Overcoming challenges in FLR initiatives
Authors: Mika Schwartz, Anna Macphie, Tim Rayden & Melissa Annetts

Abstract

This paper examines the most significant challenges currently faced by forest landscape restoration projects and explores successful solutions to these, which have been identified and utilised by teams working at the forefront of the field. Drawing on the experiences of forest restoration practitioners operating across a range of projects supported by the Trillion Trees ReForest Fund, and complemented by a literature review, this work identified three core challenges: land-use pressures, climate change, and financing restoration efforts. The paper examines how community engagement and the opportunity cost of land use are key to ensuring project success long-term. It then explores how climate change-induced changes in seasonal conditions and the increasing frequency of climate-driven events are impacting project planning and outcomes. Finally, the paper discusses the need to move beyond donor-driven approaches towards sustainable financial strategies and emphasises the importance of realistic budgeting for the true cost of high-quality restoration. Case studies from projects within the ReForest Fund portfolio of high-quality forest restoration projects present real-world examples of these restoration challenges, offering insights, actionable responses, and mitigation strategies. By bridging theory and practice, this paper highlights both the common obstacles faced by project teams and the solutions developed to implement and advance effective and sustainable forest landscape restoration.

Introduction

Almost 31% of global land area is covered by forests, totalling 4.06 billion hectares (ha) (FAO, 2020) which collectively provide a home for 80% of the world's wildlife (UN, 2023). Yet, these forests are under increasing threat. Between 1992 and 2022, 10.34% of global forest area, equivalent to 420 million ha, was lost (FAO, 2024).

Preventing deforestation is critically important for protecting forest ecosystems and the local communities and biodiversity that rely on them. Protecting forests also offer one of the most effective solutions to mitigate the impacts of climate change globally. It is estimated that if deforestation had been reduced globally by 10% from 2005-2030, 0.3-0.6 gigatons of carbon would not have been emitted per year (Kindermann et al., 2008). The Kunming-Montreal Global Biodiversity Framework, provides global targets to reach by 2030 to urgently reduce threats to biodiversity. Target 2 of this pivotal framework calls on nations to restore 30% of degraded ecosystems by 2030 (CBD, 2022). One way to protecting forests is through restrictive anti-deforestation policies. For example, Brazil's restrictive policies successfully reduced deforestation by 47% (Busch and Engelmann, 2017). Additionally, there is a need to increase the number of protected areas globally, which have been found to decrease rates of deforestation by 41% (Wolf et al., 2021). Preventing deforestation requires a multifactor approach and is vital for building a sustainable future for forests ecosystems and local communities. Another positive to FLR is that restored trees can help to protect landscapes from flooding by intercepting and slowing the water flow while the roots soak up rainwater. Additionally, trees can help to protect areas from erosion after heavy rainfall as the roots hold soil in place (Wambui and Evans, 2024).

However, unfortunately protecting the world's remaining forests and preventing further deforestation is no longer sufficient; we must now also work to put back the forests that we have lost. Combining forest landscape restoration (FLR) with deforestation prevention amplifies impact by protecting existing forests, while restoring degraded ones. FLR offers a framework for addressing the challenges of restoring degraded forest ecosystems while supporting local livelihoods long-term. FLR is guided by key principles; focus on landscapes, restore ecological functionality, allow for multiple benefits, recognize that a suite of interventions is possible, involve stakeholders, tailor to local conditions, manage adaptively, and avoid conversion of natural ecosystems (FAO, 2021). These principles form the basis for any restoration initiative and are carefully considered in each of these challenges, solutions, and case studies.

Successful forest restoration is often hindered by complex environmental and socio-political barriers. However, experience in implementing FLR initiatives is growing around the world, and, where challenges have been addressed and overcome, it is important that lessons are shared within the FLR community. This paper uses the experiences of 24 Trillion Trees ReForest Fund projects, implemented across 14 countries between 2020 and 2025, to examine and review the lessons learned from implementation. Common challenges reported by the projects were grouped into three broad categories; land-use pressures, climate-driven changes to ecosystems, and financial sustainability. This paper examines each challenge by summarising related knowledge and research from the literature and pairing this with a Trillion Trees case study to provide complementary context from an initiative's first-hand experience of looking for potential solutions to the identified challenge. It is important to note that due to forest landscapes' complexity, context-specific and localised solutions are commonly required; each landscape, community, and ecosystem experiences a unique combination of challenges and therefore each potential solution will vary in its effectiveness, depending on local context and variables.

<u>Land Use Pressures</u>

Intro:

Local communities and stakeholders are central to the principals of FLR, enabling projects to make a tangible impact on the landscapes they look to restore. Local communities rely on forests for a multitude of resources, both for their subsistence and livelihoods. FLR initiatives, however, often face socioeconomic challenges in implementation, especially when local needs, land rights, and local priorities are not integrated into planning (Shelton et al., 2024). Engaging local communities is essential for the delivery of successful and sustainable FLR initiatives, as motivation is driven by clear benefits, secure land rights, and meaningful participation in project decision making (FAO, 2021). Understanding these landscape-specific pressures is essential for FLR approaches that are socially inclusive and economically sustainable and long-lasting.

1. *Community Motivation and Involvement*

Intro:

Community motivation and inclusion are critical but often challenging aspects of successful FLR initiatives. Globally, 1.6 billion people live in rural areas within 5km of a forest, many of which are in low or middle-income countries. A large proportion of these people are impoverished, relying on forest goods and services for their daily needs (Newton et al., 2020). Deforestation, land degradation, and displacement from their traditional lands negatively impact communities who depend on resources from these areas to meet their basic needs (Hermans and McLeman, 2021). Restoring forests can directly enhance local livelihoods by improving access to ecosystem services, diversifying income sources, and increasing food and resource security when designed in collaboration with communities. A rights-based approach to FLR centers on recognizing and upholding the rights of local communities and other stakeholders in the restoration process. This approach ensures that FLR initiatives are not only ecologically sound, but also socially just and equitable, promoting sustainable and inclusive outcomes. It is essential that FLR initiatives prioritize securing and clarifying the rights of community members in each project decision to ensure their benefit and participation (CIFOR, 2017). Without meaningful engagement and benefits for local people, restoration efforts risk being harmful and/or unsustainable. Many aspects contribute to strong community involvement in conservation, such as financial incentives, a desire to improve local environments, a sense of responsibility towards future generations, and long-term commitment, which is crucial for developing sustainable livelihoods and enabling the success of the project. Significantly, there is increased risk of project failure when local communities and their needs are not considered in project design and implementation, including clear communication of the goals of the initiative (Höhl et al., 2020). et al., 2020).

Challenge/s:

FLR initiatives frequently take place in landscapes that are used for production, such as agriculture, or livestock grazing. Effective restoration can reverse land degradation (ex: soil erosion), while generating co-benefits for the land users (ex: improved soil fertility). However, this requires a change of land use practices, which is not easy to achieve in rural environments where traditional norms are embedded, or where restoration measures may result in a short term loss of revenue for a longer term gain in sustainability. Community buy-in, labor, and long-term stewardship, are essential for restoration. Without long-term community engagement and benefit from the project, FLR initiatives will not succeed (Ceccon et al., 2020). If communities are not meaningfully involved, tree planting and other initiatives may be instigated but later neglected, removed, or replaced.

There are numerous issues that can plague a project's relationship with their local community. One common issue that occurs within projects is that communities are sometimes included only as implementers, not co-designers or decision-makers. This lack of ownership weakens long-term commitment and limits the relevance of restoration strategies to local realities. Often, projects involve community members for short-term work in the field labor and do not focus on building long-term empowerment or sustainability, to the detriment of the project. If communities do not have strong governance or institutions that can lead or benefit from restoration efforts long term (like co-ops, land-user associations, or local NGOs) they will be less able to influence land use decisions (Ceccon et al., 2020). This is the phenomenon of locals being consulted, but not empowered (Lawry & Ranjatson, 2021). Stakeholder involvement challenges such as these make it difficult to build cooperation and maintain community engagement.

Additionally, communities may be sceptical of FLR practices without understanding its benefits. In many negotiations, local land users often lack the scientific knowledge that tends to shape FLR discussions and may be unwilling to adopt new or unproven practices. This low awareness can lead to apathy or mistrust in the project.

Another critical consideration to FLR goals is integrating traditional ecological knowledge (TEK) within projects. Each community has its own TEK embedded in their culture, beliefs and livelihoods. These distinct beliefs include land use, fire management, soils, and climate. Importantly, TEK may not align with restoration objectives. Excluding TEK in restoration reflects a bias towards scientific expertise, often at the expense of local culture, which has its own adverse effects. For example, when TEK is excluded key species important to communities, for medicine, food, and culture, may be left out of restoration planning (Long et al., 2020). Ignoring TEK often marginalizes local voices (Whyte, 2013), reducing their motivation to support the initiative.

Furthermore, recurringly projects can ignore gender equality, and the inclusion of vulnerable groups in FLR planning (Ceccon et al., 2020). Some of these vulnerable community members include women, youth, or marginalized groups. This can lead to disengagement or internal conflict, undermining restoration efforts.

Solutions:

To make FLR work, projects must engage with the unique political and social realities of the landscape, building not just resilient forests, but also sustainable relationships and livelihoods. This involves integrating technical restoration solutions with community values, long-term support, and local knowledge. Pacheco et al., (2022) outline several foundational principles to ensure collective collaboration with local communities in forest restoration initiatives, including: understanding the local context; ensuring free, prior, and informed consent; co-designing initiatives with communities; implementing together with local actors; and recognizing and protecting land and resource rights.

It is critical to understand local TEK, beliefs, and land-use practices to develop culturally appropriate FLR strategies that will be effective (Charnley et al., 2007). Applying TEK to restoration projects can help to restore ecosystems while simultaneously safeguarding local traditions and beliefs (Tran et al., 2025). For example, Haq et al., (2023) used TEK to prioritize the tree species used in their restoration project in the elephant corridor in Dibru Saikhowa National Park in Assam, India. The local community was involved in each stage of restoration, selection of land, planting, and monitoring seedlings. The project gathered local community knowledge about native woody tree species, such as traditional uses, wildlife habitat, and forage through interviews, group discussions and observations. The project provided field training and compensation to the local community, importantly including women, to aid in planting and monitoring of the restoration project. Community-based restoration initiatives such as these can create jobs (nurseries, planting, monitoring) and increase local autonomy over land use decisions (FAO, 2022).

Restoration plans should be screened for any gender-differentiated matters and encourage active involvement of all groups in restoration efforts through capacity building and enabling participation (Broeckhoven & Cliquet, 2015). For example, WWF works in the Usambara Mountains with an all-women nursery cooperative that shares management, financial roles, decision-making, and profits equally. This project engages local communities and empowers women both economically and socially, while restoring forests through spice tree agroforestry.

Fundamentally, projects must hold community leaders, NGOs, government officials, and other stakeholders accountable for their actions in FLR. Throughout project timelines, it is crucial to strengthen collaboration and communication across governance levels, sectors and social groups to support FLR efforts. A key priority for effective governance in FLR is empowering local communities to actively participate throughout the project planning, implementation, monitoring and evaluation stages (McLain et al., 2017).

Case Study:
[WWF Kenya – NB this case study is with the project team for final approval]

Overview
The Kaptagat forest restoration project is a collaborative effort to rehabilitate 1,000 hectares in Kenya's Elgeyo Hills-Cherangany Ecosystem. This critical landscape includes five gazetted

(fenced off) forest blocks and farmlands covering 32,000 hectares (including 21,000 hectares of protected forest). The ecosystem lies within the Lake Victoria and Rift Valley drainage basins and is a significant local water source for over 134,000 people, providing water for irrigation, industrial and hydro-power generation. The project is restoring degraded forest areas in protected public land with legal ownership land tenure agreements. The project aims to reverse deforestation through agroforestry, climate-smart agriculture, and clean energy solutions like biogas and solar water pumps. The restoration work supports biodiversity, water conservation, and food security for local communities.

Challenges and solutions

A challenge in the landscape is the increase in population size, exerting overdependence on local resources and intensifying threats to sustainable management of the region through increasing the demand for water, energy, charcoal production, firewood collection, illegal logging and harvesting of exotic trees, Bringing the community together, building understanding and involving all stakeholders in every level of the process was critical to the success of the project. Problems which needed tackling included:

- M any community members had experienced a 'top-down' approach to addressing issues in the community including restoration, giving the perception that the approach had been imposed on them
- A high level of mistrust due to past failed projects in the ecosystem and exclusion of the community in decisions and management of forest resources
- Competing interests amongst different community groups eg. herders, farmers, youths; saw each other as a threat and not as allies in forest conservation
- Dependency on the forest as a source of livelihood by the community members e.g. firewood for domestic use and sale, herbal medicine collection, grazing among others
- Information gap among the community members on the link between forest conservation and ecosystem services e.g. water availability, carbon sequestration, climate change, biodiversity

The challenges were addressed through engagements with the community at different levels including community chiefs, local opinion leaders including the political class, elders, youth and faith leaders. Through public gatherings (called 'barazas') consensus was built and with an understanding that conservation needs the efforts of all stakeholders and their voices are important in making a difference in management of forest resources. Awareness was created and information gaps filled with the support of Kenya Forest Service staff.

Transparency in all community engagements was the cornerstone of all deliberations. Complete disclosure and openness created trust and ensured the community were part of decision making.

The project focuses on involving local communities in tree planting, maintenance, and nursery development. Through the Kaptagat Community Forest Associations (CFAs), communities are the key actors in the Kaptagat project team as any action happening in the forest affects them both directly and indirectly, so they are therefore central to project implementation and beyond.

The project focuses on planting native species, such as Bamboo and Syzygium species and *Juniperous procera*. CFAs collect the seedlings from natural forests as wildlings and then raise and care for the seedlings in nurseries.

The project team promotes environmental restoration, economic opportunity, and long-term community wellbeing. Key actions include training 120 farmers in climate-smart agriculture and biogas production, installing solar-powered water pumps, and planting native trees to control soil erosion and preserve biodiversity. The project is adapting to agroforestry practices, designating areas of land for the community to use, for example, to collect hay to feed livestock. The collaborative efforts among various stakeholders ensure that the restoration activities are well-coordinated and sustainable, creating a resilient and thriving ecosystem in Kaptagat.

Several key events and gatherings were pivotal in forming and strengthening the CFAs in Kaptagat:

- Annual tree planting events saw over 500 members participate in the 1st edition in 2017. This annual event has become the turning point for community buy-in. It has helped to shift the mindset from "government project" to "our forest, our future." The annual editions have evolved into high-profile gatherings reinforcing collective identity and momentum through hands-on collaboration.
- Public Barazas and Sensitization Meetings; Facilitated by the Kenya Forest Service (KFS), and the local chiefs and held in forest adjacent villages to discuss forest challenges, legal frameworks (e.g., Forests Act 2005), and CFA benefits. Early barazas in Kaptagat Forest focused on mapping user groups (e.g., beekeepers, firewood collectors), building trust and consensus for participation

Members of the five CFAs involved in the project have also been trained in governance, conflict resolution, resource mobilization, and communicating impact, allowing them to play a crucial role in conservation. CFAs are trained on Monitoring and Evaluation (M&E), where each CFA selects one M&E champion to spearhead the work. Monitoring of seedlings and maintenance of restoration sites through the CFAs has led to an enhanced seedling survival rate of 93%. One reason for this success is the CFA members utilizing tree establishment and livelihood improvement system (TELIS) where the community can plant seasonal crops (eg. beans, peas, potatoes) in between the restored trees. This has ensured that farmers benefit from crop harvests while the seedlings remain weed free and protected from livestock damage. The team conducts Organizational Capacity Assessments of CFAs to determine whether the CFAs have benefited from capacity building initiatives and to identify gaps in support for the community that the project can then target to further fill. Strengthening the capacity building for CFAs has deepened the community's understanding of conservation roles, improved governance structures, and enhanced collaboration with the Kenya Forest Service which ensures accountability as duty bearers.

2. *Opportunity Cost of Land Use*

Intro:

Opportunity cost refers to the economic value that landowners or communities forgo when they choose a restoration approach over more profitable land use. This is a central economic dilemma in FLR, and restoration efforts must offer competitive and sustainable economic alternatives to make restoration viable and appealing for landowners and communities.

Recognizing the opportunity cost enables policymakers and stakeholders to make more informed decisions about land use, striking a balance between ecological benefits and economic needs.

Challenge:

Tenure is a significant and often underestimated FLR matter (Shelton et al., 2024). The term tenure refers to how land and its resources can be accessed, who the beneficiaries of the resources are, the length of the contract, and terms (Robinson et al., 2014). Tenure insecurity can impact the roles of stakeholders as well as their long-term rights and returns (Mclain et al., 2021). In some cases, tenure security issues can result in the displacement of communities, often for already marginalised groups (Shelton et al., 2024). Women and migrants are increasingly likely to have insecure land tenure (Mclain et al., 2021). Legalities of policies are frequently inconsistent for rights owners (Sunderlin et al., 2014), leading to confusion and bureaucratic barriers directly impacting the livelihoods of individuals.

Another issue with the opportunity cost of land is that it is challenging to make a strong economic argument for restoration to landowners when government policies actively support land degradation. This is particularly evident in agriculture, where many governments provide subsidies to farmers to purchase fertilizers, seeds, and other agricultural aids (OECD, 2010). A total of $700 billion per year is spent globally by governments on agricultural subsidies in 2020 (FAO, 2021). When such incentive structures are widespread, they can undermine the economic case for forest restoration.

Building on this, often communities' motivations and economic goals do not align with conservation goals. Conservation measures, such as controlled burns or limitations on resource extraction, may generate resistance among local communities who rely on these land-use practices (Santini & Miquelajauregui, 2022). Another point of dispute with conservation outcomes is the planting of economically or ecologically beneficial species. Chechina & Hamann (2015) found a strong negative correlation between species that were ecologically beneficial and those that were socioeconomically preferred. In forest restoration initiatives it is common that threatened native tree species, which would be preferred for ecological objectives, are not considered profitable, fast-growing, or useful in daily life, so even if they are important for the ecosystem, the community may not be motivated to cultivate them.

Solutions:

Tenure security has been found to motivate community engagement in restorations as well as allows landholders to benefit from their conservation investments (McLain et al., 2017). Tenure security provides landholders with confidence that they will benefit from FLR. FLR efforts must integrate the recognition and actualization of land rights to reduce barriers to restoration. Formal legal recognition can protect communities from being displaced or undermined when land value rises. These interventions must include marginalized groups in the recognition and actualization strategies of securing land tenure (McLain et al., 2021).

Sustainable agroforestry offers another socioeconomic approach to reduce disparities between forest restoration and agriculture. This strategy can provide local communities short-term revenue as well support ecosystem biodiversity (Kumar et al., 2024). Agroforestry has been shown to increase productivity of agriculture, for example Islam et al., 2024 found a 2.74 increase in land productivity across 40 agroforestry programs in Madhupur Sal, Bangladesh as well as being economically profitable, and improving soil carbon content, nutrient availability, and pH.

The adoption of sustainable agriculture is also taking place in the Atlantic Forest in Argentina, Brazil and Paraguay. Here, BirdLife International and SAVE Brasil are planting and harvesting organic yerba mate, a traditional drink in Argentina, Paraguay, Uruguay and Brazil, which is increasingly in-demand in the US and Europe. Yerba mate plants are native to the Atlantic Forest and can grow effectively in a mixed agroforestry system which allows producers to have a forest friendly crop as well as generate important income while doing so. Similarly, in Madagascar, WCS leads a dynamic agroforestry system, integrating cocoa, vanilla, cloves, and native trees, to restore over 1,300 ha of degraded land, support biodiversity in and around Makira Natural Park, and improve local livelihoods through sustainable, conservation-driven farming.

To address the opportunity costs associated with shifting land from productive use to restoration it is essential to ensure that local communities receive both short term and long-term economic benefits. In some cases, it may be possible to achieve this by establishing markets for ecosystem services, such as carbon credits, water regulation, or biodiversity conservation (discussed in the following section in more detail) or through government-funded subsidy schemes that reward landholders for adopting sustainable and restorative practices. Governments can redesign subsidy approaches in agriculture to invest in low-carbon agriculture to increase sustainable investment long-term as well as avoid land degradation, among many benefits (Sánchez, 2022). For example, in Brazil, their rural-credit policy framework has a RenovAgro plan that promotes agricultural practices that reduce greenhouse gasses. The plan promotes sustainable agricultural practices such as, crop-livestock-forest integration systems, with a low interest rate. The financed plans have resulted in a reduction of 193.67 million Mg CO_2eq from 2010-2020 (IISD, 2024).

Case Study:

Overview

In the Madidi-Tambopata Landscape, restoration focuses on the protection and recovery of a forest landscape of global importance that spans Bolivia and Peru. In Peru, the project restores degraded areas of montane forests (yungas) on coffee farms owned by local families. The families sign conservation agreements with the Wildlife Conservation Society (WCS), in which they commit to halting forest conversion into agricultural land in exchange for technical and financial support to improve the productivity and quality of their coffee, as well as for the long-term maintenance of restored areas and their forest zones. The project aims to plant 20,000 native trees in 20 hectares of degraded land and, to a lesser extent, in agroforestry systems. This seeks to improve forest connectivity, support biodiversity conservation, enhance microclimatic conditions, and boost sustainable coffee production for the benefit of the local community.

Sixty coffee-growing families, 29 of whom have conservation agreements, committed to participate by allocating part of their private land ('finca' in Spanish) to conservation, restoration, and improving their coffee farms through the establishment of agroforestry systems. WCS has signed a contract with ZOOPLANTS, a local Peruvian company, to produce 22,500 native seedlings from 11 species: Andean walnut (*Juglans neotropica)*, cedar (*Cedrela odorata*), regional laurel (*Nectandra reticulata*), coffee laurel (*Cordia alliodora*), mahogany (*Swietenia macrophylla*), requia or male cedar (*Cabralea canjerana*), incense tree (C*lusia pachamamae*), bamboo (*Guadua weberbaueri*), quina (*Cinchona officinalis*), Amazonian pine (*Schizolobium amazonicum)*, and shaiña (*Colubrina glandulosa*).

Challenges and Solutions

A challenge faced in restoration work with native species is that the local population often prefers to plant exotic trees (e.g., pine and eucalyptus), promoted by government initiatives. These species have a known local market value and fast-growing characteristics, although they provide fewer benefits for soil health and biodiversity conservation. This has led the population to develop practical and detailed knowledge about these species, including the conditions that favour their growth and their development time, among other aspects. On the other hand, the knowledge of the local community about native species is limited, since most of its members are Quechua and Aymara indigenous people who migrated from other Andean areas of the Puno region,, and therefore are not familiar with the local flora. Finally, among some locals there persists the belief that native species such as Andean walnut (*Juglans neotropica*), cedar (*Cedrela odorata*), and Amazonian pine (*Schizolobium amazonicum*) "exhaust" the soil, and therefore they do not want to include them in coffee agroforestry systems. While this perception is not entirely correct, it represents a concern that must be considered, especially when implementing agroforestry systems.

In this context, WCS has designed strategies to encourage the use of native species and address the concerns of coffee-growing families. First, the project team works with families who have greater knowledge of native species or who are willing to try them, combining tree planting in non-cultivated areas they wish to restore with agroforestry systems to incorporate nutrients and shade into coffee-growing. Some of them are more willing to try native species because they believe exotic species, such as pine, take more than a year to decompose without enriching the soil, and that pine trees often break under strong winds while growing, damaging coffee plants. These families act as pioneers and references within the community, with the potential to influence their neighbours and motivate greater adoption of native species. In addition, responding to local concerns and as a strategy to improve the perception and value of lesser-known native species, the project team has sought to reach agreements with families on the proportion of species to be planted under agroforestry systems, delivering more trees recognised locally for their benefits, such as Amazonian pine (*Schizolobium amazonicum*), cedar (*Cedrela odorata*), and bamboo (*Guadua* sp.). By promoting native species and sustainable land use, the initiative supports both environmental objectives and the long-term well-being of forest-dependent communities.

Many families have noted further benefits to the agroforestry approach including restoring soil, generating future income when timber species reproduce, supporting beekeeping, improving habitat for wildlife, improving air quality and contributing to water care. This region is one of the most biodiverse on the planet, home to thousands of plant and animal species, including spectacled bears, jaguars, giant otters, and endangered primates. The project seeks to halt deforestation, restore degraded lands, and safeguard critical habitats that support biodiversity and climate stability. Working with Indigenous peoples, local communities, and government agencies, the initiative promotes sustainable land use under a watershed management approach, stronger forest governance, and alternative livelihoods—including coffee produced by these farming families, which enjoys growing global appreciation due to its profile, quality, and flavour.

<u>Climate Change</u>

Intro:

The current climate crisis presents significant challenges to forest ecosystems and biodiversity, and the communities that rely on them. In 2024, the global surface temperature reached 1.5°C above the 1850-1900 average. This marks a critical threshold that could indicate the world is on track to exceed 2°C, a milestone that carries significance in the context of the Paris Agreement, which set the goal of limiting the global surface temperature to below 2°C, preferably to 1.5°C, above pre-industrial levels (WMO, 2025). The frequency and strength of seasonal changes as well as natural disturbances are both increasing (Yao, 2022) (WMO, 2021). Climate change makes it harder to predict future forest conditions and select appropriate tree species for restoration. What might thrive in a particular area today might not be suitable in the future due to changing climate parameters. Restoration strategies need to integrate both climate change mitigation and adaptation strategies to changing seasonal conditions and natural disturbances. While these two challenges have similarities, they require different ground approaches to respond. These considerations need to be integrated into all stages of forest restoration planning, from site and species selection to management practices.

1. *<u>Changing Seasonal Conditions</u>*

Intro:

Intensifying seasonal changes due to climate change pose significant challenges to forest restoration efforts. These changes can complicate restoration strategies, including affecting tree growth, species distribution, and ecosystem resilience. Well-functioning forest ecosystems, with greater biological diversity and covering heterogeneous landscapes, are more resilient to the impacts of climate change (Baig et al., 2015). It is imperative that FLR projects seek to re-create resilient landscapes that can be robust in the face of climate-induced seasonal changes.

Challenge/s:

Restoration efforts often rely on predictable precipitation patterns for tree planting and establishment. Climate change is disrupting these patterns; rain may come too early, too late, or not at all, leading to poor seedling survival and failed planting seasons. Extended drought stress combined with heat events can severely impact forest ecosystems and restoration efforts. These events cause physiological stress, increasing mortality in young or drought-sensitive species (Lalor et al., 2023). Drought and heat stress may also impact restoration success as seedlings struggle to survive under extreme conditions (Gardiner et al., 2019). As temperatures and rainfall patterns change, the climatic suitability of native tree species may shift. Meaning that trees planted today might not thrive in the same location in the future. This complicates species selection and long-term planning. It requires some knowledge of predicted future climate conditions and means restoration initiatives should make provisions for higher levels of seedling mortality, and plan for repeated replanting(s).

Similarly, climate change is shifting forest growing seasons, impacting tree phenology (biological cyclic events) and regeneration. In forests, phenology tracks when key life cycle events occur including budburst, flowering, and fruiting. Forest greening has led to earlier spring and autumn phenology in temperate and boreal forests, ultimately affecting seasonal leaf production and ecosystem dynamics (Guo et al., 2024). Additionally, earlier springs have been found to result in phenology changes in trees, such as advanced bud burst and flowering (Parmesan and Yohe 2003). These changes can have cascading impacts such as on species interactions (ex: pollination), ecosystem functioning, carbon cycling, and biodiversity (Singh, 2024). This has implications for projects collecting seeds from natural forests, as they will need to adapt nursery rhythms to seed availability.

Solutions:

It is imperative to update restoration planning to include climate-smart adaptation actions. Although plants can have adaptive responses to climate change extremes, there are constraints such as limited genetic variation and habitat fragmentation causing disrupted gene flow (Anderson & Song, 2020). Since the adaptability of forests to climate change effects is unknown, strategies must be adjusted to decrease forests' vulnerability to these effects (Rizvi et al., 2015).

One way to address this is by planting climate-resilient tree species, which have low sensitivity to change and/or a high capacity to adapt to change (Lee et al., 2019). Fremout et al. (2022) introduce a Diversity for Restoration (D4R) tool, which helps identify climate-resilient tree species and seed sources for tropical forest restoration by integrating ecological, climatic, and functional trait data. This scalable and free tool supports evidence-based decisions for ecosystem restoration projects in the face of climate change.

Furthermore, monitoring and evaluation are critical to adapting FLR projects to climate change. One such strategy is via monitoring forest hydrology through sensor technologies, remote sensing, or interdisciplinary approaches. This will reveal climate change effects to water availability, allowing for the implementation of mitigation strategies. Forest monitoring and evaluation can enable early detection of climate-related changes, thus enabling FLR projects to respond with adaptive responses (Singh et al., 2024). For example, a study based in the southwestern U.S. ponderosa pine forests that monitored drought-induced tree mortality led to adaptive treatments like thinning and fuel reduction to reduce water stress and drought vulnerability (McCauley et al., 2022).

Crucially, FLR initiatives can support agroforestry and local community businesses through the uncertainty of a climate crisis. There are many innovative adaptive agroforestry advances including tree buffers around crops which help to moderate the microclimate, through shading and cooling, improve water-use efficiency, ultimately reducing heat stress and improving crop yields (Kumar et al., 2024). Furthermore, FLR depends on engaging stakeholders and incorporating local communities' knowledge into the research and planning process of climate change monitoring and mitigation to forests (Singh et al., 2024).

St Laurent et al. (2021) propose a transformative approach to implementing climate adaptations to conservation; resistance, resilience, and transformation, the R-R-T scale. Resistance being to prevent or minimize changes, resilience focuses on helping ecosystems recover and return to its previous state, and transformation refers to actively guiding ecological change toward anticipated future states.

Case Study:

Overview

In the Jovel Valley Basin in the Highlands of Chiapas, Mexico, a restoration project led by Birdlife International partner, Pronatura Sur, addresses the environmental challenges this region faces, including rapid urban growth, pollution, and climate change. The overall goal of the project is to propagate and plant at least 200,000 native trees and restore 1,000 hectares of forest ecosystem over the next five years.

The project seeks to restore ecosystems, improve water quality, support endangered species like the Golden-cheeked Warbler (*Setophaga chrysoparia*) and Guatemalan Fir (*Abies guatemalensis*), and boost climate resilience. Through community, government, and corporate collaboration, it aims to enhance both environmental health and local livelihoods. Jovel Valley Basin restoration is based on a community-centred approach that addresses environmental degradation from urban growth, illegal logging, and climate change. Collaborations with authorities and local businesses provided support and resources. By combining conservation with community engagement, the project is boosting biodiversity, improving water quality, and create resilient ecosystems that benefit both nature and people.

This project is restoring forests on large private properties using a mix of different native species through typical planting as well as enrichment planting.

Challenges and Solutions

In the past two years the project team has been faced with high temperatures in an unseasonable time, an intense drought in the dry-season, and strong frosts in the colder months, which have all impacted plant and seedling stress as well as caused seedling mortality.

Preliminary reports indicate that the duration of dry periods has been variable but with increasing severity in recent years. In particular, the 2024 season was considered the most critical, extending into June - longer than the usual period. This extension not only created greater water deficits in both nursery and field but also disrupted synchronization with the rainy season, generating a longer window of vulnerability for newly planted seedlings. In the field in 2024 mortality reached approximately 50% of the seedlings established.

In the nursery, stable production was maintained thanks to irrigation and management measures, and any adjustments in numbers were made through continuous germination of additional seeds. A water storage infrastructure was put in place – a 30,000-litre ferrocement tank was installed, with a storage capacity lasting approximately one month. The nearest water source is located nearly 500 meters away, making the tank essential for maintaining irrigation during critical periods. In addition, a nebulization system was introduced and installed in all nursery sheds, ensuring more efficient and uniform distribution of water during drought conditions. Frost nets were also installed in the nursery sheds. While this reduced cold stress, some plants still dried out once transplanted to the field and on several restoration plots, clay-rich soils meant that rainwater did not soak through into the soil during the first rains. This resulted in reduced soil moisture retention, directly affecting the survival of planted seedlings.

At this stage, no specific mitigation measures were implemented in the field to address drought impacts on planted seedlings. This gap highlights a critical vulnerability in the restoration process and points to the need for soil management interventions (e.g., mulching, soil amendments, or micro-catchments) in future cycles.

Two additional problems were reported:

- Earlier seed maturation, which represents a risk for collection since some species may not have reached full physiological maturity when harvested, compromising subsequent germination. This phenomenon requires adjustments in seed collection calendars and closer monitoring of the plant cycles by species.

- Sheep coming into restoration sites was noted, adding further pressure on established seedlings and reducing survival probabilities. This type of disturbance by animals compounds climate impacts, increasing project vulnerability.

Recommendations by the project team for other similar restoration projects, include detailed observation of seasonal changes. While literature and historical records provide a baseline, field reality shows that climatic patterns are shifting rapidly. Restoration planning must therefore include ongoing monitoring rather than past climatology alone. Another recommendation is to avoid planting outside the rainy season, as this severely compromises survival rates. Finally, it is recognised that implementing preventive measures—such as irrigation infrastructure, frost protection, and water storage—increases operational costs. However, these additional expenses should be considered essential investments to ensure seedling availability and successful establishment in the field.

2. *Increased Occurrence of Climate-Related Events*

Intro:

Climate change effects have increased the frequency and severity of natural disturbances, furthering the degradation of forests. For example, periods of heat stress can combine with other risks like fires (Brando et al., 2014) or insect and pathogen outbreaks and amplify the impact on forests (Hartmann et al., 2018) The success of FLR depends on forest permanence to climate-driven risks such as fire, drought, and insect and pathogen outbreaks (Williams et al., 2020).

Challenges:

Rising temperatures and changing precipitation patterns are leading to more frequent and severe climate-related events, such as droughts, wildfires, and pest infections (Singh et al., 2024). Wildfires are the second leading cause of forest loss (Sims et al., 2015). The occurrence of fires is increasing in tropical, temperate, and boreal forest (Andela et al., 2017). In 2024, wildfires driven by climate change led to 6.7 million ha of tropical forest loss and an 80% increase from 2023 (Andreoni & Villegas, 2025). These fires can become feedback loops, combined with heat stress as landscapes become increasingly dry and flammable (Bowman et al., 2020). This pattern increases the rate of deforestation and disrupts the restoration work of FLR projects as post-fire recovery is also uncertain. Storms and hurricanes can make restoration riskier, especially in coastal or high-wind landscapes. For example, in tropical forests, extreme events like the 2015–16 El Niño led to elevated seedling mortality (~11%) in wetter ecosystems

(Browne et al., 2015). Furthermore, the frequency and intensity of extreme floods in mid-latitude and tropical human regions have been increasing (IPCC, 2014).

Elevating global temperatures are increasing the occurrence of pest and disease outbreaks in forests. This occurs for a multitude of reasons including that warmer temperatures allow more insects to survive for seasons they wouldn't normally and sometimes allows the pests to breed more generations than they would typically (Buckley et al., 2017). Also, the increasing temperatures of areas that are not regularly warm causes pests and diseases to move into these areas where the trees lack the defenses to protect themselves (Kirilenko & Sedjo, 2007). All climate-related events can cause significant impacts on communities that rely on the forests, such as loss of livelihood, forced displacement, and food and water insecurity. Furthermore, a paramount challenge caused by climate-related events is that they can be very either unpredictable, sudden, or both. For example, wildfires can occur quickly, while others, such as disease outbreaks, are slow moving (Vose et al., 2018). This can make planning for these events even more challenging.

Solutions:

The ability to respond and adapt to changing climatic conditions will be critical to the future success of FLR efforts. Incorporating climate-smart forestry practices into FLR can build fire-resilient forests and there are many innovative solutions. One of these practices is thinning and prescribed burning for fuel reducing of canopy bulk density, which can improve forest resilience (Brodie et al., 2024). A 20-year study in California supported this approach as forests with thinning and prescribed burns resulted in an 80% probability that at least 80% trees would survive a fire event (Stephens et al., 2023). Another practice that has been found to be successful is planting species that have fire-resistant qualities, such as being able to sprout after a fire or have fire-stimulated seed release (Enright et al., 2014). For example, the rocky mountain lodgepole pine (*pinus contorta* var. *latifolia)* stores seeds in the tree crowns and can survive and release seeds after severe fires (Stephens et al., 2013). Moris et al., (2022) found that forests with a higher number of fire-resistant species underwent less severe fires than forests with fewer of these species. A combination of approaches to fire-resistant forests will build strong and sustainable forests for the future of our climate and local communities.

On a broader scale, Simonson et al. (2021) created a framework to help structure a climate resilient restoration approach that includes projects using climate-resilient native species, monitoring for early signs of pests or disease, planning restoration in areas with lower disaster risk when possible, and engaging with communities in disaster preparedness and response. Communities can aid restoration with TEK about how their forests and species respond to fires, it can increase community engagement and buy-in to the initiative, as well as prepare communities for climate-related events that can be detrimental to their livelihoods (Evans et al., 2018). Frameworks such as Simonson et al. (2021)'s provide FLR projects and local communities with the tools they need to be ready in the face of sudden climate-related events.

Case Study:
[WWF Bolivia: NB this case study is with the project team for final approval]

Overview
WWF Bolivia is working to protect and restore forests in Northern Chiquitanía, a region heavily affected by deforestation and wildfires. The project supports long-term ecosystem recovery and biodiversity conservation, with a focus on restoring natural habitats and preventing further forest loss. The main threats to the landscape are land use change resulting from the expansion of agriculture and cattle ranching and frequently occurring human caused forest fires - more than 10 million hectares of forest were destroyed by wildfires in Bolivia in 2024. The speed of forest degradation and destruction resulting from these events is a huge challenge.

The goal of this project is to achieve zero net deforestation and stop the conversion of natural habitats by 2030. This will be done by restoring forests and managing them sustainably, especially in key wildlife corridors to ensure connectivity.

Challenges and Solutions
The project focuses on a monitoring area in Northern Chiquitanía, Bolivia. Two main local stakeholders are involved: the Indigenous community of Colorado, which borders the area, and a private landowner from the Caparú property located inside the area. Both groups play important roles in leading restoration monitoring and managing wildfire risks, which are a major threat to natural recovery.

The team has engaged these communities through awareness sessions about the benefits of forest and landscape restoration, the damage caused by wildfires, and discussions about challenges to restoration efforts. The creation of the community fire prevention plan for Colorado, has identified priority actions to prevent fire from affecting communal lands. Thanks to this work, zones where it is important to establish defense lines or firebreaks have been identified. The vegetation monitoring system installed in the field through permanent plots measures the availability of existing fuel in the area (e.g. quantity of dry material). With this data, the risk of future fires can be analysed by considering the amount of plant material present alongside historical fire occurrence.

The team coordinates with the Wildfire Early Warning System (SATIF) of the Autonomous Departmental Government of Santa Cruz. Additionally, a monitoring system has been set up to track recovery and jaguar (*Panthera onca*) populations. Specifically, three Permanent Monitoring Plots (PMPs) and four camera traps were installed in the Colorado community, both in burned and unburned forests. At the Caparú property, six PMPs and 14 camera traps were set up, all in burned forest areas because there were no unburned zones. Local people have shown strong interest in the fieldwork and the monitoring results, especially since the data can help manage conflicts between jaguars and livestock.

The most effective approach taken to-date has been to bring community and private land management under an integrated fire management scheme, where passive and adaptive restoration is an element that can't be achieved without first anticipating and reducing the risk of future fires.

Financial Challenges

Intro:

Financing forest restoration is a significant and ongoing challenge. At a project level it is essential to accurately cost and budget for high quality restoration. Evidence shows that many large forest restoration programmes are vastly under-budgeted, leading to overestimations of the area of forest potentially restored (Bodin et al., 2021) and an increased risk of failure. FLR projects' long-term viability, and the opportunity for restoration to take place at scale, often depend on demonstrating clear economic benefits and financial sustainability. This requires approaching project planning with the goal of integrating long-term financial strategies beyond short-term funding cycles. Transitioning away from philanthropy as the primary source of funding for FLR initiatives towards more sustainable finance mechanisms is essential for restoration to move from localised projects to landscape scale FLR. Successfully navigating these challenges allows projects to deliver long lasting benefits to forest ecosystems and local communities. Strong financial mechanisms can also enable initiatives to better address some of the land use and climate change challenges outlined above.

1. *Cost of Restoration*

Intro:

Restoration budgets often focus on visible, short-term expenses like seedlings and labour for planting. However, the true cost of FLR lies within site preparation, community engagement, maintenance, monitoring, training, governance, capacity-building, stakeholder coordination, and land tenure clarification; all of which carry hidden or indirect costs that aren't always accounted for in initial budgets. Projects that are underfunded have a higher chance of failing, which can result in an inflated estimate of the restored area (Bodin et al., 2022). Therefore, many FLR initiatives need a more holistic budgeting approach.

Challenge/s:

Restoration is a long process that cannot be rushed while being successful. Building relationships and co-designing projects with local communities takes time as does tree planting and monitoring to ensure survival and healthy growth. This includes protecting young trees from fire, grazing, pests, or drought, all of which require consistent investment over time. Tracking restoration outcomes and adjusting strategies based on what works is essential but rarely included in budgets. Monitoring systems, data collection, and evaluation are often seen as non-essential, even though they're key to long-term success. Donor cycles typically last 2-5 years, while restoration outcomes often take 10-20 years to fully materialize. This mismatch creates a budgeting gap that threatens long-term success unless multi-phase financing plans are in place.

Solutions:

Best practice for the design and implementation of FLR initiatives includes recognising and including the full lifecycle costs of restoration, which are outlined into five budget considerations to follow (Trillion Trees, 2022)

1. Account for planning: Clearly define the project objectives and appropriate intervention strategies

FLR projects can have many different objectives, all of which require distinct approaches to be adopted, whose costs can vary significantly. Approaches include conserving biodiversity, enhancing ecosystem processes, counteracting climate change, provisioning income and goods, conserving cultural values or reconnecting with nature, and/or complying with legislation. FLR projects may include multiple approaches (ex: natural regeneration combined with direct planting, farmer managed natural regeneration (FMNR), or agroforestry on private farmlands). Each strategy will have different costs that need to be budgeted separately.

2. Account for participation and privilege local knowledge

Projects should ensure that local communities benefit directly by involving their knowledge, traditions, and active participation. Community engagement must begin early, before any tree planting, to make sure that indigenous peoples and local groups give their free, prior, and informed consent (FPIC) and are fully involved in planning, decision-making, and carrying out the project. It's also essential to clearly define and respect land ownership and usage rights, which can be time-consuming and add significantly to the project's overall cost.

3. Account for different interventions within the same landscape

Projects often involve multiple types of restoration activities within a single landscape, each with its own set of costs. For instance, one part of the project might help farmers plant trees that will eventually provide economic returns (ex: timber) while another part focuses on restoring natural forests with no planned economic use. Although both actions support the overall landscape restoration goals, their cost structures will differ. When calculating project costs (ex: cost per tree per ha), the project must itemize the costs separately for each type instead of averaging them and adjust the overall cost estimates based off that list.

4. Account for site preparation and ongoing maintenance

Many factors affect the cost of site preparation and maintenance, including local site conditions, restoration approaches, site protection, and climate disasters. These maintenance issues are ongoing and projects need to 'front-load' these expenses into their costs per tree calculations.

5. Account for monitoring outcomes, assessing progress and developing local capacity

Another important aspect of FLR that often gets overlooked and under-resourced is monitoring tree growth and survival.

To ensure credibility and long-term success, projects should:

- Monitor over multiple years to assess true impact and identify challenges.
- Track biodiversity and ecosystem services, not just tree counts.
- Invest in technical expertise and local capacity to ensure robust, context-appropriate monitoring.
- Use findings to support adaptive management and correct course when needed.

Defining when a project is 'complete' is complex and budgeting for long-term monitoring from the outset is vital, especially as it can require up to 20% of total project costs (Trillion Trees, 2022).

2. *Moving Beyond Philanthropy to Sustainable Finance Mechanisms*

Intro:

To achieve global climate and biodiversity goals, large-scale land restoration is essential. However, delivering this at scale will require a significant increase in funding for FLR, far beyond what philanthropy alone can provide. Forest restoration efforts worldwide are largely dependent on small, grant-funded projects, typically supported by philanthropic donations from individuals, foundations, or corporate social responsibility programs. While this support is valuable, it is often fragmented, short-term, and insufficient to drive long-lasting, large-scale impact. To bridge this funding gap and enable projects to generate their own income, they will need access to long-term, reliable financing, integrating market-based solutions and sustainable financial models, such as payments for ecosystem services, carbon credits, and water resource management. There are increasingly innovative solutions for FLR initiatives to integrate and generate different types of financial support. Additionally, corporations and investment funds are being incentivized to move beyond one-time donations and toward long-term, impact-aligned investment. For instance, innovative funds like TIG and re.green are demonstrating that multi-year, impact-aligned capital can scale forest restoration through blended revenue strategies (e.g.: carbon credits and sustainable timber) with backing from major corporates like Microsoft and Meta (Sanjayan, 2025).

Challenge/s:

Many conservation efforts aren't financially sustainable and struggle to scale. This is not because they lack environmental merit, but because they were not structured around the production of marketable environmental services and thus fail to attract return-seeking investors (Guillon & Bennet, 2025). Sole reliance on charitable donations is not sufficient to restore and safeguard hundreds of millions of hectares, because the scale and cost of the task exceed available grant resources. Furthermore, insecure land rights and lack of supportive government policies can limit community investment in long-term economic activities tied to restoration. People are less likely to invest time and resources if they are unsure they will benefit in the future. Considering all these factors, projects often remain small-scale, short-term and grant-dependent, struggling to evolve into investment-ready models capable of becoming larger, sustainable ventures.

Solutions

Despite the challenges, there are innovative ways for FLR projects to achieve sustainable financial mechanisms to support themselves. Guillon & Bennet (2025) suggest adopting a new project with a startup-like approach and using real customer insights to design a “minimum viable offer," a small-scale version of the project (eg. mock credits, pilot restoration) to test if it resonates financially before scaling. FLR projects must co-design initiatives with local stakeholders to see what the community needs.

One way for projects to support their own financing is through Payment for Ecosystem Services (PES) systems, which are financial incentives given to landowners, communities, or stakeholders to restore and manage forests and landscapes sustainably, conditional on measurable improvements in ecosystem services. These could include provisioning services, for example food, fuel and shelter; regulating services, for example flood or pest regulation, water purification and air quality regulation (Everard, 2022); supporting services, for example soil formation and the provision of wildlife habitat, and cultural services.

When PES models are designed so that payments are made in exchange for protecting ecosystem services, those payments directly support conservation outcomes. In these cases, local communities receive economic benefits from preserving their natural environments, incentivising long-term stewardship rather than short-term exploitation. For example, In Nam Et-Phou Louey, Laos, WCS introduced nature-based tourism and local communities receive payments linked to wildlife sightings captured by tourists and confirmed through camera traps.

In the Usambara Mountains of Tanzania, a critical part of a Water Towers Landscape, WWF-Tanzania works to restore forests and ensure water security for over 3.5 million people. Through projects like Equitable Payments for Watershed Services (EPWS), WWF collaborates with local communities and partners such as Friends of Usambara and 4H Tanzania, to reduce sedimentation in the Zigi River, improve livelihoods through sustainable agriculture, and restore degraded areas. The overall goal is to restore the ecosystem's ability to provide water and other services, supporting both the environment and human well-being.

Carbon markets allow FLR projects to generate and sell carbon credits that capture carbon from the atmosphere or reduce greenhouse gas emissions. Companies and individuals purchase these carbon credits on a voluntary basis. The voluntary carbon market has experienced problems including concerns around greenwashing, poor quality of some carbon credits, and a lack of transparency, standardisation, and robust verification (Romm et al., 2025). Key issues include "additionality" (whether emissions reductions would have happened anyway), "permanence" (if carbon removal is long-lasting), and the risk of "double counting". These issues can undermine the market's credibility and effectiveness and expose companies to reputational and legal risks. However, carbon offsetting has become a profitable and scalable solution in forest finance, attracting institutional investors and being increasingly integrated into timberland strategies (Begemann et al., 2022).

While provisioning, regulating, and cultural ecosystem services are often directly linked to a project's economic impacts, supporting services, such as soil formation and the provision of wildlife habitat, do not typically have direct market value (Everard, 2022). These underlying services are not currently captured by markets, yet they play a critical role in maintaining the resilience of global farming systems. This resilience, while often overlooked, holds real value for both growers and buyers, as it underpins the long-term sustainability and reliability of agricultural production.

Case Study: The Forest Restoration Catalyst

Delivering Forest Landscape Restoration at scale requires substantial financing, hinging on a robust investment case and a strong enabling environment. But few projects pioneering nature-based solutions have the resources to reach investment readiness. Lack of early-stage financing can be a problem; capital is needed to turn restoration ideas into investible, operational initiatives. For most initiatives, this means years of work to build feasibility studies, stakeholder partnerships, financial models, and monitoring frameworks.

A growing number of project accelerators are emerging to provide support for early stage programmes. These programmes can help with critical elements of the project preparation process, such as feasibility assessments, outcomes modelling and development of robust and investible business plans.

Trillion Trees has developed the Forest Restoration Catalyst (FRC) to address the challenge of securing early-stage investment in FLR. The FRC provides catalytic funding to forest restoration initiatives with the potential to leverage outcomes-based finance to achieve scale. It is a landscape preparation facility to help create the enabling environments for nature-based investment by co-designing initiatives with local stakeholders, supporting pilot projects, and ensuring equitable benefit sharing models are the foundation of any investment.

The FRC provides grant support and technical assistance to FLR projects through three stages: feasibility, investment readiness, and acceleration to identify and develop sustainable revenue streams.

Through these stages the FRC works closely with landscape partnerships to identify key pathways across three work streams that, together, create:

- Finance frameworks: Establishing sustainable financing models through robust feasibility assessments, developing viable landscape financing transition plans, alongside commitments from all relevant stakeholders, including buyers.
- High quality FLR: Strengthening capacity for to implement and scale sectoral best practices for impact forecasting, monitoring, and accountability by co-developing interventions with rights holders and partners strengthening marginalized voices to support just transition.
- Enabling conditions: Identifying policies and regulations to promote and secure restoration. Developing governance frameworks ensuring equitable decision making and benefit sharing.

The FRC aims to deliver sufficient returns from blended finance structures for landscapes to be self- sustaining in their scaling and development within 5 years. Over the longer term, successful projects can return a portion of the development finance they have received to enable recycling of funds to a growing pipeline of landscape partnerships.

As an example in practice, the FRC supported WWF in Brazil to develop an investable model to drive forest restoration at scale across the Upper Paraná water catchment, part of the Atlantic Forest ecoregion. This area has been subjected to high levels of deforestation for soy bean agriculture, but climate change, biodiversity loss, and water availability concerns now make it a priority region for restoration efforts that protect water courses and prevent soil loss. FRC support helped deliver an inclusive and scalable landscape business plan to restore 1.6 million hectares of high priority degraded land in the Upper Paraná Atlantic Forest over the next 25 years. This included cost-benefit modelling, analysis of market opportunities for high value commodities, for example yerba mate, and Payment for Ecosystem Services (PES) options (water and carbon) that could incentivise farmers to switch away from monoculture crops to agroforestry systems, and restore riparian areas which increases connectivity for wildlife.

<u>Conclusion</u>

FLR initiatives face complex and wide-reaching challenges, three of which have been explored in this paper; land use pressures, climate change effects, and financing models. Despite the difficulties that these can create for restoration initiatives, they can be addressed in many ways. This paper has reviewed multiple solutions to these challenges, demonstrating how FLR initiatives can mitigate and adapt to problems. For example, incorporating TEK into project planning can increase community engagement, building fire-resistant forests can protect landscapes, and accessing carbon markets can provide projects with their own financial resources and reduce reliance on philanthropic donations. These challenges and solutions were explored both through a literature review and through the analysis of the Trillion Trees ReForest Fund portfolio of tropical forest restoration initiatives, representing multiple geographies and socio-economic conditions, demonstrating that these solutions are not only theoretical but render successful outcomes in practice.

Among many benefits, FLR is imperative to building resilient forests and supporting communities by cultivating a socio-ecological relationship that is sustainable in the long term. Although FLR initiatives face many challenges, it is evident throughout this paper that there are multiple potential solutions to said challenges. Each project has its own unique combination of challenges and needs to identify the specific solutions that will work best in those circumstances, while taking local ecological and cultural contexts into account. While the challenges facing FLR will likely change over time as climate and financial problems evolve, it is clear that there are multiple ways in which projects can ensure their long-term sustainability, while remaining adaptable, enabling maximum benefits of FLR for people, nature, and the climate.

<u>References:</u>

Anderson, J. T., & Song, B. (2020). *Plant adaptation to climate change—Where are we? Journal of Systematics and Evolution: JSE*, 58(5), 533–545. https://doi.org/10.1111/jse.12649

Andreoni, M., & Villegas, A. (2025, May 21). *Amazon fires drive unprecedented global forest loss in 2024, report says.* Reuters. https://www.reuters.com/sustainability/cop/amazon-fires-drive-unprecedented-global-forest-loss-2024-report-says-2025-05-21/

Baig, S., Barrow, G. C., Kumar, C., & Rizvi, A. R. (2015). *Synergies between climate mitigation and adaptation in forest landscape restoration.* IUCN. https://iucn.org/resources/grey-literature/synergies-between-climate-mitigation-and-adaptation-forest-landscape

Begemann, A., Dolriis, C., & Winkel, G. (2022). *Rich forests, rich people? Sustainable finance and its links to forests.* European Forest Institute.

Bodin, B., Garavaglia, V., Pingault, N., Ding, H., Wilson, S., Meybeck, A., Gitz, V., d'Andrea, S., & Besacier, C. (2022). *A standard framework for assessing the costs and benefits of restoration: Introducing The Economics of Ecosystem Restoration. Restoration Ecology*, 30(3), e13515. https://doi.org/10.1111/rec.13515

Brancalion, P. H. S., & Chazdon, R. L. (2017). *Beyond hectares: Four principles to guide reforestation in the context of tropical forest and landscape restoration. Restoration Ecology*, 25(4), 491–496. https://doi.org/10.1111/rec.12519

Brando, P. M., Balch, J. K., Nepstad, D. C., Morton, D. C., Putz, F. E., Coe, M. T., Silvério, D., Macedo, M. N., Davidson, E. A., & Nóbrega, C. C. (2014). *Abrupt increases in Amazonian tree mortality due to drought–fire interactions. Proceedings of the National Academy of Sciences of the United States of America*, 111(17), 6347–6352.

Broeckhoven, N., & Cliquet, A. (2015). *Gender and ecological restoration: Time to connect the dots. Restoration Ecology*, 23(6), 729–736. https://doi.org/10.1111/rec.12270

Buckley, L. B., Arakaki, A. J., Cannistra, A. F., Kharouba, H. M., & Kingsolver, J. G. (2017). *Insect development, thermal plasticity, and fitness implications in changing, seasonal environments. Integrative and Comparative Biology*, 57(5), 988–998. https://doi.org/10.1093/icb/icx032

Busch, J., & Engelmann, J. (2017). *Cost-effectiveness of reducing emissions from tropical deforestation, 2016–2050. Environmental Research Letters*, 13(1), 015001. https://doi.org/10.1088/1748-9326/aa907c

CBD. (2023). *2030 Targets (with Guidance Notes) — Kunming-Montreal Global Biodiversity Framework.* https://www.cbd.int/gbf/targets

Ceccon, E., Méndez-Toribio, M., & Martínez-Garza, C. (2020). *Social participation in forest restoration projects: Insights from a national assessment in Mexico. Human Ecology*, 48, 609–617. https://doi.org/10.1007/s10745-020-00178-w

Charnley, S., Fischer, A. P., & Jones, E. T. (2007). *Integrating traditional and local ecological knowledge into forest biodiversity conservation in the Pacific Northwest. Forest Ecology and Management*, 246(1), 14–28. https://doi.org/10.1016/j.foreco.2007.03.047

Chechina, M., & Hamann, A. (2015). *Choosing species for reforestation in diverse forest communities: Social preference versus ecological suitability. Ecosphere*, 6(11), 1–11.

CIFOR. (2017). *Implementing forest landscape restoration initiatives: Experiences from REDD+ and early FLR projects.* Center for International Forestry Research.

Enright, N. J., Fontaine, J. B., Lamont, B. B., Miller, B. P., & Westcott, V. C. (2014). *Resistance and resilience to changing climate and fire regime depend on plant functional traits. Journal of Ecology*, 102(6), 1572–1581. https://doi.org/10.1111/1365-2745.12306

Evans, K., Guariguata, M. R., & Brancalion, P. H. S. (2018). *Participatory monitoring to connect local and global priorities for forest restoration. Conservation Biology*, 32(3), 525–534. https://doi.org/10.1111/cobi.13110

Everard, M. (2022). *Ecosystem services: Key issues* (2nd ed.). Routledge. https://doi.org/10.4324/9781003182313

FAO, IUCN CEM, & SER. (2021). *Principles for ecosystem restoration to guide the United Nations Decade 2021–2030.* FAO.

FAO. (2021). *The state of food and agriculture 2021: Making agrifood systems more resilient to shocks and stresses.* Food and Agriculture Organization of the United Nations. https://www.fao.org/publications/sofa/2021/en/

Fremout, T., Thomas, E., Taedoumg, H., Briers, S., Gutiérrez-Miranda, C. E., Alcázar-Caicedo, C., Lindau, A., ... Muys, B. (2022). *Diversity for restoration (D4R): Guiding the selection of tree species and seed sources for climate-resilient restoration of tropical forest landscapes. Journal of Applied Ecology*, 59(3), 664–679. https://doi.org/10.1111/1365-2664.14079

Food and Agriculture Organization of the United Nations. (2022). *Forest resources and restoration for livelihoods.* FAO. https://openknowledge.fao.org

Gardiner, R., Shoo, L. P., & Dwyer, J. M. (2019). *Look to seedling heights, rather than functional traits, to explain survival during extreme heat stress in the early stages of subtropical rainforest restoration. Journal of Applied Ecology*, 56(12), 2687–2697. https://doi.org/10.1111/1365-2664.13505

Guillon, B., & Bennett, G. (2025, June 4). *Why we should take a venture approach to protecting nature.* World Economic Forum. https://www.weforum.org/stories/2025/06/venture-approach-protecting-nature

Guo, J., Wang, J., Qiao, Y., Huang, X., Smith, N. G., Liu, Z., Zhang, R., Chen, X., Wu, C., Peñuelas, J., & Chen, L. (2024). *Greening-induced biophysical impacts lead to earlier spring and autumn phenology in temperate and boreal forests. Earth's Future*, 12(11). https://doi.org/10.1029/2024EF004618

Haq, S. M., Pieroni, A., Bussmann, R. W., et al. (2023). *Integrating traditional ecological knowledge into habitat restoration: Implications for meeting forest restoration challenges. Journal of Ethnobiology and Ethnomedicine*, 19, 33. https://doi.org/10.1186/s13002-023-00606-3

Hartmann, H., Moura, C. F., Anderegg, W. R. L., Ruehr, N. K., Salmon, Y., Allen, C. D., Arndt, S. K., Breshears, D. D., Davi, H., Galbraith, D., Ruthrof, K. X., Wunder, J., Adams, H. D., Bloemen, J., Cailleret, M., Cobb, R., Gessler, A., Grams, T. E. E., Jansen, S., ... O'Brien, M. (2018). *Research frontiers for improving our understanding of drought-induced tree and forest mortality. New Phytologist*, 218(1), 15–28. https://doi.org/10.1111/nph.15048

Höhl, M., Ahimbisibwe, V., Stanturf, J. A., Elsasser, P., Kleine, M., & Bolte, A. (2020). *Forest landscape restoration—What generates failure and success? Forests*, 11(9), 938. https://doi.org/10.3390/f11090938

IPCC. (2023). *Sections.* In *Climate change 2023: Synthesis report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 35–115). IPCC. https://doi.org/10.59327/IPCC/AR6-9789291691647

International Institute for Sustainable Development (IISD). (2024, June 5). *Challenges to fostering low-carbon agriculture through public policies and support in Brazil.* International Institute for Sustainable Development.

Islam, K. K., Saifullah, M., Mahboob, M. G., Jewel, K. N. E. A., Ashraf, S. K., & Hyakumura, K. (2024). *Restoring soil fertility, productivity and biodiversity through participatory agroforestry: Evidence from Madhupur Sal Forest, Bangladesh. Land*, 13(3), 326.

Kindermann, G., Obersteiner, M., Sohngen, B., Sathaye, J., Andrasko, K., Rametsteiner, E., Schlamadinger, B., Wunder, S., & Beach, R. (2008). *Global cost estimates of reducing carbon emissions through avoided deforestation. Proceedings of the National Academy of Sciences of the United States of America*, 105(30), 10302–10307. https://doi.org/10.1073/pnas.0710616105

Kirilenko, A. P., & Sedjo, R. A. (2007). *Climate change impacts on forestry. Proceedings of the National Academy of Sciences of the United States of America*, 104(50), 19697–19702. https://doi.org/10.1073/pnas.0701424104

Kumar, S., Alam, B., Taria, S., Singh, P., Yadav, A., & Arunachalam, A. (2024). *Agroforestry solutions for climate change and environmental restoration* (1st ed.). Springer Nature Singapore. https://doi.org/10.1007/978-981-97-5004-7

Lalor, A. R., Law, D. J., Breshears, D. D., Falk, D. A., Field, J. P., Loehman, R. A., Triepke, F. J., & Barron-Gafford, G. A. (2023). *Mortality thresholds of juvenile trees to drought and heatwaves: Implications for forest regeneration across a landscape gradient. Frontiers in Forests and Global Change*, 6. https://doi.org/10.3389/ffgc.2023.1198156

Lawry, S., & Ranjatson, P. (2021, November 16). *Forest restoration and democracy: Making communities visible in Madagascar.* Rights + Resources. https://rightsandresources.org/blog/forest-restoration-and-democracy/

Lee, A. T. K., Carr, J. A., & Ahmad, B. (2019). *Reforesting for the climate of tomorrow* (IUCN-2019-002, En). International Union for Conservation of Nature (IUCN).

Long, J. W., Lake, F. K., Goode, R. W., & Burnette, B. M. (2020). *How traditional tribal perspectives influence ecosystem restoration. Ecopsychology*, 12(2), 71–82. https://doi.org/10.1089/eco.2019.0055

McCauley, L. A., Falk, D. A., Crimmins, M. A., Swetnam, T. L., & Meunier, J. (2022). *Landscape-scale forest restoration decreases vulnerability to drought mortality under climate change in southwest USA ponderosa forest.* U.S. Geological Survey.

McLain, R., Guariguata, M. R., & Lawry, S. (2017). *Implementing forest landscape restoration initiatives: Tenure, governance, and equity considerations.* In *Accelerating restoration of degraded forest landscapes: The role of tenure security and local forest governance in catalyzing global restoration initiatives.*

McLain, R., Lawry, S., Guariguata, M. R., & Reed, J. (2021). *Toward a tenure-responsive approach to forest landscape restoration: A proposed tenure diagnostic for assessing restoration* *opportunities. Land Use Policy*, 104, Article 103748. https://doi.org/10.1016/j.landusepol.2018.11.053

Moris, J. V., Reilly, M. J., Yang, Z., et al. (2022). *Using a trait-based approach to assess fire resistance in forest landscapes of the Inland Northwest, USA. Landscape Ecology*, 37, 2149–2164. https://doi.org/10.1007/s10980-022-01478-w

Newton, P., Kinzer, A. T., Miller, D. C., Oldekop, J. A., & Agrawal, A. (2020). *The number and spatial distribution of forest-proximate people globally. One Earth*, 3(3), 363–370.

OECD (Organisation for Economic Co-operation and Development). (2010). *The use of input subsidies in developing countries.* OECD. https://www.oecd.org/tad/agricultural-policies/46340359.pdf

Pacheco, K., Einhorn, G., & Gunderson, I. (2022, February 14). *5 principles for partnering with communities on forest restoration.* World Economic Forum. https://www.weforum.org/stories/2022/02/5-principles-for-partnering-communities-forest-restoration/

Parmesan, C., & Yohe, G. (2003). *A globally coherent fingerprint of climate change impacts across natural systems. Nature*, 421(6918), 37–42.

Pent, G. J. (2020). *Over-yielding in temperate silvopastures: A meta-analysis. Agroforestry Systems*, 94, 1741–1758. https://doi.org/10.1007/s10457-020-00494-6

Rizvi, A. R., Baig, S., Barrow, E., & Kumar, C. (2015). *Synergies between climate mitigation and adaptation in forest landscape restoration.* IUCN. https://portals.iucn.org/library/sites/library/files/documents/2015-013.pdf

Romm, J., Lezak, S., & Alshamsi, A. (2025). *Are carbon offsets fixable? Annual Review of Environment and Resources.* https://www.annualreviews.org/content/journals/10.1146/annurev-environ-112823-064813

Sánchez, M. (2022). *Repurposing agriculture's public budget to align healthy diets affordability and agricultural transformation objectives in Ethiopia: Background paper for the State of Food Security and Nutrition in the World 2022.* Food & Agriculture Organization.

Sanjayan, M. (2025, April 23). *How new financial models for forest restoration create opportunities for nature, communities and investors.* World Economic Forum. https://www.weforum.org/stories/2025/04/new-model-forest-restoration-nature-communities-investors/

Santini, N. S., & Miquelajauregui, Y. (2022). *The restoration of degraded lands by local communities and Indigenous peoples. Frontiers in Conservation Science*, 3, 873659.

Shelton, M. R., Kanowski, P. J., Kleinschmit, D., & Ison, R. L. (2024). *Critical social perspectives in forest and landscape restoration – a systematic review. Frontiers in Environmental Science*, 12. https://doi.org/10.3389/fenvs.2024.1466758

Simonson, W. D., Miller, E., Jones, A., García-Rangel, S., Thornton, H., & McOwen, C. (2021). *Enhancing climate change resilience of ecological restoration—A framework for action. Perspectives in Ecology and Conservation*, 19(3), 300–310. https://doi.org/10.1016/j.pecon.2021.05.002

Singh, H. (Ed.). (2024). *Forests and climate change: Biological perspectives on impact, adaptation, and mitigation strategies* (1st ed.). Springer Nature Singapore. https://doi.org/10.1007/978-981-97-3905-9

Stephens, S. L., Agee, J. K., Fulé, P. Z., North, M. P., Romme, W. H., Swetnam, T. W., & Turner, M. G. (2013). *Managing forests and fire in changing climates. Science*, 342(6154), 41–42. https://doi.org/10.1126/science.1240294

St-Laurent, G. P., Oakes, L. E., Cross, M., & Hagerman, S. (2021). *R–R–T (resistance–resilience–transformation) typology reveals differential conservation approaches across ecosystems and time. Communications Biology*, 4(1), 1–9.

Tran, T. M. A., Gagnon, V. S., & Schelly, C. (2025). *A review of traditional ecological knowledge in resilient livelihoods and forest ecosystems: Lessons for restoration sciences and practices. Forests, Trees and Livelihoods*, 34(1), 27–53. https://doi.org/10.1080/14728028.2024.2408725

Trillion Trees. (2022). *Defining the real cost of restoring forests: Practical steps towards improving cost estimates* [White paper]. https://trilliontrees.org/wp-content/uploads/2022/08/Trillion-Trees_Defining-the-real-cost-of-restoring-forests.pdf

UN. (2023). *The Sustainable Development Goals Report 2023: Special Edition.* https://unstats.un.org/sdgs/report/2023/

Vose, J. M., et al. (2018). *Ch. 6: Forests.* In *Impacts, risks, and adaptation in the United States: Fourth national climate assessment, volume II* (p. 240). U.S. Global Change Research Program.

Wambui, J., & Evans, M. (2024, May 9). *Explainer: How trees help protect us from flooding: As East Africa and Brazil grapple with floodwaters, what can we learn from nature to prevent future devastation?* CIFOR-ICRAF.

Whyte, K. P. (2013). *On the role of traditional ecological knowledge as a collaborative concept: A philosophical study. Ecological Processes*, 2, 7. https://doi.org/10.1186/2192-1709-2-7

Wilson, S. J., Alexandre, N. S., Holl, K. D., Reid, J. L., Zahawi, R., Celentano, D., Sprenkle-Hyppolite, S., & Werden, L. (2022). *Applied nucleation: A restoration guide for tropical forests* [Report]. Conservation International. https://www.conservation.org/docs/default-source/publication-pdfs/applied_nucleation_full_report_final.pdf

WMO. (2025, January 10). *WMO confirms 2024 as warmest year on record at about 1.55°C above pre-industrial level.* https://public.wmo.int/news/media-centre/wmo-confirms-2024-warmest-year-record-about-155degc-above-pre-industrial-level

Wolf, C., Levi, T., Ripple, W. J., Zárrate-Charry, D. A., & Betts, M. G. (2021). *A forest loss report card for the world's protected areas. Nature Ecology & Evolution*, 5(4), 520–529. https://doi.org/10.1038/s41559-021-01389-0