, long-term process, creating flexible and adaptive results suited for an uncertain future.

FaBRestor in numbers

Principles of the holistic restoration framework FaBRestor have been applied to 10 active projects spanning a diversity of tropical biomes in Brasil and French Guiana (Figure 4).

Results to date for the ensemble of projects are summarized in Table 2.

Together, these numbers demonstrate that FaBRestor does more than deliver short-term gains: they translate into a site-specific restoration strategy that balances ecological effectiveness, social inclusion, and resilience under both current and projected climate conditions. By coupling strategic planning and climate foresight with community participation, and ongoing monitoring, FaBRestor supports the long-term recovery of ecosystem functions and biodiversity while strengthening local capacities and collaborative efforts for sustaining restoration across time.

FaBRestor in action: Comparative lessons from the field

Building upon the previous description of FaBRestor in practice, this section presents examples from the literature contrasting conventional restoration with approaches embodying FaBRestor's core dimensions. This case-based comparison underscores the critical role these principles play in achieving project success and long-term resilience.

A primary FaBRestor dimension is the shift from static, historical baselines to a forward-looking perspective that anticipates future uncertainty. The risk of managing for the past is illustrated in In Austria's Rosalia Mountains, Norway spruce, once well suited to the area's cooler, wetter climate, has shown reduced performance on sites that are now warmer and drier, making the trees more prone to drought stress and bark-beetle damage (Netherer et al. 2024). In contrast, an approach embodying FaBRestor's temporal lens used assisted migration informed by climate models. This forward-looking strategy resulted in approximately 20% higher stand survival through a similar climate stress event (Royo et al. 2023).

Beyond its temporal focus, FaBRestor also reimagines socioeconomic inclusion within restoration projects.Traditional projects often largely overlook local communities, leading danger to the project success. Conventional mangrove restoration, for instance, often fails when it overlooks local socio-ecological dynamics, sometimes harming the very livelihoods it is meant to support by degrading resources like fish nurseries (Ellison et al. 2020). Conversely, a parallel project demonstrates the success of a FaBRestor-aligned approach. By empowering local cooperatives through participatory co-design, the integration of local knowledge, and paid monitoring roles, the project achieved measurable success. This included increased finfish and crab yields, providing direct ecological and economic benefits to the community (Wylie et al. 2016).

A detailed comparison of the differences between projects with and without FaBRestor's core dimensions can be found in the supplementary materials section (Supplementary table S1).

A call for future-oriented restoration

There is a critical need to shift from static, past-oriented restoration approaches toward flexible, context-aware strategies that can address the challenges of global change. The Future-based Restoration (FaBRestor) framework provides a practical and conceptual scaffold for this transition, offering a coherent strategy that systematically integrates emerging best practices. By integrating multitemporal lenses, transdisciplinary collaboration, socioeconomic inclusion, and predictive tools, FaBRestor moves beyond simply restoring the past. This forward-thinking practice enables the shaping of resilient and adaptive ecosystems, ensuring that restoration efforts can better support both ecological integrity and societal needs in an uncertain future. We therefore call for the adoption of such integrated, forward-looking frameworks to supportthe future of restoration science and practice.

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Figure Captions

List of Figures

Tables

Table 1: Key recommendations for an ecological restoration framework, including actions such as integrating multitemporal lenses, fostering transdisciplinary collaboration, and enhancing stakeholder engagement. The table highlights specific actions and expected outcomes to guide effective and sustainable restoration efforts.

Recommendation	**Purpose**	**Key actions**	**Expected outcomes**
Integrate multiple lenses	Ensure a comprehensive approach	Review past projects, Inform present decisions, Forecast future impact and changes	Sustainable and effective restoration efforts
Adopt transdisciplinarity	Foster holistic planning	Collaborate across disciplines, Integrate diverse data sources	Innovative and effective solutions
Develop comprehensive frameworks	Structured assessment and tracking	Conduct area diagnostic, Set clear goals, Monitor and adapt	Accountability and continuous improvement
Enhance supporting materials and Knowledge sharing	Facilitate knowledge sharing	Create accessible guides, Develop evaluation frameworks, Conduct reviews	Accessible best practices and updated knowledge
Address challenges and barriers	Overcome barriers	Identify challenges, Promote adaptive management	Resilience and flexibility in restoration efforts
Legal and policy compliance	Protect intellectual property	Ensure legal compliance, Safeguard proprietary technologies and Assure traceability	Integrity and protection of proprietary information
Stakeholder engagement	Ensure collaborative efforts	Engage local communities, researchers, policymakers	Shared ownership and sustained efforts
Strategic planning and execution	Ensure effective implementation	Define and evolve means	Clear roles and adaptive strategies

Table 2: Key FaBRestor projects metrics

Value	Metric
1 500	Local seed collectors mobilised
30	Network suppliers
31	New collectors fully trained
60	Priority species incorporated into predictive models
60%	Establishment species success rate
183 ha	Total area under restoration

391 # Figures

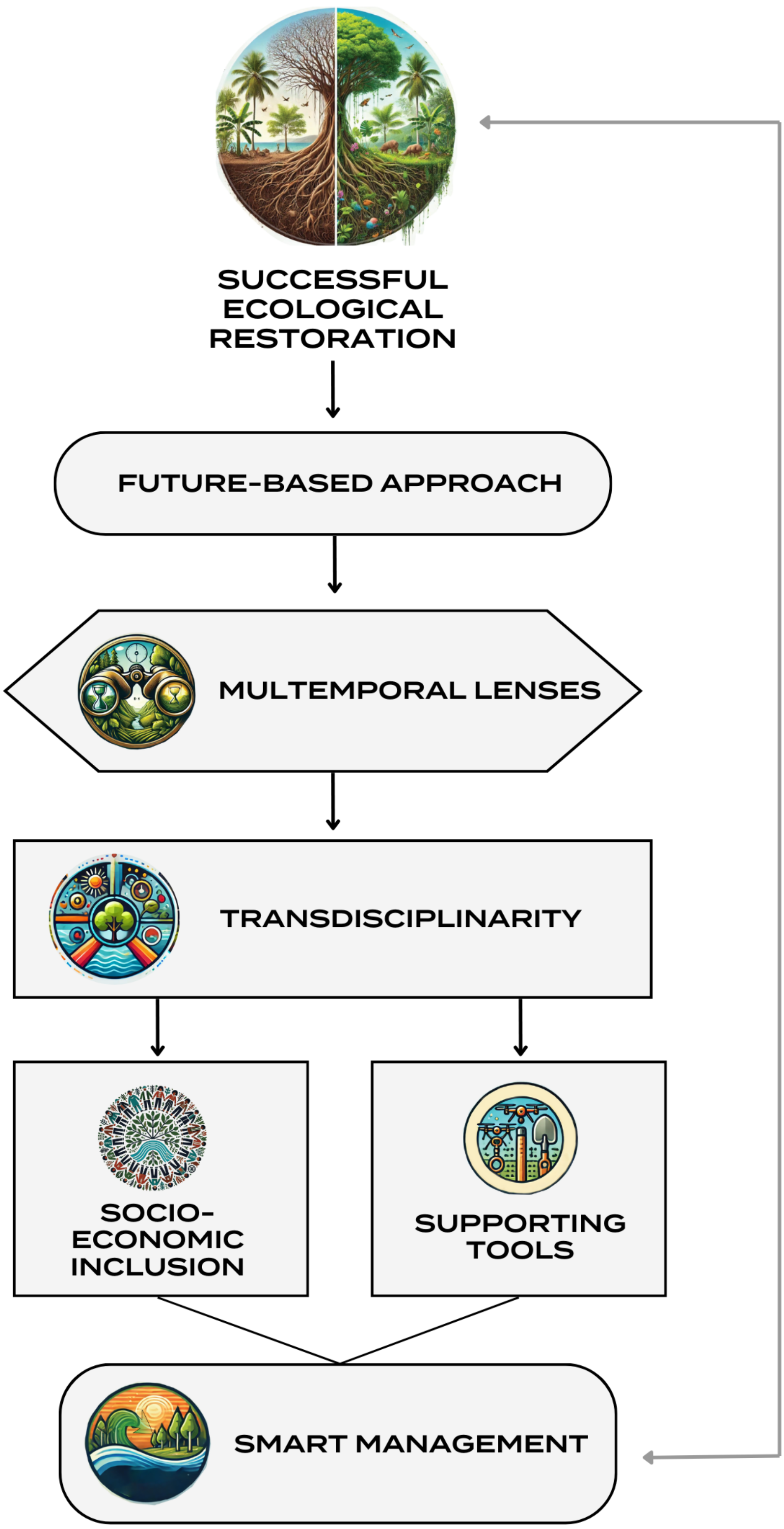

Figure 1: Framework illustrating the FaBRestor, the integration of multitemporal lenses, transdisciplinarity, socio-economic considerations, and technology leading to smart, adaptive management for lasting restoration success.

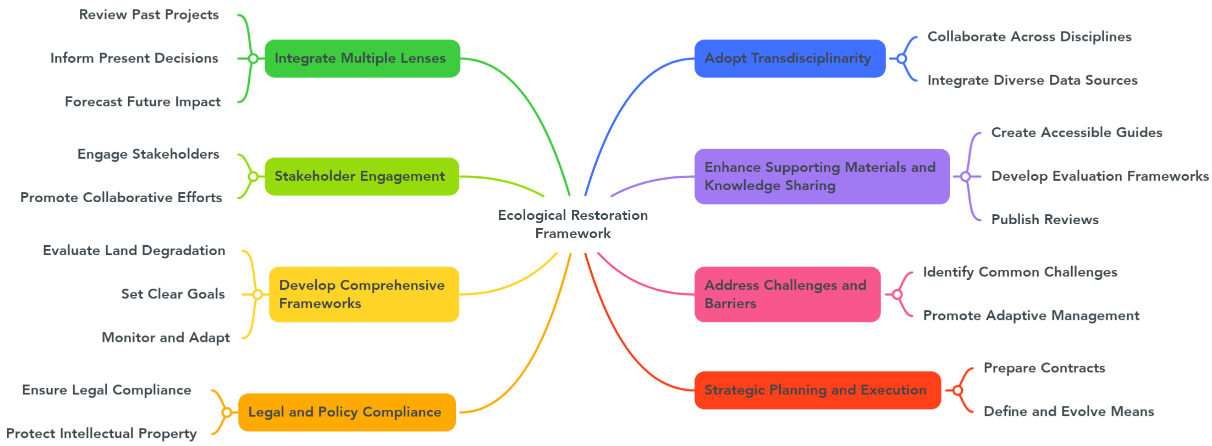

Figure 2: FaBRestor illustrating a comprehensive approach to restoration efforts. It emphasizes key elements such as integrating multitemporal lenses to inform decision-making, fostering stakeholder engagement, and ensuring legal compliance. The framework promotes transdisciplinary collaboration and the development of technology and models and addresses common challenges through adaptive management. Strategic planning and execution are at the core of this process, aiming for well-defined goals and evolving methodologies to enhance restoration success.

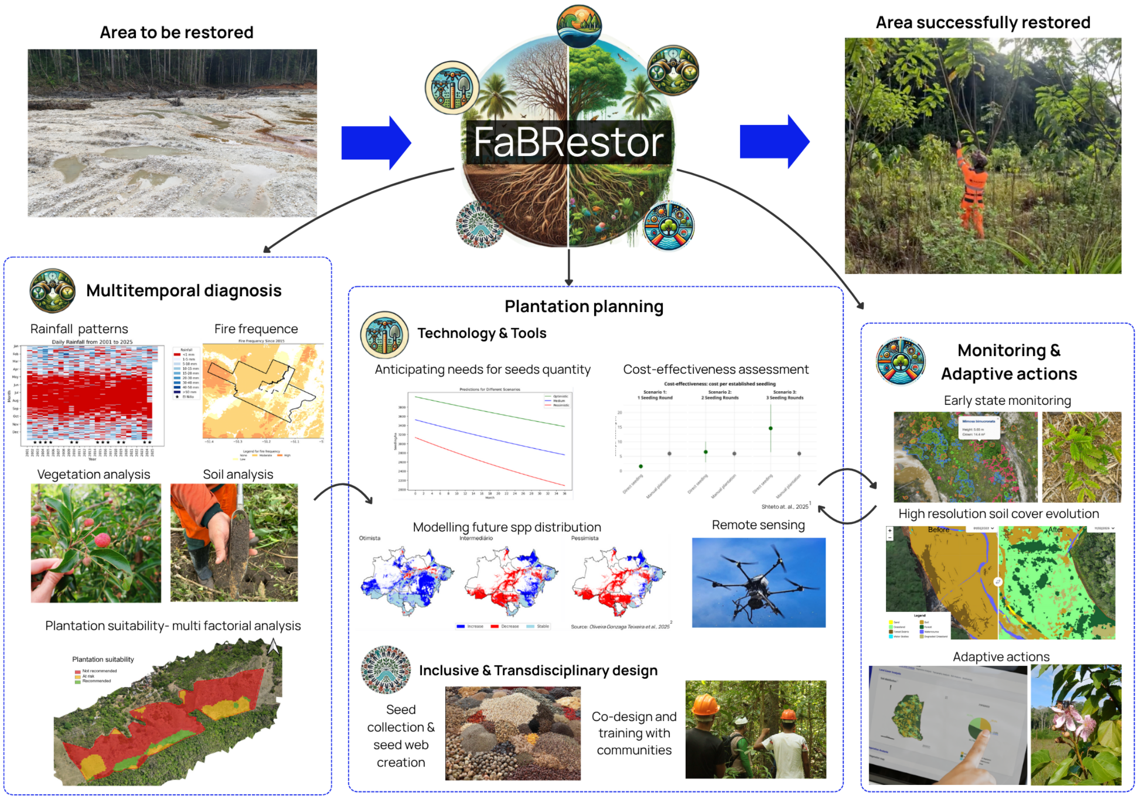

Figure 3: Illustration of FaBRestor applied in on-the-ground restoration projects. This figure illustrates how FaBRestor guides restoration efforts through a holistic approach. It counts with a multitemporal diagnosis that assesses environmental history, as well as current and future conditions, to inform decision-making during plantation planning. This planning phase integrates technological tools, transdisciplinary collaboration, and co-design processes. Finally, monitoring and adaptive actions ensure long-term success through high-resolution tracking and responsive interventions. Together, these steps embody FaBRestor's integrated, science-based, and participatory approach to ecological restoration.
[1] (Shteto et al. 2025)
[2] (Teixeira et al. 2025)
*The illustration made on multiple projects from different biomes of tropical forests
**In the top pictures, area from a degraded mining site under in French Guiana restoration

Figure 4: Location of restoration projects

1 Supplementary Material

1.1 FaBRestor: From concept to practice

Below is a detailed explanation of the elements inside the illustration of FaBRestor applied in on-the-ground restoration projects:

Multitemporal diagnosis

The Multitemporal Diagnosis assesses environmental change over time to guide present-day decisions. It combines the analysis of past patterns (rainfall, fire regimes) and past land uses, current conditions (vegetation, soil degradation), and future projections (climate scenarios) to build a full picture of ecosystem dynamics. A multifactorial plantation suitability analysis integrates terrain, soil, and hydrological data to identify priority areas.

By linking ecological history with future risks, this diagnosis informs planting strategies—such as soil preparation, species selection, and zoning—tailored for long-term resilience. It also reduces costs and failure risks by avoiding non-suitable areas and aligning interventions with the site's environmental possible trajectories.

Plantation planning

This step combines technical planning tools with collaborative design to ensure restoration strategies are both climate, resilient and socially grounded. Seed demand forecasting and species distribution models (SDMs) are used to simulate optimal seed quantities and how different species may respond to future climate scenarios. These projections, along with cost-effectiveness assessments and spatial tools like drones and remote sensing, guide strategies and species selection. Restoration strategies are co-developed through inclusive processes involving local communities, scientists, planners, and technicians. This ensures that plans reflect both ecological realities and local needs. The creation of seed networks strengthens supply chains and supports genetic diversity, while the integration of traditional and scientific knowledge fosters ownership, legitimacy, and long-term commitment to restoration efforts.

Monitoring & adaptive actions

FaBRestor emphasizes adaptive management. Monitoring is conducted from early stages to track key indicators of restoration success, using tools such as high-resolution mapping of soil cover and drone imagery. These data feed into continuous feedback loops, allowing for real-time adjustments to the strategy. Adaptive actions such as, species enrichment, or shifts in management approach can be implemented based on field observations and monitoring results. This ensures that the restoration process remains responsive, efficient, and grounded in evidence.

Table S1: Comparison between conventional restoration projects and those aligned with the FaBRestor framework. The table highlights differences across core dimensions such as time perspective, disciplinary scope, socioeconomic integration, technology use, and decision-making. For each dimension, a conventional and a FaBRestor-aligned approach are described, along with real-world project examples illustrating each approach.

Core dimension	**Conventional restoration**	**Future-based restoration**	**Example – Conventional**	**Example – FaBRestor**
Time perspective	Focused on static past baselines; short-term goals.	Learns from the past, acts in the present, plans for uncertain futures.	Norway spruce stands show high mortality when exposed to recent drought and bark-beetle outbreaks [1].	A forward-looking approach uses assisted migration informed by climate-envelope models, resulting in 20% higher stand survival through the same climate stress event. [2].
Disciplinary scope	Primarily ecological and biological perspectives.	Transdisciplinary: integrates ecology, technology, socio-economics, genetics, etc.	In degraded peatlands, restoration efforts focused only on rewetting, ecosystem may continue to function as a carbon source, indicating that hydrological measures alone are insufficient to restore peatland function [3].	An integrated design by a multidisciplinary team (hydrology, ecology, social science) optimises the water level to minimise methane flux and establishes a compensation mechanism for affected farmers. [4].
Socioeconomic aspects	Communities mainly overlooked; top-down implementation.	Emphasizes active community participation, local knowledge and benefit-sharing.	Top-down implementation where a government agency plants non-native mangroves without local consultation leads to low survival rates and degradation of fish nurseries, harming local livelihoods. [5].	Participatory co-design empowers local cooperatives to select native species, manage nurseries, and conduct paid monitoring, resulting in increased finfish and crab yields. [6].
Technology and tools	Limited use; often disconnected from practice.	Uses predictive models (e.g., AI, remote sensing) to explore plausible futures.	Restoration designs based on field observations and traditional silvicultural routines, absent predictive models, failed to anticipate species-specific responses and long-term growth patterns. It limited adaptability and increased risks under variable conditions. [7].	Drone-based multispectral imagery and standardized analysis protocols were used to map vegetation structure and fractional photosynthetic cover across dryland restoration sites. These tools enhanced the monitoring of plant functional types and vegetation dynamics across environmental gradients. [8].
Decision-making	Based on fixed trajectories, assumes predictable futures.	Acknowledges multiple possible restoration trajectories; applies adaptive pathways thinking.	In many semi-arid forest restoration projects, planting follows a fixed, calendar-based schedule driven by contracting timelines. This rigidity has led to widespread seedling mortality during recent droughts. [9].	In urban forest, ecological variables were used following different trajectories over time, with structural thresholds,such as canopy closure, groundcover shifts, and seedling dynamics. These predictable yet diverse trajectories enabled timing of targeted interventions, illustrating how recognition of multiple ecological pathways improves restoration planning. [10].

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Core dimension	**Conventional restoration**	**Future-based restoration**	**Example – Conventional**	**Example – FaBRestor**
Risk and uncertainty	Treats deviations as failures without corrective feedback.	Anticipates uncertainty; builds in resilience and contingency buffers.	In several South African woodland restoration efforts, deviations from predefined ecological targets were automatically treated as failures. There were no adaptive feedback loops or corrective strategies in place. As a result, unexpected outcomes halted implementation rather than guiding course corrections.[11].	The CFLRP restoration initiatives anticipated uncertainty and incorporated adaptive strategies. Using structured decision-making, ecological modeling, and long-term monitoring, these programs built resilience into restoration designs and enabled course corrections. Deviations were reframed as learning opportunities, integrating feedback loops, and engaging stakeholders leads to more robust restoration outcomes. [12].
Adaptability	Reactive, rigid, limited flexibility.	Proactive, iterative learning cycles with built-in feedback loops.	Invasive grass in savanna treated once with herbicide, without follow-up management, resprouted and spreaded rapidly, illusttating how intervations without monitoring area often ineffective. [13].	Invasive plant in savanna managed with rotational grazing, targeted herbicide, and patch-burning. Annual monitoring guided adjustments, preventing regrowth. This shows how integrated, adaptive strategies can effectively control invasion and support recovery. [14].
Monitoring and actions	Minimal feedback; sporadic monitoring.	Continuous, technology-assisted monitoring linked to actionable triggers.	Adopted in 1994, the U.S. Northwest Forest Plan relied on formal monitoring systems but lacked genuine feedback loops—management rarely adjusted plans based on collected data. Due to these limitations, the plan has been under revision since the 2010s to better integrate adaptive management and ecological responsiveness. [15].	Monthly drone imagery analyzed with machine learning achieved up to 82% accuracy in detecting "green attack" bark beetle infestations. This proactive, low-latency monitoring enabled targeted sanitation felling, helping contain outbreaks before they spread. [16].
Long-term sustainability	Risk of failure due to misalignment with future conditions.	Resilient and socially embedded, integrating ecological and social dimensions.	Large-scale forest restoration initiatives have failed to deliver lasting outcomes due to poor alignment with future environmental and land-use conditions, minimal stakeholder involvement, and lack of adaptive planning. Such missteps, especially the absence of social integration, frequently led to stalled or abandoned projects, highlighting the importance of designing restoration with dynamic, inclusive strategies. [17].	The Lake Tahoe West Restoration Partnership was built using co-produced science, long-term climate-informed landscape modeling, and structured stakeholder engagement. By combining ecological interventions, future climate scenarios, and participatory decision tools, the strategy was explicitly aligned with future conditions, reflecting a resilient, socially and technically integrated restoration design. [18].

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Core dimension	**Conventional restoration**	**Future-based restoration**	**Example – Conventional**	**Example – FaBRestor**
Outcome orientation	*Restoration* = return to former states.	*Restoration* = functionality, resilience, adaptability and co-benefits.	An experimental planting in Australia used locally sourced seeds to recreate historical forest conditions. After 15 months, seedlings from the local (wet-climate) provenance showed only 40% survival, compared to up to 70% for provenances from drier origins. Growth rates were also significantly lower. Ignoring environmental change and relying on historical baselines can lead to lack of adaptation and restoration failure. [19].	The SUPERB initiative explicitly incorporated future climate scenarios and local ecological conditions. Instead of reverting to historical spruce monocultures, restoration designs across twelve sites in this western German state use climate projections to guide mixed-species plantings, natural regeneration, and forest development types. Co-designed with diverse stakeholders and managed adaptively through monitoring, the approach enhances ecosystem services, resilience, and long-term functionality. [20].

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