Silviculture in Natural Forests

Basic knowledge

Welcome to the Silviculture in Natural Forests Module. This module is intended for forest owners and managers wishing to design, implement, monitor and evaluate silvicultural practices to enhance the productivity, resilience and value of natural forests.

The module provides information and links to tools and case studies, to guide users in planning silvicultural interventions in natural forests at the forest management unit level.

Natural forests are forests that have regenerated naturally; they are composed of all the species (e.g. trees and other plants, fauna and fungi), that occur naturally in them. Natural-forest silviculture can be defined as the practice of controlling the establishment, growth, composition, health and quality of natural forests to meet diverse needs and values. Silvicultural practice consists of the interventions applied to forests to maintain or enhance their utility for specific purposes, such as the production of wood and other forest products, biodiversity conservation, recreation and the provision of environmental services.

Decisions on silviculture in natural forests can occur at three levels: silvicultural systems; silvicultural treatment regimes; and silvicultural operations.

- A *silvicultural system* is "the process by which the crops constituting a forest are tended, removed and replaced by new crops, resulting in the production of stands of distinctive form ... The terms 'stand' and 'crop' are both used to denote silvicultural or management units that are homogeneous in one or several aspects" (Matthews 1994).
- A *silvicultural treatment* is a planned programme of silvicultural operations that can be implemented during the entire or partial rotation of a stand. Within the context of silvicultural stand treatment, each stand is assigned a specific silvicultural objective and separately assessed for the characteristics of its site (e.g. locality, slope and soil type) and stocking (e.g. composition, age, diameter distribution and regeneration). Based on this information, a *silvicultural treatment regime* is formulated.
- *Silvicultural operations* are procedures that aim to achieve stand-specific objectives by using silvicultural techniques. Such techniques include, for example, canopy alterations to induce natural regeneration, the harvesting of mature trees, planting, and thinning to improve timber quality and stand growth. Silvicultural operations involve decisions on machinery and other equipment, techniques, work organization and human resources, as well as considerations of operational cost and investment.

Silvicultural systems usually develop as a response to the practical need to balance market, socioeconomic and ecological requirements in a technically feasible way. Silvicultural systems in natural forests can be categorized broadly as either monocyclic ("uniform", "even-aged") or polycyclic ("selective", "uneven-aged"). Monocyclic systems involve harvesting all marketable timber in a single felling operation, and the length of the cycle is more or less equal to the rotation age of the species under exploitation. Clearcutting is the most obvious example of a monocyclic system, and the Malayan Uniform System (which is not a clearcutting system) is a monocyclic system that has been used successfully in some tropical forests. Polycyclic systems involve the harvesting of trees in a continual series of felling cycles; selection cutting using a minimum diameter for harvesting is a common method. The length of these felling cycles is usually about half the time required for a particular species to reach marketable size.

There are many variations of these two systems, depending on biological, ecological, economic and administrative conditions and silvicultural goals. An important difference between them is that polycyclic systems rely on the existing stock of seedlings, saplings and poles in the forest to produce the next harvestable crop, whereas monocyclic systems generally do not make use of existing stock, instead relying on seedlings recruited after felling to produce the next crop of trees.

Silvicultural interventions should be planned in accordance with the management objectives of the forest and as specified in the forest management plan. In forests managed for wood production, silvicultural interventions may be necessary to address the relative depletion of commercial tree species caused by past logging interventions, to increase the growth of commercial species, and to optimize the commercial value of the forest. The intensity of interventions will vary depending on, for example, accessibility, markets, site quality, management objectives and ownership.

In planning silvicultural interventions, forest managers should ensure they have adequate biological and socioeconomic information on the forest (see Forest Inventory), as well as sufficient knowledge of operational aspects such as weather, access, funding and human resources. Forest managers should also have a good understanding of the ecology of the forests in which interventions are planned, especially the structure of the existing stand and the requirements for ensuring the adequate regeneration of desirable species.

Silviculture in natural forests contributes to SDGs:

Related modules

- Forest inventory
- Forest management planning
- Forest restoration
- Management of non-wood forest products
- Management of planted forests
- Occupational health and safety in forestry
- Participatory approaches and tools for SFM
- Wood harvesting

In more depth

Planning silviculture

The correct choice of silvicultural system in a given forest management unit depends on the management goals and objectives as well as the ecological characteristics of the forest, such as forest type, site conditions, species composition, species' associations, diameter distribution, cutting age, the size of desirable species, and the regeneration status of desirable species and their ecological requirements at the seed and seedling stage. *Desirable tree species* may be commercial or potentially commercial species (for either wood or non-wood products), locally valued species (such as those with household uses or which have social, cultural or religious value), and ecologically important species (such as keystone species for wildlife). Managers should bear in mind that commercial value can change over time and that this might have implications for silviculture.

In choosing a silvicultural system, adequate consideration should also be given to socioeconomic aspects, such as the availability of human and financial resources, the desired end products and services (taking into account both current and foreseeable demand), and the institutional and regulatory environment. Other considerations may include the views and needs of local people and the likely impacts on forest resilience. Most of this information is usually gathered in the preparation of forest management plans (see Forest Management Planning).

Decisions on the types and purposes of silvicultural treatments to be applied in a harvesting area (e.g. a coupe or compartment) should be made based on the condition of the forest – such as the existence (or otherwise) of an adequate number and distribution of trees of desirable species to constitute the next crop, the response of desirable species to different light conditions, and other factors that may assist or impede tree growth. Forest inventories that collect data on, for example, the abundance and diameter distribution of the species of interest and the total basal area in the corresponding forest types are usually essential for such decision-making. Other relevant studies, such as on market prospects for desirable tree species, as well as silvicultural trials and analyses of the costs and benefits of silvicultural treatments, should also be considered.

Diagnostic sampling is a rapid and inexpensive technique for estimating the potential productivity of a forest stand and for assisting decision-making on silvicultural treatments, including which treatments (if any) are necessary and when they might be needed. The focus of diagnostic sampling is the frequency of selected pre-commercial trees (i.e. those commercially desirable species that are not yet of harvestable size), which are usually the largest, best-formed individuals with vigorous crowns, known as "leading desirables". Leading desirables must meet a range of quality criteria that define them as the trees most likely to be targeted in future harvests. Diagnostic sampling was developed for humid tropical forests and can be applied in unlogged, previously logged and secondary forests. It can also be applied before or immediately after harvesting, and at intervals between harvesting events.

The results of diagnostic sampling can be used in setting the priorities of silvicultural tending in different forest types and in determining an appropriate initial sequence and design of silvicultural operations and the need for, and extent and density of, enrichment planting. Apart from this traditional use, diagnostic sampling can be used for forecasting the prospects of plants important for non-wood forest products, such as fruit-bearing trees important in wildlife management, flowering trees for beekeeping, and medicinal plants. Steps and field procedures for diagnostic sampling, including a silvicultural decision-making structure, can be found in Hutchinson (1991) and FAO (1998).

Silvicultural practices in primary logged forests

Degraded primary forests are becoming a predominant forest type in many countries and are increasingly having to perform the productive and environmental functions of primary forests. Degraded primary forests usually require silvicultural interventions to restore productivity and other ecosystem functions.

Harvesting

In practice, tree harvesting is the logical starting point of silvicultural systems and also the silvicultural operation with the most profound and lasting effects on forest structure, composition and functioning. Harvesting should be planned to enable good technical control, minimize harvesting costs and reduce environmental impacts, including on the residual forest. Environmental impacts can be minimized through the use of reduced-impact logging (RIL) procedures and techniques. RIL involves the implementation of a series of pre- and post-logging practices designed to protect advance regeneration (i.e. seedlings, saplings, poles and small trees) from injury, minimize soil damage, prevent unnecessary damage to non-target species (e.g. those important for wildlife and non-wood forest products), and protect critical ecosystem functions such as water catchment protection and carbon sequestration (see Wood Harvesting).

Post-harvest silviculture

In general, silvicultural interventions are necessary in logged forests to overcome the relative depletion of commercial tree species, compensate for slow growth rates and ensure future commercial wood harvests. Such interventions fall into two general categories – stand-tending treatments, and regeneration treatments – and they can be conducted in conjunction with harvesting to reduce the cost associated with additional stand entries.

Stand-tending treatments aim to promote the survival and growth of existing trees of desirable species. They are usually the first step in improving the productivity of the resource and its capacity to meet commercial, social and cultural objectives, and they can be undertaken in two phases. The first phase entails an operation called overstorey removal, in which overmature, defective non-commercial stems ("relics") are removed, usually by poison-girdling, from the upper levels of the forest canopy. A second phase consists of liberation thinning, a treatment that releases young saplings of desirable species ("potential crop trees") from competition by commercially less-desirable species. Methods for liberation thinning include felling, girdling, and girdling followed by herbicide application (see details in FAO, 1998; Wadsworth, 2000; Peters, 1996).

The success of silvicultural tending operations depends on: the existence of a sufficient number of potential crop trees (for example, at least 100 specimens per ha is generally considered sufficient in tropical rainforests); a more-or-less even distribution of potential crop trees over the entire area; and the adequate and long-lasting responsiveness of desirable trees to liberation thinning.

Regeneration treatments aim to induce or enhance the regeneration of desirable tree species and to control competing vegetation. These treatments are necessary in heavily disturbed forest, where insufficient or poorly distributed advance regeneration is a major constraint. The first step is to locate and protect remaining seed trees of the desirable species. In many cases, the retention of only 2–6 well-formed, reproductively mature trees of the desired species per ha will be sufficient to attain sufficient regeneration. Seed trees should have healthy, well-developed crowns and straight boles free of excessive taper and with no forking below the base of the crown. After selection, seed trees should be marked clearly and monitored until seed-fall is completed.

The most critical action for assisting desirable regeneration is improving light conditions. Stand-tending treatments, and treatments in the undergrowth and even at soil level, can all be considered.

Cleaning operations aim to reduce competition between existing seedlings or seedlings that have established from seed-fall. These operations include control measures against aggressive vines and plants such as bamboo, undergrowth palms and ferns. Cleaning the undergrowth is a time-demanding and costly intervention that is subject to error and carelessness in species identification. A more effective application is to clear ground vegetation below the crowns of a limited number of desirable adult trees prior to seed-fall to enhance the seed germination and seedling establishment of those species and also to facilitate seed collection.

Thinning is usually applied to juvenile trees of desirable species. It involves the selective removal of saplings or pole-sized stems to favour the growth of the residual stand. This operation is frequently conducted in situations where there is an overabundance of individuals of intermediate size, not all of which will survive to maturity, a situation that sometimes occurs with species regenerating in patches.

Soil-level treatments include controlled burning (prescribed fire) and mechanical scarification (e.g. using logging machinery) and are particularly useful for species (e.g. mahogany – *Swietenia macrophylla*) that require mineral-soil seed beds or minimal competition for germination, establishment and growth.

Enrichment planting

Enrichment planting generally consists of transplanting nursery-grown seedlings or wildlings into natural forest openings, gaps created by tree felling, or lines or strips opened specifically for this purpose. Enrichment planting may be appropriate in areas where the natural regeneration of desired species is insufficient or irregularly distributed, or to favour particular (usually high-value) species that do not regenerate easily. Enrichment planting has commonly been used in the restoration of logged primary forests and for increasing the wood volume and economic value of secondary forests.

The two most common enrichment-planting options are line plantings and gap plantings. The choice of method depends primarily on the condition of the forest stand; the gap planting method is generally recommended for overlogged forests, in which planting lines are more difficult to open and maintain.

Successful enrichment planting requires the provision of adequate light conditions, proper supervision, and follow-up maintenance (especially to manage light conditions and reduce competition). Species suitable for enrichment planting are likely to: produce timbers of high value; have rapid growth, low crown diameter, regular flowering and fruiting, wide ecological ranges, tolerance to moisture stress and good natural stem form; and be free of significant pests. The condition of seedlings at the time of planting is a major determinant in the success of enrichment planting; it is crucial that high-quality planting stock is used.

Guidance on enrichment planting can be found in FAO (1998), Palmer and Palmer (1989), Appanah and Weinland (1993), Dupuy (1998), Evans et al. (2003), and Bais (2012).

Silvicultural practices in secondary forests

Secondary forests form when disturbances to primary forest, such as severe overlogging, results in major changes in forest structure and composition. Secondary forests can also develop on land abandoned after shifting cultivation, settled agriculture, pasture and failed tree plantations.

Secondary forests often have special economic importance for the rural poor and those who live outside the cash economy because such forests are usually accessible to local people. They can provide a range of goods to meet immediate livelihood needs, such as timber for housing, fencing and posts, foods, and herbal medicines. Secondary forests are also being recognized increasingly for their value in fallow agriculture, in the industrial wood sector, as sources of locally or commercially valuable non-wood forest products, and for the provision of environmental services such as those associated with biodiversity conservation, climate-change mitigation, and water and soil conservation.

The characteristics of secondary forests are highly variable, depending on past site history (e.g. the type and intensity of previous land uses, and the time since disturbance) and site conditions (e.g. substrate fertility and seed availability). The potential of secondary forests to provide goods and environmental services depends on such factors as well as on the market and socioeconomic contexts.

The management of secondary forests in smallholdings and on community lands requires an understanding of the roles of such forests in farm production systems and within rural communities and of the socioeconomic factors that influence land and resource use. In many situations, secondary forests are fragmented patches in landscapes dominated by non-forest land uses, and management requires an understanding of the interactions between these uses as well as of the associated risks (such as fires or grazing) and opportunities (in terms of forest products and environmental services). Management decisions should be made from a landscape-level perspective, and they should be responsive to changes in biophysical, socioeconomic, policy and institutional conditions over time.

Secondary forests may be managed in either monocyclic or polycyclic systems. The silvicultural treatments used to stimulate the production of commercial timber species in primary forests, such as liberation thinning and refining, are also applicable in most secondary forests. Young secondary forests (e.g. less than 10–15 years of age) are usually most receptive to silvicultural manipulations because of the relatively small tree sizes and the growth responses of young trees to treatments.

In secondary forests with the potential to produce income-earning wood and non-wood forest products and environmental services, possible silvicultural practices include:

- the retention and management of seed trees of commercially valuable species;
- liberation thinning to favour trees of commercial value;
- canopy opening and undergrowth cleaning to favour the establishment of commercial regeneration;
- soil exposure to favour desirable regeneration;
- enrichment planting with commercial tree species (in lines, groups or gaps);
- the protection of species to benefit wildlife or as seed trees; and
- wildlife management.

If, on the other hand, the management objective is to increase the availability of useful products for use in farming and to diversify production, thus guiding the system to a *improved* or *enriched fallow* system, possible silvicultural practices include:

- the selection and tending of naturally established useful (wood and non-wood) tree, palm or shrub species;
- enrichment with desirable tree species (e.g. those preferred for lumber, woodfuel, fruits, medicine or forage); and
- the development of multi-strata crops using semi-perennial and perennial species.

When high wood productivity is a main objective, a monocyclic system that creates an even-aged stand by opening the middle and upper canopies shortly before tree harvesting is perhaps the most amenable. This strategy is likely to be particularly appropriate for pioneer, light-demanding species that require almost complete canopy removal, either to stimulate seed germination or to ensure sustainable seedling growth and survival. The financial competitiveness of secondary forests compared with wood plantations should be taken into account when this silvicultural management option is considered.

Silvicultural for multiple-use forest management

A shift from wood-focused management that aims to achieve high yields of a few economically attractive species towards multiple-use forest management, which aims to produce a mix of wood and non-wood forest products and environmental services, poses important challenges for silviculture because it requires knowledge and skill sets that are still segregated among different forest users.

For non-wood forest resources, the focus of silvicultural treatments is primarily on the seedling and sapling stages. Basic silvicultural operations include selective weeding, liberation thinning, coppicing and enrichment planting (see, for example, Peters 1994, 1996).

Forests provide a wide range of environmental services, but silvicultural planners need to know which such services are in demand and whether they should be provided through the integrated management of a forest area or by zoning forest areas according to their primary management objectives. Silvicultural planning should include the identification of sensitive areas or structures, for example to avoid downstream impacts on soil and water quality. Cutting cycles may need to be adapted and directional felling employed.

Silvicultural interventions may need to be managed in ways that are sensitive to ecotourism. For example, an aim may be to ensure that stands and landscapes are maintained in a biodiverse and attractive condition (obvious logging damage, for example, is unlikely to be compatible with ecotourism).

Guiding silvicultural practice

The following points, which are based on accumulated practical experience and research in the tropics, provide general guidance for planning and implementing silvicultural interventions in natural forests:

1. Wherever possible, use simple, clear silvicultural practices and techniques because these will produce faster results, keep costs and labour requirements down, and facilitate participatory processes.
2. Integrate silviculture with main harvesting operations. This will reduce the cost of silvicultural treatments and reinforce the idea that logging itself can be silviculturally useful.
3. Avoid unnecessary silvicultural interventions. Given the currently limited knowledge of the ecology and biology of tropical forests, and the effects of interventions (e.g. on biodiversity), any silvicultural treatment should be applied cautiously. Silvicultural interventions should address specific objectives.
4. Include a gender perspective in each stage of the planning process. Undertake a gender assessment while considering plantations in order to accommodate both women’s and men’s use of forests and specific needs, since women and men tend to rely on different resources. When setting the objectives, consider interventions that also target and address women’s needs.
5. Include traditional and indigenous empirical knowledge and practice in the planning of silvicultural work. The vast experience of indigenous peoples can provide valuable insights into forest management and has the potential to improve silvicultural approaches.
6. Increase the number of desirable species. The more intensive the use of the forest (i.e. the greater the range of tree species of commercial value), the greater the number of feasible silvicultural options.
7. In very diverse forests, group species into ecological and socioeconomic classes to simplify silvicultural interventions.
8. Avoid delaying post-harvesting silvicultural treatments because regrowth will quickly reduce access.
9. The potential to release the advance regeneration of desirable tree species should always be one of the main silvicultural considerations in natural forests.
10. Silvicultural interventions should not be so intense as to damage soils or residual vegetation. Not all forest areas will require silvicultural treatment, and efforts should be made to reduce costs by prioritizing those areas where most benefits will be obtained.
11. In intensive silvicultural treatments that reduce biodiversity (e.g. refining), consider excluding sufficient areas of the production forest (e.g. 10 percent) from silvicultural treatments to assist in biodiversity conservation.
12. When undertaking enrichment planting in natural forests, preferentially use indigenous species with proven commercial value.
13. Consider the use of different management practices for different types of products (both wood and non-wood). Silvicultural practices to promote specific non-wood forest products may include: sparing individual trees; imposing size restrictions on the harvesting of trees important for non-wood forest products; overstorey light management; thinning; transplantation; and coppicing.
14. Define and properly apply simple and practical ways for monitoring silvicultural interventions.

Monitoring silvicultural interventions

The silvicultural system and its related interventions (e.g. thinning) should be documented and justified in the forest management plan. The process of justifying the choice of silvicultural approach and techniques helps ensure that all stakeholders understand what is being done, and why.

Monitoring the applicability of technical specifications for silvicultural operations (e.g. weeding, enrichment planting, thinning and climber-cutting) should be done through on-the-ground random sampling within compartments in which operations have been applied. Effectiveness can be assessed by comparing the outcomes of different interventions (including “no intervention” controls).

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:

Initiator(s): Cesar Sabogal - FAO, Forestry Department

Contributor(s): Jonas Cedergren, Walter Kollert - FAO, Forestry Department

Reviewer(s): CATIE; CIFOR

This module was revised in 2017 to strengthen gender considerations.

Initiator(s): Gender Team in Forestry

Reviewer(s): Cesar Sabogal