Forest Restoration and Rehabilitation

Basic knowledge

Welcome to the Forest Restoration and Rehabilitation Module, which is intended for people involved in afforestation and reforestation programmes. The module establishes the difference between forest restoration and rehabilitation and sets out the main steps involved in both.

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

Forest restoration and forest rehabilitation are challenging long-term endeavours that require thoughtful planning, implementation and monitoring. While they are closely related, a conceptual distinction may be made between them. The purpose of **forest restoration** is to restore a degraded forest to its original state – that is, to re-establish the presumed structure, productivity and species diversity of the forest originally present at a site. The purpose of **forest rehabilitation** is to restore the capacity of degraded forest land to deliver forest products and services. Forest rehabilitation re-establishes the original productivity of the forest and some, but not necessarily all, of the plant and animal species thought to be originally present at a site. Both forest restoration and forest rehabilitation are implemented on sites or in landscapes where forest loss has caused a decline in the quality of environmental services. They aim to strengthen the resilience of forest sites and landscapes and thereby to keep future land-use and management options open.

An emerging concept is forest landscape restoration (FLR), an approach to forest restoration that involves stakeholders in all affected land-use sectors as well as participatory decision-making processes. FLR is an approach to managing the dynamic and often complex interactions between the people, natural resources and land uses that comprise a landscape. It makes use of collaborative approaches to harmonize the many land-use decisions of stakeholders with the aims of restoring ecological integrity and enhancing the development of local communities as they strive to increase and sustain the benefits they derive from the management of their land.

Forest restoration and rehabilitation may be carried out on unproductive or abandoned agricultural land, deforested grasslands, brushlands, scrublands or barren areas, and in understocked or degraded forests. Forests may be restored and rehabilitated by protective measures (e.g. protection from fire or grazing and erosion control), measures to accelerate natural recovery (e.g. through direct seeding or by planting seedlings in degraded primary or secondary forests), measures to assist natural regeneration (e.g. through weed control on degraded lands and marginal agricultural sites), and the planting of native or introduced trees in single-species or mixed-species plantations, in agroforestry production systems and as trees outside forests.

Successful, ecologically sound, socially acceptable and economically viable forest restoration and rehabilitation initiatives should take into account the following

10 key guiding principles

1. Select a suitable site or landscape, including the analysis and evaluation of current land uses and land tenure/ownership, and identify involved stakeholders.
2. Analyse and evaluate the drivers of deforestation or forest degradation.
3. Engage stakeholders, discuss long-term goals of forest restoration considering the interests of all stakeholder groups, and draft a preliminary restoration/rehabilitation plan.
4. Develop a restoration management plan, including:
    - preparing a topographic land-use map, including a designation of forest functions, assessment of road accessibility, existence of natural regeneration and needs for planting;
    - agreeing on restoration/rehabilitation objectivess
    - selecting the restoration/rehabilitation method
    - choosing the species to be used, and establishing a nursery and
    - assessing possible positive and negative social and environmental impacts.
5. Collect seeds, produce seedlings in nurseries and prepare for planting.
6. Plant trees.
7. Assess capacity-building needs and plan for the necessary training.
8. Establish realistic time schedules and plan for financial requirements.
9. Monitor restored/rehabilitated areas, and conduct maintenance activities as required
10. Consider possible climate-change impacts.

Forest restoration and rehabilitation contributes to SDGs:

In more depth

The ten key guiding principles for successful, ecologically sound, socially acceptable and economically viable forest restoration and rehabilitation initiatives outlined in Basic knowledge are described in more detail below.

1. Site or landscape selection

Sites or landscapes suitable for forest restoration and rehabilitation projects may vary in size from a few hectares to several thousand. The selection process requires the careful consideration of social and legal constraints – such as land tenure, the demand for productive agricultural land, and land accessibility. It is crucial to clarify ownership and tenure at the outset because land disputes must be avoided. Any forest restoration or rehabilitation initiative should have strong buy-in from landowners, both public and private, who should see clear benefits from the initiative. Possible sites or landscapes for forest restoration and rehabilitation 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.

2. Drivers of deforestation or forest degradation

The intensive exploitation of forests and related disturbances has created large areas of degraded forests. Globally, more than one billion hectares (ha) of deforested and degraded forestland are estimated to be available for forest restoration and rehabilitation. Understanding and effectively addressing the drivers of deforestation and forest degradation on a specific site or in a landscape is the key to any successful forest restoration or rehabilitation plan.

3. Stakeholder engagement

Forest restoration and rehabilitation efforts will only be sustainable if they are socially acceptable. The principal stakeholders (e.g. forest owners, local communities, concessionaires, and forest and other authorities in charge of land use) should be engaged from the start to, for example, agree on long-term goals, on roles and responsibilities and the equitable distribution of incentives, costs and benefits; establish a consensus on the trade-offs involved in addressing the drivers of forest degradation; and discuss a preliminary forest restoration or rehabilitation plan.

At the landscape level, forest restoration and rehabilitation projects interact ecologically and socioeconomically 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 in the landscape.

Ensuring transparent, just and sound stakeholder engagement is at the heart of all successful forest restoration and rehabilitation projects. Such engagement includes a comprehensive analysis of interactions among local communities, agriculture, animal husbandry and natural and planted forests, an adequate diagnosis and evaluation of the drivers of forest degradation, and an honest assessment and discussion of the benefits of forest restoration or rehabilitation for local communities and society at large.

Stakeholder engagement should also take into account gender issues. Both men and women are important players in the process of forest restoration and rehabilitation and should be consulted, in particular for the analysis of the causes of forest deterioration and at each stage of the resource planning process. Case studies in many African countries give evidence that women can play a significant role in forest restoration and rehabilitation. In Niger, e.g., the inclusion of women in decision making was fundamental in addressing land conflicts and managing the regeneration process of degraded forests. Women in Senegal and Ghana, were more likely (than found in other studies) to embrace complementary support programs, such as the usage of group savings and the use of wild fruits and berries for nutritional and medicinal purposes. Hence, if women participate and exercise control over resource use, communities benefit, especially with regards to child nutrition and family health.

An important part of the land-use planning exercise is the zoning of the restoration or rehabilitation areas by their intended functions (e.g. production, protection and community needs) on the basis of socioeconomic and ecological criteria; this is best done through a combination of technical considerations and stakeholder involvement. The forest functions ultimately determine the forest management goals (e.g.

biodiversity protection, erosion control, watershed protection, sawlog production and wood fuel production) and the corresponding management regime.

Financial benefits, such as those created by employment, the harvesting of forest products, ecotourism and payments for environmental services, are the most obvious and measurable sources of motivation for stakeholders to participate in forest restoration and rehabilitation projects. Communities often also regard non-financial benefits, such as improvements in the environment (e.g. soil and water resources) and village infrastructure (e.g. the renovation of school buildings), the maintenance of cultural traditions or political gain (e.g. the strengthening of land-tenure rights), as equally – or more – important reasons for restoring forest landscapes.

4. The restoration management plan

Prepare a topographic land-use map. Various biophysical and silvicultural characteristics should be identified and mapped to help determine the feasibility and suitability of different restoration and rehabilitation approaches. Characteristics that should be mapped 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.

Define restoration/rehabilitation objectives. Forests can be restored and rehabilitated for multiple combined objectives, such as to enhance land productivity, produce wood and non-wood products, support livelihoods, contribute to poverty alleviation (e.g. by supplying a variety of forest products to local communities), provide environmental services (e.g. water and soil protection), and create landscapes that sequester large quantities of carbon and are diverse, productive and resilient to adverse change.

Select restoration/rehabilitation method(s). In degraded logged-over forests that still have populations of desirable tree species, natural regeneration methods are likely to be most effective. Such methods are particularly promising if tree seedlings (or other forms of natural regrowth) are already present at the site, indicating that site conditions are suitable for natural regeneration (and possibly that fertile seeds are being shed by parent trees). The success of a natural regeneration approach will be determined by, among other things, the adequate production of regenerative materials (such as seeds) by the parent vegetation at suitable times, good weed control, and the receptiveness of the site to seedling establishment at the time of seed fall. Insight into assisted natural regeneration (see box) and the conditions under which natural regeneration is most likely to succeed is provided here.

In open, largely deforested areas that have been subject to, for example, intensive animal husbandry or mining, the natural regeneration of trees or shrubs may be difficult due to a lack of seed sources and the loss of topsoil. In such cases it may be necessary to plant trees, shrubs and grass species for successful forest restoration and rehabilitation. Tree-planting is one of the most common activities in forest restoration and rehabilitation projects, but it is not as simple and easy as it may appear and by no means is it the end of the restoration or rehabilitation 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 sowing the seeds of native tree species in natural gaps or along planting lines in existing stands, a practice known as enrichment planting. The selection of the restoration method should also include an assessment of the possible positive and negative social and environmental impacts of the various options.

Choose species and establish nursery. The choice of species (e.g. tree, shrub or grass, and which particular species of these) depends on the goals of the forest restoration or rehabilitation project, the prevailing site conditions (e.g. terrain, climate and soil) and the availability of parent trees or planting stock. Ideally, the selected species will yield products such as lumber, fibre, woodfuel and non-wood products such as foods and medicines. Non-wood species that colonize restored sites, such as bamboo, honeybees, fungi and wildlife, can provide early financial returns for forest restoration and rehabilitation projects. In general, native species should be used in preference to exotic ones because they are likely to pose a lower environmental risk (especially in terms of invasiveness) and have biodiversity benefits. If, however, there is a lack of native species suitable for colonizing barren land, grassland or forest clearings, the establishment of a “nurse crop” of sturdy pioneer or introduced species may be beneficial.

Assess possible negative environmental and social impacts. Forest restoration and rehabilitation initiatives should be assessed for possible negative environmental impacts. Species should be selected in consultation with local communities, taking into account ecological, social, economic and cultural factors. Depending on the scale of the operation, a formal environmental and social impact assessment may be required.

5. Seed collection and seedling production

In forest restoration and rehabilitation projects where the aim is to restore or re-establish a natural forest, efforts should be made to collect seeds and other propagative material from a diverse range of native plants in the local area. In some cases, this might mean that characteristics such as high growth rates or good stem form are only secondary considerations. Commercial and public nurseries may grow some local forest species, but possibly not on a large scale. It may be necessary, therefore, for the restoration or rehabilitation project to produce its own forest seedlings, possibly in community nurseries. Containerized seedlings are preferred because digging up seedlings from a soil bed and transporting them to a planting site in a bare-rooted state increases the risk of dehydration and transplantation shock and reduces the likelihood that they will establish successfully (although see Forest Pests for an argument for the use of bare-root seedlings).

An alternative to the use of nursery-grown seedlings would be to sow the seeds directly in the restoration or rehabilitation area after experimentation to determine the most successful direct-seeding techniques.

Nursery preparations to maximize the success of planting operations may include the following:

- Assess the number, quality and species of seedlings available in nurseries and ready for planting.
- Harden off seedlings in the nursery.
- Demarcate planting plots in the field, mark existing natural regeneration, prepare planting lines and planting holes, and slash weeds on planting lines to ground level.
- Water seedlings and transport them to the planting site, along with planting equipment and materials.
- Brief stakeholders on planting plans and agree on the roles of all stakeholders.
- Develop a schedule of works and assign responsibilities for implementing the planting operation.

6. Planting trees

For planting to succeed, the following points should be considered:

- A combined density of planted plus naturally regenerated seedlings or trees in the range of 400–1000 stems per ha is usually sufficient to restore or rehabilitate a forest stand.
- The optimal height of seedlings for planting is generally considered to be in the range of 25 to 50 cm. When planting into existing vegetation, however, a seedling height of 50–75 cm may be required because taller plants are more likely to compete successfully with other plants (e.g. weeds). The higher cost of producing larger plants in the nursery is likely to be offset by lower mortality rates and reduced weeding costs.
- Planting on deforested or degraded sites requires sturdy plants that have been hardened off in the nursery and watered prior to planting. In bare areas it may be necessary to establish nurse crops of fast-growing species prior to planting or to maintain secondary vegetation for site protection.
- The best time to plant trees is early in the rainy season to ensure that newly planted seedlings receive adequate moisture in their first months as they develop their root systems. Locally appropriate planting dates can be determined from local meteorological data.

7. Capacity-building and training

Ongoing capacity development through professional education and training, extension support services and the strengthening of national research capabilities is essential for improving planning, management and technical decision-making on forest restoration and rehabilitation and to enable organizations to understand and respond to the priority needs and aspirations of stakeholders. In particular, nursery managers and staff should be trained and supported to produce high-quality seedlings with the best possible chance of establishing in the field and growing rapidly when planted out in the often difficult environment of a deforested or degraded site.

8. Establish realistic time schedules and plan for financial requirements

Forest restoration and rehabilitation are long-term investments preparing the way for sustainable forest and land management. They require awareness and diligence in policy and planning to mitigate the ecological and socioeconomic risks associated with them. Some indicative costs, which will vary depending on local conditions, are given below.

Nursery costs include nursery construction and equipment, consumable materials, and labour (salaries and wages). A simple community tree nursery with a capacity to produce 10 000–20 000 seedlings per year can be established for US$500–1 000. The cost of seedlings (including material and labour) is likely to average US$0.1–0.5 per seedling. The total cost of seedlings is likely to be between 125 and 625 US dollars per ha, assuming a planting density of 1 000 plants per ha and the need to replant about 25 percent of the area (to replace failed seedlings).

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 3–6 months per year, depending on the duration of the dry season.

The total cost of a successful forest restoration project, 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$1500–2 000 per ha. Forest restoration and rehabilitation projects, therefore, are considerable investments, and long-term protection is essential.

It is a common mistake to underestimate the total time required to implement forest restoration and rehabilitation projects. Reconnaissance surveys of the project site should start two or three years prior to planting. 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 and rehabilitation 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.

9. Monitoring and maintenance

Tree seedlings – whether planted or established naturally – may need to be protected for up to five years after establishment against: competition from weeds for light, moisture and nutrients; wildfire; and browsing by wild and domestic animals. Seedling growth can be promoted by the application of fertilizers that accelerate tree growth and facilitate rapid canopy closure. In seasonally dry climates, an effective fire prevention programme is essential. A ground survey should be conducted 3–6 months after the planting event to assess the establishment rate. Dead seedlings should be replaced early in the next rainy season, ideally with seedlings of a similar size to those surviving nearby.

The table provides guidance on maintenance and monitoring requirements.

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 watch towers; organize fire patrols
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; and apply fertilizer as appropriate

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. Chemical weeding in forest restoration and rehabilitation projects is risky and, for ecological reasons, should be avoided as far as possible.
- **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.

10. Climate change

Climate change is likely to pose new challenges for forest restoration and rehabilitation projects. Specific interventions to build ecological and socioeconomic 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.

Conditions and management actions for successful natural regeneration

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

1. Topsoil remains onsite or is supplemented.

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

Where these ten 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;
- removal of exotic species;
- protection of sites from fire and overharvesting;
- provision of perches and roosts for seed-dispersing birds and bats; and
- planting of seeds or nursery-grown seedlings of native forest species not present in the seed rain.

In some cases, non-native species that enhance soil fertility and shade out weeds and grasses can be planted to initiate forest establishment. Where topsoil has been removed, such as in bauxite mining, successful reforestation requires the replacement of the removed soil following storage, the addition of leaf litter and organic matter from local forests, and the planting of mixtures of native tree species. Source: Chazdon (2013).

Further learning

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Web links

http://www.itto.int/project_search/ ITTO - Project search. 2004-2014. Last accessed 23.09.2014.

Credits

This module was developed with the kind collaboration of the following people and/or institutions:

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