Forest Restoration

Basic knowledge

Welcome to the Forest Restoration Module, which is intended for people involved in forest restoration programmes.

The module provides basic background and more detailed information on forest restoration, as well as links to key tools and case studies of effective forest restoration efforts.

Forest restoration has received a great deal of attention from scientists and policymakers for its potential contribution to climate change mitigation (Shukla *et al*., 2019). Natural climate solutions may be able to provide more than a third of the carbon capture from the atmosphere needed in order to limit the risks of climate change above 1.5 ºC (Griscom *et al.*, 2017). Forests have the largest potential of these natural climate solutions. Forest restoration also has important links with biodiversity, as restoration of stable forests that provide multiple ecosystem services requires a functional understanding of the biodiversity that underpins ecosystem functioning (Aerts and Honnay, 2011). Forest restoration is thus included along with conservation in the decisions and targets of the Sustainable Development Goals, the Convention on Biological Diversity, the UN Decade on Ecosystem Restoration, and the Bonn Challenge. Forest restoration follows processes of forest degradation and deforestation, which are dealt with in separate modules in the Sustainable Forest Management Toolbox.

Recently the concept of Forest and Landscape Restoration has become prominent. This refers to the restoration not only of the forest cover at a particular site, but views the site in the context of the landscape as a whole; it includes all land uses and the people in it. Forest and Landscape Restoration is covered in a separate module: the Forest and Landscape Restoration Module deals with the restoration of many sites within the context of a multiple-use landscape.

This module therefore deals with forest and its restoration at the site level. However, it is very important that even when dealing with forest restoration at a single site that this site be considered in its environmental and social context. Guiding principles are presented in more depth, and the reader is directed to specific reference works in the tools section of this module. Cases are presented across ecological zones to illustrate concepts of site-based restoration.

Forest restoration encompasses a large variety of staring points and objectives. It is thought of as reversing forest degradation or loss of productivity of ecosystem goods and services such as food, wood, biodiversity, and water. As a consequence of human activity and other natural processes, these types of needs for restoration are found all over the world's forests, from drylands to tropical rainforests, from high latitudes and altitudes, and from poor to rich regions. By some estimates, the annual economic losses due to deforestation and land degradation were EUR 1.5–3.4 trillion in 2008, equalling 3.3–7.5 per cent of the global GDP at that time (ELD Secretariat, 2015).

Forest restoration includes:

- rehabilitation, meaning the restoration of desired species, structures or processes to an existing ecosystem;
- reconstruction, meaning restoration of native plants on land which is in another use;
- reclamation, meaning restoration of severely degraded land devoid of vegetation;
- most radically replacement, in which species or provinces maladapted for a given location and unable to migrate are replaced with introduced species as climates change rapidly.

(Stanturf, Palik and Dumroese, 2014)

Forest restoration can be understood in relation to the forest transition curve shown in Figure 1. Rehabilitation would normally be carried out in order to restore the productivity of a forest in the degraded stage whilst reconstruction or reclamation would be carried out in forests that were so degraded as to have ceased functioning as effective forests. In many parts of the world, land abandoned from agricultural purposes will regenerate naturally to form secondary forests that are in their nature and composition different from the forests that preceded them. Active management can accelerate this process or change the trajectory of the succession so that the structure or composition better achieves certain management objectives. Disasters, including fires and high winds, may cause the loss of forest cover over large areas, and this may require restoration in order to accelerate natural regeneration processes and a return to a more productive condition.

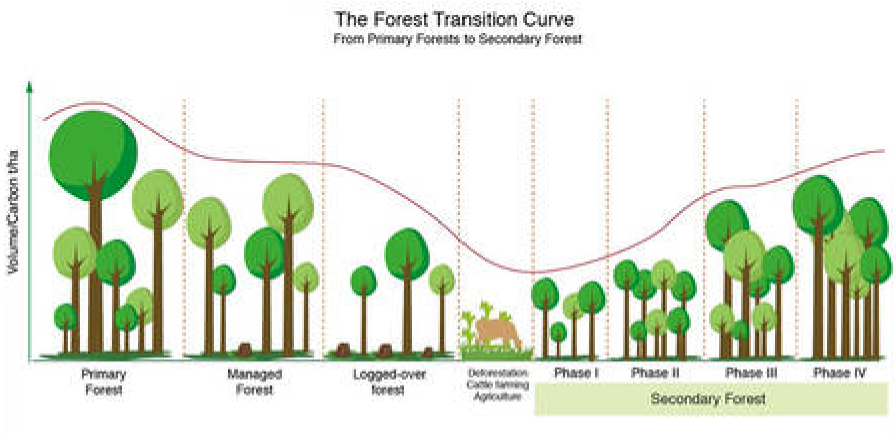

Figure 1. Land that is ecologically suitable for forest often transitions from primary forest to an unproductive forest state or a non-forest state due to exploitative management. Once that occurs, forest restoration can accelerate a transition back to a productive forest state (source: https://www.forestryandclimate.com).

When thinking about forest restoration in terms of the forest transition curve, it is important to consider ecological differences between forest types. For example, forest successions proceed quite differently in tropical moist forests compared to dry forests; in moist forests early successional trees usually have timber of low density and strength while trees appearing later have denser, stronger timber. In dry forest the opposite is true, with early successional trees typically having very dense timber while later successional trees have lighter, weaker timber (Poorter *et al.*, 2019). This is a result of the changes in the ambient moisture of the environment caused by the forest cover and by competition between the trees. Moreover, in dry forests establishment of trees from out planted seedlings is often less cost-effective than reliance on direct seeding and regeneration of rootstocks.

There are many ways forest owners and managers can restore forest, including planting of seedling regeneration, removal or control of less desired species, or weeding to reduce competition. Natural regeneration is promoted by protection from fire or from grazing animals. Forest restoration is not necessarily restricted to natural forest systems, since, in many cases, either as a result of neglect or due to the disruption of normal life due to civil unrest or war, planted forests have become degraded due to lack of management or lack of protection. Plantations may have trees that are overmature and incapable of meeting their original purpose, or may otherwise not have enough crop trees to make them financially viable. In some cases, plantations of exotic species may be used as nurse crops both to provide shelter for shade-tolerant species and to provide a source of income to finance the restoration process. The next section of this module will explain in greater depth how some of these options may be successfully implemented.

Forest restoration contributes to SDGs:

Related modules

- Forest pests
- Land-use planning
- Management of planted forests
- Participatory approaches and tools for SFM
- Protected areas
- Silviculture in natural forests
- Vegetation fire management
- Wildlife management

In more depth

Guiding principles for successful, ecologically sound, socially acceptable and economically viable forest restoration initiatives outlined in Basic Knowledge are described in more detail in this section. Readers may refer to the ToolsTools and Further learningFurther LearningFurther learning sections for more comprehensive coverage of the topic.

Identify viable sites for forest restoration

Sites suitable for forest restoration may vary in size from large landscapes with multiple owners and managers, to smaller forests or sites managed by one owner. At the site level, landowners' and forest users' management decisions on restoration will be driven by their private benefit, by social pressures and considerations at a local level, and by public regulations and incentives on certain types of management.

Decisions on the management of public and common lands are similarly driven by an assessment of costs and benefits. Compared to private lands, though, these decisions typically involve a larger group of decision-makers. There is also usually the need to set up a governance and management mechanism to balance differences of opinion and maintain consistency in management (Ostrom, 2009).

Possible sites or landscapes for forest restoration projects include:

- logged-over or poorly stocked secondary forests in need of supplementary natural regeneration through enrichment planting;
- degraded natural forest ecosystems in protected areas to be used for watershed management, wildlife conservation, ecotourism or community development;
- wildlife habitats or corridors;
- alluvial sites along streams, rivers and other water bodies to preserve riparian zones or coastlines;
- steep slopes at risk of soil erosion and landslides;
- unproductive sites that are suitable for producing forest products; and
- unproductive industrial wood plantations that are suitable for conversion to natural or semi-natural forest.

While these sites have the potential for restoration, demand from the owners and managers of the land will depend on their perception of the benefits of the initiative. They will choose sites for restoration that provide these benefits and will not intervene on the rest of the sites. Financial benefits, such as those created by employment, income from the harvesting of forest products, ecotourism, and payments for ecosystem services, are the most obvious and measurable sources of motivation for stakeholders to participate in forest restoration projects. Local residents may also regard non-financial benefits (such as improvements in the environment and village infrastructure, the maintenance of cultural traditions, or political gain) as equally or more important reasons for restoring forest landscapes.

Those who wish to increase the proportion of managers and landowners who chose to restore land have a plethora of options; the challenge is to implement these incentives in a cost-effective manner (Table 1).

Reduce costs	Increase returns	Lower risk
· Provide tax incentives for good practices and investments · Create simplified regulatory requirements for tree crops and wood products · Provide or subsidize loans for certain management practices or standards	· Provide Improved technical assistance · Provide subsidized inputs for certain types of management · Support markets and exchanges for pollution and payment for ecosystem services through laws and regulation	· Provide certification of inputs' quality · Provide increased security of tenure · Create simple and fair regulation that is equitably enforced · Reduce perverse incentives that encourage encroachment on forest land

Table 1. indicative policy options to increase forest restoration: landowners and managers will undertake restoration activities if they see the benefits of doing so. here are some indicative options that can increase forest restoration.

Those undertaking management activities will do so if they perceive the benefits to outweigh the costs. This benefit, however, should not come at the expense of neighbours, broader society, or the environment surrounding the forest.

Understand why the land is currently degraded

An important part of identifying the right incentives for forest restoration is developing an understanding of why the forest is currently degraded.

The intensive exploitation of forests and related disturbances has created large areas of degraded forests. Globally, about 900 million hectares of deforested and degraded forestlands are estimated to be biophysically suitable for forest restoration (Bastin et al., 2019). In addition to identifying areas that have biophysical potential for restoration, understanding and effectively addressing the drivers of deforestation and forest degradation on a specific site or in a landscape is a key to any successful forest restoration plan. At the site level, landowners may understand the drivers of deforestation and degradation but lack the tools or incentives to avoid, halt, or reverse these drivers. Healthy systems of local government, extension, and landowner-to-landowner exchanges about the problems and solutions can help to overcome these barriers. Similarly, local government may well understand the drivers of deforestation and degradation on public lands but lack the means to effectively manage these areas. Linking both classes of landowners to the right types of incentives can improve management practices.

Poorly formulated or outdated public policies are an important reason for forest degradation. Another common challenge is poorly designed and resourced monitoring and enforcement mechanisms. Ensuring that regulations do not overcomplicate the harvest of forest products, that forest owners have secure tenure, and that regulations on land and forest use are accompanied by well-governed, cost-effective monitoring and enforcement mechanisms is necessary for successful restoration.

Good governance and forest restoration

Forest restoration and rehabilitation efforts will only be sustainable if they are socially acceptable. Good governance and respect for human rights should thus underpin efforts to restore forest, particularly those initiated or funded externally. At the landscape level, forest restoration efforts interact ecologically and socio-economically with all other land uses, such as agriculture, urban living, water production, infrastructure and industry. Accordingly, they should be based on a coordinated, transparent and participatory land-use planning process with full stakeholder engagement linking agriculture, forestry and other land uses.

At the local level, the main stakeholders (e.g. forest owners, local communities, concessionaires, and forest and other authorities in charge of land use) should be engaged from the start of any external plan for forest restoration in their area. Planning and implementation should include a process to ensure the most vulnerable and least powerful (often women, children, and the poor) have a means to participate in the planning and have a voice in the decision-making process. Stakeholder engagement should take into account gender. Both men and women are important players in the process of forest restoration; both cultural roles and power dynamics between genders should be mainstreamed into the forest restoration process.

Define management objectives, and roles and responsibilities

Assuming governance is good, forest management will be most effective if objectives are clearly defined and well thought through. It can also be helpful to agree on different roles and responsibilities for engaging in restoration, and for the equitable distribution of incentives, benefits, and costs. Frequent changes in these management objectives will drive up costs and make the realization of benefits less certain. Because forest management takes place over large time scales, and often over large areas of land, careful definition of management objectives is usually worthwhile. Indeed, forest restoration efforts are typically lower-risk investments if the principal stakeholders (e.g. forest owners, nearby communities, concessionaires, and forest and other authorities in charge of land use) are engaged from the start. This can help avoid mistakes and misunderstandings that can drive up costs or result in failure of the endeavour. Definition of objectives should also involve consultation of the manager with owners, neighbours, government, and relevant subject experts as appropriate. Ideally, local and regional government will develop transparent and well thought-through regulation in advance and apply it consistently over a long period, lowering transaction costs and creating a level playing field for forest owners.

Forests can be restored for multiple combined objectives. These should be defined and prioritized at the outset, and periodically revisited in an adaptive management framework. Particularly for common and public forestlands, a process of prioritization is often necessary when defining management objectives, to reconcile competing or incompatible objectives and resource limitations.

Make a management plan

If management objectives are clear and agreed by all relevant parties, realizing them probably depends most on a good plan implemented in an adaptive management framework. In forest management, this usually involves creating a map of compartments and defining when and where silvicultural activities take place in those compartments.

1. Prepare a land-use map

Mapping biophysical and silvicultural characteristics is useful to determine the feasibility and suitability of different restoration approaches. Characteristics that are helpful to map include: the area of residual forest (e.g. primary, secondary and degraded); forest functions; the area and quality of agricultural land; the area of unused and degraded land; environmental priority areas; areas of biological and cultural significance; and road accessibility. The act of producing and refining the map is an excellent opportunity for structured discussion on the management activities.

2. Select restoration method(s)

The selection of restoration method will depend on the objective of the restoration, the time and money available, and the ecological potential of the site. For example, rapid stabilization of bare soil is possible using plantation species, but this is a costly process that requires personnel, access to the site, and planting material. Less intensive methods such as assisted natural regeneration, direct seeding, or exclosure of wildlife and livestock may be cost-effective when a rapid response is not necessary. Multiple methods can be used within the same region to achieve larger management goals (Table 2).

Table 2. Selected restoration objectives, methods, and references

Objective	Selected methods and references
Reforestation	· Commercial forestry: (Evans and Turnbull, 2004; Lamb and Gilmour, 2003) · Using assisted natural regeneration: (FAO, 2019) · Taungya systems: (Menzies, 1988)
Rehabilitate Degraded Forests	· Landscape approaches: (Lamb and Gilmour, 2003) · Enrichment planting (Hadengganan *et al.*, 1995; Schulze, 2008)
Transform Degraded Forest	· To increase biological diversity: (Carnus *et al.*, 2006; Lamb, 1998) · To increase structural diversity: (O'Hara, 2014)
Reclaim or rehabilitate contaminated sites	· Phytoremediation: (Favas *et al.*, 2014) · Mined sites (Adam *et al.*, 2017)
Increase product diversity from damaged forest	· Storm damage (Pischedda, 2004)
Restore forest from severe disturbances	· Fire: (Ager, Vaillant and McMahan, 2013; Moore, 2005) · Hydroperiod and coastal restoration, including planting and site function restoration: (Lewis and Brown, 2014)

Source: modified from Stanturf, Palik and Dumrose (2014)

In degraded logged-over forests that still have valuable tree species, natural regeneration methods are worth considering. Such methods are particularly promising if tree seedlings (or other forms of natural regrowth, such as root or stump sprouts) are already present at the site, indicating that site conditions are suitable for natural regeneration. The success of a natural regeneration approach will be determined by the adequate production of regenerative materials (such as seeds) by the parent vegetation at suitable times, weed control, and the receptiveness of the site to seedling establishment at the time of seed fall (e.g. some tree seeds can only establish on bare mineral soil). Insight into assisted natural regeneration and the conditions under which natural regeneration is most likely to succeed is provided in Figure 2.

In degraded sites without sources of natural regeneration or when more intensive management is preferred to meet management objectives, it may be necessary to plant trees, shrubs and grass species for successful forest restoration. Tree-planting is one of the most commonly identified activities in forest restoration projects, but it is not as simple and easy as it may appear and by no means is it the end of the restoration process – the long-term commitment of all stakeholders to manage and maintain a forest is essential for success. Planting may also be applied in degraded secondary or logged-over forests by planting or direct seeding of native tree species in natural gaps or along planting lines in existing stands, a practice known as enrichment planting. Finally, planting is often appropriate when the objective is to increase timber production or for other management objectives with a clear business case in the private market. Planting trees may not be appropriate in areas with limited water resources, land pressure, or capacity to tend the stand.

Assisted natural regeneration/farmer managed natural regeneration success factors

Natural regeneration approaches are most likely to succeed if the following conditions apply:

- Topsoil remains onsite or is supplemented.
- There are forest fragments, preferably large and well preserved, in close proximity to the target site.
- Re-sprouting natural vegetation promotes rapid early growth and soil stabilization.
- Seeds of early- and late-successional woody species are present in the seed bank and in seed rain.
- Common and rare native species are able to colonize over the long term.
- Weed suppression happens rapidly after site abandonment.
- A diversity of fauna (insects and vertebrates) serving as pollinators and seed-dispersal agents is present in the landscape.
- There is protection against frequent fires that promote fire-resistant grasses.
- Hunting and the excessive harvesting of litter and forest products are prevented.
- The site is protected from grazing and clearance from agricultural land use.

Where these conditions are not met, assistance is needed to overcome barriers to natural regeneration. Management options that can catalyse natural regeneration include the:

- active suppression of weeds/grasses;
- management of invasive species;
- protection of sites from fire and premature harvesting;
- protection from grazing (fencing or other controls);
- provision of perches and roosts for seed-dispersing birds and bats; and
- planting of seeds or nursery-grown seedlings of useful species not present in the seed rain.

In some cases, fast-establishing species that enhance soil fertility and shade out weeds and grasses can be planted to initiate forest establishment.

Source: Chazdon (2016)

Figure 2. Conditions and management actions for successful natural regeneration

The selection of the restoration method should therefore depend on the objective of the restoration, the means available, and a balanced assessment of the merits and drawbacks of the options available to achieve those objectives with the means at hand.

3. Establish realistic time schedules and plan for financial requirements

Forest restoration efforts are long-term investments that prepare the way for sustainable forest and land management. They require awareness and diligence in policy and planning to mitigate the ecological and socio-economic risks associated with them. Some indicative costs and timelines for restoration involving wholesale replanting serve to illustrate the matter.

The costs of forest restoration vary widely, depending on local costs and the restoration techniques used. See table 1 of Shono, Cadaweng and Durst, (2007) for a comparison of the merits of different restoration approaches. Nursery costs include nursery construction and equipment, consumable materials, and labour (salaries and wages). The total work required for site preparation, planting, weeding, fertilizer application, replanting and monitoring from the first to the third year after planting can be estimated at 50–150 person-days per ha excluding fire prevention, which is usually necessary for three to six months per year, depending on the duration of the dry season. Thus, the total cost of a successful full-scale forest restoration project that involves planting trees, including seedling production and all materials and labour for planting, maintenance and monitoring for three years, is likely to be in the range of US$1000–3,000 per ha (Evans and Turnbull, 2004, table 6.1; FAO and UNCCD, 2015, table 2; Hitimana, 2019, personal communication).

Though the costs thus vary widely, forest restoration is a considerable investment and long-term protection is essential. It is an unfortunately common mistake to underestimate the total time required to implement forest restoration projects. Reconnaissance surveys of the project site should start two or three years prior to silvicultural operations. If trees are grown locally from seed, nursery construction and seed collection must begin at least two years before the first planting. Large-scale forest restoration campaigns with ambitious targets to replant vast areas are likely to fail if they do not take into account the limited capacity available for field operations. It is usually better to plant relatively small areas annually over several years than to plant a large area in a single season and have large numbers of planted trees die because of a lack of tending.

Monitor and maintain forest management

Regardless of the type of forest restoration undertaken, monitoring and maintenance (i.e. tending) is an essential component of success. It should be part of the planning and resources allocated to the effort. Every monitoring effort should be built around three basic questions:

1. What do we intend to do?
2. Did we do it?
3. Did it work?

In other words, the purpose of monitoring should be to establish whether planned management interventions were implemented and had the expected effect. This allows the manager to adjust interventions (silviculture, in this case) so that objectives can be reached.

Maintenance is related to monitoring, and much monitoring of progress can be done when going to the site to do necessary maintenance. Maintenance in forest restoration involves additional silvicultural operations that keep the forest on the planned trajectory towards the desired forest condition. To illustrate these points, Table 3 provides guidance on maintenance and monitoring requirements of planted forests.

Table 3. Indicative guidance on monitoring and maintenance of planted forests

Period after planting	Monitoring and maintenance action
1–2 weeks	Check quality of planting; adjust poorly planted seedlings
3–6 months	Monitor growth and survival rates of naturally regenerated and planted trees; control weeds and apply fertilizer, and repeat as appropriate
Start of dry season	Cut firebreaks; build fire lookout towers; organize fire patrols; fence the area if large populations of grazers and browsing animals are expected
End of dry season	Survey the growth and survival of naturally regenerated and planted trees and assess the need for replanting
6–12 months	Replant failed areas (if required)
Subsequent years	Control weeds and climbers along planting lines; regulate shade; apply fertilizer as appropriate; prescribed burns if indicated; thin and prune where needed

Maintenance activities also include the following silvicultural treatments:

Weed control. Dense weed growth will retard the growth of both naturally regenerating and planted seedlings – and can cause their death – as a result of competition for moisture, nutrients and light. Weed control helps newly established trees to survive and grow by minimizing the damaging effect of other plants on the desirable trees. If chemical weeding is undertaken it requires compliance with regulations, implementation per manufacturer instructions, and the use of adequate safeguards to protect workers and the environment.

Prescribed burns, in which low-intensity fire is used to control the growth of the understorey, may be an effective option to control fire risk in compartments once the desired trees are large enough to resist fire.

Tending and thinning. Tending and thinning in naturally regenerated and planted stands are silvicultural operations to improve stand quality by eliminating or suppressing undesirable vegetation, including climbers and vines, and removing poorly formed, damaged or diseased trees. The objective is to increase the crown development and diameter growth of desirable trees, concentrate future increment on the best-formed trees, and increase the stability of the stand by giving more growing space to the roots and crowns of the potential final crop trees. Tending and thinning operations are decisive factors in the achievement of production goals. There are many tools for forest workers when it comes to thinning, including mechanical thinning, girdling and slashing, as well as many methods (e.g. systematic, selective). For more information on tending planted forests, see for example Chapter 16 of Evans and Turnbull's text, Plantation Forestry in the Tropics (Evans and Turnbull, 2004). There is a huge variety of tending and thinning operations possible in forestry. For a general introduction to silviculture and thinning, see Ashton and Kelty, (2018).

Make long-term investments that reduce risk

Beyond restoration of sites, the public and private sector can reduce risk and increase chances of success in forest restoration by investing in their citizens and employees. This means ensuring that they have good foresters and training laypersons living and working in the agriculture sector and in rural areas; the public sector can do this by maintaining schools of forestry and extension services that can train qualified personnel, and employers in the forest sector can do this by investing in professional development. Climate risk and uncertainty is another relevant consideration for long-term investments like forestry, and both site-based and larger-scale approaches to mitigate that risk have a role to play.

1. Capacity-building and training

Ongoing capacity development is essential for improving planning, management and technical decision-making on forest restoration. Key groups to target include:

- the administrators of responsible agencies, so they can plan and budget for effective programmes;
- foresters, so that they can effectively manage and implement the work in the forest;
- landowners and rural populations, so they can understand and engage in restoration activities

Developing a forestry extension programme and organizing it require an understanding of the subject, the situation of the target population, the resources available, and the principles of adult learning. In recent years, there has been a transition to extension programmes that emphasize and facilitate peer-to-peer exchange and learning rather than creating an extensive network of extension workers. This should be complemented with vocational and professional programmes of certification in forestry in institutions of higher learning.

2. Risk management

Climate change is likely to pose new risks for forest restoration projects; for example, unpredictable rainfall will pose challenges for reforestation, and increase in wind and storms will cause more damage than in the past. Specific interventions to build ecological and socio-economic resilience are set out in FAO's climate change guidelines for forest managers and Global guidelines for restoring the resilience of forest landscapes in drylands.

Beyond the additional risks posed by climate change and uncertainty, forest owners and managers have always dealt with the risk that comes with managing trees that take a long time to mature. This risk can be mitigated, for example:

- financially, by providing lower taxes and lower-cost loans;
- ecologically, by planting mixtures of species in landscapes or in a compartment;
- technologically, by planting genetically improved trees that mature more quickly or are resilient to certain risks.

Helping landowners reduce their vulnerability to risk will increase their engagement in forest restoration.

E-learning

[Introduction to forest and landscape restoration]

Degradation of forests and landscapes impacts the global climate, and also the food security and livelihoods of communities. Forest and landscape restoration (FLR) is a process which brings stakeholders together to create healthy, resilient and productive landscapes and meet national, regional and global commitments.?

[Developing bankable business plans for sustainable forest-based enterprises]

This course has been developed to improve the capacity of small-scale producers, their organizations, and small and medium-sized enterprises to access investment and other forms of finance. Facilitating this allows these stakeholders to derive socioeconomic benefits from their participation in forest value chains, and also complements the resources of official channels in contributing to achievement of the Sustainable Development Goals (SDGs).

[Monitoring forest and landscape restoration]

As countries work to meet their national commitments to restoring degraded landscapes, it is important that all FLR interventions have manageable monitoring systems in place, to assess progress towards specific goals, support adaptive management and ensure transparency...

[Sustainable financing of Forest and Landscape Restoration]

To meet countries' national commitments to restoring degraded landscapes, adequate public and private investments are needed to support the different steps of the FLR cycle. Financing sources are more efficient when used in a coordinated way.?

Further learning

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Credits

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