Silviculture and Management of Planted Forests

Basic knowledge

Welcome to the Silviculture and Management of Planted Forests Module, which is targeted at stakeholders involved in the management of planted forests. The module provides specific information on good practices for the establishment and management of planted forests, from site selection and seed collection through to the planting of sites and their subsequent management.

The module also provides links to planted forest tools and case studies of effective management of planted forests.

Planted forests are established by planting and/or deliberate seeding native or introduced species, either on land previously not classified as forest (afforestation, implies a transformation of land-use from non-forest to forest), or on previously forested land (reforestation). Planted forests are established for many reasons, such as conservation, production and amenity. Planted forests can provide a wide range of environmental services, many of which cannot be provided by other types of land use. Planted forests can supply wood and non-wood forest products while also helping to restore and rehabilitate fragile ecosystems. They can help combat desertification, reduce erosion and absorb sewage water. They can help protect and improve soil and water resources, including when integrated with agriculture (see Agroforestry). Fast-growing planted forests can be an efficient way to produce woodfuel, either as a byproduct from forests planted for other purposes (e.g. lumber production) or in dedicated bioenergy plantations.

Planted forests can be effective in sequestering carbon and therefore in mitigating climate change. Globally, planted forests were estimated to have sequestered 1.5 gigatonnes (1.5×10^9 tonnes) of carbon in 2010, which was about 3.1 percent of global greenhouse gas emissions in that year. The volume of carbon sequestered by planted forests is expected to increase as the area of such forests continues to expand. The responsible management of planted forests can also reduce the need to harvest natural forests for wood and other products, enabling more such forests to be designated for protective and conservation purposes, with additional benefits for climate-change mitigation and the provision of other environmental services.

The potential and actual role of planted forests in addressing socioeconomic and environmental challenges such as poverty, food and energy insecurity, climate change and biodiversity loss is widely acknowledged. But the provision of such services is not an inevitable consequence of planting trees, and poorly designed and managed planted forests can result in a loss of biodiversity and soil and water quality and an increase in greenhouse gas emissions and can also cause major social disruptions, including by alienating people from their traditional lands. To avoid such problems, the establishment of planted forests requires good planning and the use of participatory multistakeholder processes.

Observing gender aspects in planted forest management can be key to achieving the set goals and objectives, especially when planted forests are established for the rehabilitation of degraded lands, to combat desertification and for landscape restoration. The multipurpose role of planted forests also helps increase the resilience of women and men against natural disasters and diseases and is fundamental to ensure a sustainable supply of wood for housing, household items, fodder and shadow for cattle, fuel and non-wood forest products including traditional medicines. The roles played by women in seed collection and nursery practices can be a valuable resource to be taken into consideration in the establishment of planted forests.

When establishing productive plantations, special attention must be given to the environmentally sound species' choice (see also paragraph under "In more depth"), in order to reduce and manage the risk of competition for water with other land uses, which always affects women in their role of securing food and water for their families.

Silviculture and management of planted forests contributes to SDGs:

In more depth

In 2010, the global planted forest area was estimated at 264 million hectares (ha), of which three-quarters was grown for productive purposes (e.g. the production of lumber, fibre, woodfuel and non-wood forest products) and one-quarter for protective purposes (e.g. the rehabilitation of degraded lands, combating desertification and the protection of soil and water resources). In 2010, planted forests accounted for only 7 percent of the global forest area, but they provide between one and two thirds of the global industrial roundwood demand. In 2005–2010, the planted forest area increased by an average of almost 5 million ha per year, with most of the expansion occurring in Asia (especially China, India and Viet Nam). The global area of planted forest area is projected to increase to 300 million ha by 2020. The species used in planted forests vary by region. Overall, however, conifers account for 52 percent and broadleaved species for 37 percent of the global planted-forest area (with 11 percent comprising unspecified species). The main planted coniferous genera, by area extent, are *Pinus*, *Cunninghamia*, *Picea*, *Larix* and *Cryptomeria*, and the main planted broadleaved genera are *Eucalyptus*, *Acacia*, *Hevea*, *Tectona* and *Populus*.

Topical issues

Natural and planted forests. Globally, demand for forest products such as lumber, wood fibre, woodfuel and non-wood forest products is increasing, driven by demographic changes, economic growth, policies that favour the use of renewable energy, and worldwide campaigns advancing the value of wood as an environmentally friendly material. At the same time, the area and quality of natural forests is declining, and remaining natural forests are increasingly being designated for the protection of soil and water, biodiversity conservation and other purposes that preclude or limit wood production. Thus, the role of planted forests in meeting the growing demand for forest products is increasing.

Well designed and managed, planted forests can provide many – although rarely all – of the social, environmental and economic functions of natural forests. On degraded forest lands, unprofitable or marginal agricultural lands, and abandoned or idle lands, planted forests may constitute a legitimate land-use option for providing sustainable livelihoods, ensuring food security and alleviating poverty. Planted forests have not always lived up to their potential, however. Some investments in planted forests have led to social, cultural and environmental conflicts and resulted in unsustainable management practices. Natural forests and unique ecosystems have been destroyed to make way for planted forests, often with major negative impacts on the lives, cultures and livelihoods of indigenous peoples and minority groups.

Climate change. The higher intensity, quantity and frequency of biotic and abiotic hazards (e.g. extreme weather events) projected as a consequence of climate change could increase the vulnerability of planted forests and have serious impacts on forest productivity and the provision of environmental services. Single-species plantations of fast-growing, even-aged stands that lack adequate management interventions (e.g. thinning and the removal of logging debris) are likely to be particularly vulnerable. FAO's Climate change guidelines for forest managers set out specific interventions to reduce the risk to planted forests posed by climate change.

Biotechnology. The application of biotechnologies in planted forests is seen by many as an opportunity to provide new tree varieties and reproductive materials adapted to changing environmental, social and economic conditions. Genetic engineering, for example, has the potential to increase the productivity of planted forests and to generate planting material that is more resilient to pests, water scarcity and the impacts of climate change. However, there are also serious concerns about the potential environmental risks posed by genetically modified organisms. They include the possibility of developing aggressive, invasive species, and the loss of biodiversity due to the displacement of traditional cultivars by a small number of genetically modified organisms.

Silviculture and management

Species' choice. A wide range of factors, such as the purpose of the planted forest, the production goal (if applicable), the prevailing site conditions (e.g. terrain features, climate and soil), the availability of planting stock, and desired silvicultural and growth characteristics, will determine the choice of suitable species in a planted forest. Depending on the purpose, the selected species should yield marketable products such as lumber, fibre, woodfuel, foods and medicines. While indigenous species should be preferred to exotic species, difficult terrain and climatic conditions (steep slopes, strong rainfall, high winds, high temperatures, frequent droughts), sometimes impede the use of these species. Where these conditions exist, pioneer or introduced species may be more successful than indigenous species, that are usually not early-succession species and do not readily colonize barren land, grassland, or forest clearings.

Large-scale, single-species plantations are less likely to contribute to the **conservation of biodiversity** than are mixed-species plantations that are managed according to close-to-nature principles (the acceleration of the natural regeneration processes). Non-native species should be used only when required to meet specific management objectives and after a careful evaluation of the risk that such species will become invasive and have adverse effects on local biodiversity.

Sites suitable for planted forests. Selecting sites for the establishment of planted forests requires the careful consideration of social and

legal constraints – such as land tenure, the demand for productive agricultural land, and land accessibility. At the beginning of a project to establish a planted forest it is crucial to clarify ownership and tenure because land disputes must be avoided. Landowners – public or private – who have made the decision to establish a forest should be fully committed to maintaining the site as forest in the long term. Suitable targets for afforestation and reforestation projects include:

- logged-over or poorly stocked secondary forests that are unlikely to regenerate naturally due to the lack of desired seed trees or adverse environmental conditions (e.g. dense, impenetrable ground-cover vegetation such as *Imperata cylindrica* [alang-alang] grass);
- forests in which enrichment planting is required to fully stock the forest;
- degraded natural forests to be used for watershed management, wildlife conservation, ecotourism or community development;
- planted forests that have been subject to a final harvest;
- steep slopes at risk of soil erosion and landslides;
- abandoned and unproductive agricultural land; and
- unproductive sites (e.g. former mining areas) that are suitable for supplying forest products to local economies.

Propagation material. A vital consideration in planted-forest management is the use of high-quality seeds or other propagation material (e.g. seedlings and cuttings) originating from healthy, well-formed parent trees. The use of high-quality propagation material reduces seedling mortality due to transplantation stress and the likelihood of having to replant. Commercial nurseries may stock some economic or ornamental tree species, but they rarely grow forestry species with known provenances. For large-scale afforestation/reforestation projects, therefore, it is advisable to produce forest seedlings in specialized forest nurseries, tree seed centres or project-run centralized or decentralized (community) nurseries. Containerized seedlings are preferred over bare-root stock because of the lower risk of dehydration and transplantation shock and increased likelihood of successful establishment (although see Forest pests for an argument for the use of bare-root seedlings). For tree species that fruit rarely or have seeds that are difficult to germinate, clonal planting stock can be produced from individuals that show desirable traits such as high growth rates, pest resistance and wood quality.

Ground and site preparation. Preparing a planting site so that it is conducive to the survival and rapid adaptation and growth of the planting stock is paramount to success. To reduce soil erosion and nutrient loss, the complete removal of ground-cover vegetation should be avoided, and heavy machinery should be used to the minimum extent possible to avoid soil compaction. If no mechanized low-impact procedures are available, ground preparation should be carried out manually as far as possible to maintain soil texture and reduce nutrient losses. Controlled burning may be used to clear larger areas of dense secondary undergrowth but requires expert knowledge to minimize environmental damage. Planting lines in flat or slightly undulating terrain should be oriented in an east–west direction to optimize light conditions; where the terrain has a 15 percent slope or greater, planting lines should follow the contour.

Tree-planting. Successful tree-planting is not as simple as it may appear, and it is by no means the end of an afforestation/reforestation process – the long-term commitment of all stakeholders is essential for success. While it may be relatively easy to initiate a tree-planting campaign, it is often more difficult to maintain motivation to protect and tend the trees after planting. Unless weeds are controlled, fertilizer applied and fires prevented, the hard work of tree-planters and the effort expended in the nursery to grow seedlings may amount to nothing. Thus, afforestation and reforestation must be understood as a long-term process and not just a one-time tree-planting event. For planting to succeed, the following points should be considered:

- Several suitable tree species may be planted on a given site, but for logistical reasons it may be easier to keep the number of species small.
- Seedlings may be positioned randomly across a site at an average distance between adjacent trees of 2–3 m, or they can be planted in lines or clusters.
- The combined density of planted plus naturally regenerated seedlings is usually in the range of 625 stems per ha (average spacing of 4 m x 4 m) but can go as high as 10 000 (1 m x 1 m) for certain broadleaved species. The planting density should be sufficient to establish a forest stand capable of meeting the objectives while minimizing the cost of seedlings and labour.
- The optimal height of seedlings for planting is generally considered to be in the range of 25–50 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 weeds. The higher cost of producing larger plants in the nursery is likely to be offset by lower mortality rates and reduced weeding costs.

- 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, during which time they can develop root systems that penetrate deeply enough into the soil to obtain sufficient water in subsequent drier seasons. Locally appropriate planting dates can be determined from local meteorological data. The recommended planting time on any given day is before 11 a.m.

- A ground survey should be conducted 3–6 months after the initial planting to assess the establishment rate. Dead seedlings should be replaced at the beginning of the next rainy season, ideally with seedlings of a similar size to those surviving nearby.

Protection of seedlings. Tree seedlings, whether natural or planted, 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 or domestic animals. Planted forests usually fail if seedlings are planted and then forgotten. Dense weed growth will retard the growth of both natural regeneration 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 minimize the damaging effect of other plants on the desired trees. Chemical weeding in planted-forest projects is risky and, for ecological reasons, should be avoided as far as possible.

Tending, thinning and pruning. Tending and thinning in planted forests are silvicultural operations to improve stand quality by eliminating or suppressing undesirable vegetation, including climbers and vines, and by removing poorly formed, damaged or diseased trees. The objective is to increase the crown development and diameter growth of the trees, to concentrate future increment on the best-formed trees, and to increase the stability of the stand by giving more growing space to the roots of the potential final crop trees. Tending and thinning operations are significant factors in the achievement of production goals (e.g. high-quality sawlogs) in as short a time as possible. The option of not thinning is usually not appropriate for the production of general utility timber or good-quality saw or veneer logs, but may be suitable for the production of pulpwood or woodfuel.

Pruning is the removal of live or dead side branches, close to or flush with the stem, and of multiple leaders, from a standing tree with the aim of improving the quality of the tree's timber. Pruning is costly and should only be implemented in stands that are expected to yield good-quality sawlogs or veneer logs. Many species grown in planted forests self-prune, reducing the need for active pruning of the stand. Where it is necessary, pruning should only be carried out after the first thinning operation, and it should be confined to potential crop trees.

Work organization and schedule

The participation and role of stakeholders should be agreed on and a schedule of work developed to implement planted-forest projects. It is a common mistake to underestimate the time required for implementation. 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 planting 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. The table presents an example of an appropriate work schedule for a medium-to-large-scale planted-forest project aimed at producing sawlogs or veneer logs.

Time relative to planting event	**Action**
30 months before	Reconnoitre project site; clarify legal and tenure issues; demarcate boundaries; engage stakeholders and establish consensus; draft a preliminary project plan; start nursery establishment
24 months before	Start controlled seed collection and seedling production in nurseries
12–24 months before	Survey project site; produce topographic land-use map including a designation of forest functions; assess road accessibility and natural regeneration
6 months before	Assess the number, quality and species of seedlings available in nurseries
2 months before	Begin hardening off in the nursery
4–6 weeks before	Demarcate planting plots in the field; mark natural regeneration; prepare planting lines; slash weeds on planting lines down to ground level
1 week before	Brief stakeholders and planting teams
1–2 days before	Water seedlings and transport them to the planting site, along with planting equipment and material
	Planting campaign (early in rainy season): planting at the specified spacing, plant size 25–50 cm
1–2 weeks after	Check quality of planting; adjust any poorly planted seedlings
3–6 months after	Survey growth and survival of planted trees; undertake weeding 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 growth and survival of planted trees; and assess the need for replanting
6–12 months after	Replanting of failed areas (if required)
Subsequent years	Control weeds and climbers along planting lines; regulate shade; and apply fertilizer, as appropriate
Young planted forest	Control climbers along lines and in intervening areas; remove wolf trees (trees that are shading out others), forked trees, multiple leader trees and any other undesirable stems
Medium-aged planted forest	Select and mark 200–300 potential crop trees of superior growth and quality; mark competitors to be removed; conduct two thinnings, resulting in the removal of about 60 percent of the trees
Mature planted forest	Conduct two thinnings down to final crop trees; about five years before the end of the rotation, conduct the first felling of the final crop trees to remove about 50 percent of the standing stock to promote natural regeneration; at the end of the rotation, harvest all remaining crop trees

Economics and costs

Planted forests are long-term investments, with costs associated with, for example, the selection of germplasm, nursery production, site preparation, establishment, tending, weeding and other silvicultural operations, protection and harvesting. 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 about US$500–1000. Seedling production costs should average about US$0.1–0.5 per seedling (including material and labour). The total costs of the seedlings required to plant one hectare is about US$125–625, assuming a planting density of 1000 plants per ha and a replanting quota of 25 percent.

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 costs of a successful planted-forest project, including seedling production and all materials and labour for planting, maintenance and monitoring over three years, is likely to be in the range of US$1500–2000 per ha. Planted forests are considerable investments, therefore, and their long-term protection is essential.

Benefits for local communities

Financial benefits, such as those created by employment, the harvesting of forest products, ecotourism and environmental services, are the most obvious and measurable sources of motivation for stakeholders to participate in tree-planting projects. Additionally, communities often regard less-tangible benefits, such as improving the environment (e.g. soil and water resources) and village infrastructure (e.g. the renovation of school buildings), maintaining cultural traditions, and political gain (e.g. the strengthening of land-tenure rights), as equally – or more – important reasons to plant trees and reforest landscapes.

Further learning

Arriaga, V., Cervantes, V. & Vargas-Mena, A. 2006. Manual de reforestación con especies nativas: colecta y preservación de semillas, propagación y manejo de plantas. SEDESOL, Instituto Nacional de Ecología, Universidad Nacional Autónoma de México. México.

Carle, J. & Holmgren, P. 2003. Definitions related to planted forests. Paper presented at the UNFF inter-sessional expert meeting on *The Role of Planted Forests in Sustainable Forest Management - Maximizing Planted Forests' Contribution to SFM.* Wellington, New Zealand, March 2003.

Carnus, J.-M., Parrotta, J., Brockerhoff, E., Arbez, M., Jactel, H., Kremer, A., Lamb, D., O'Hara, K. & Walters, B. 2006. Planted forests and biodiversity. *Journal of Forestry*, 104 (2) : 65-77.

Cossalter, C. & Pye-Smith, C. 2003. *Fast-wood forestry. Myths and realities.* Center for International Forestry Research (CIFOR), Jakarta, Indonesia.

Evans, J. 1999. *Sustainability of forest plantations. The evidence.* Department for International Development (DFID). London, UK.

Evans, J. (ed.) 2009. *Planted forests: uses, impacts, and sustainability.* CAB International & FAO.

FAO. several years. Working paper series on planted forests.

FAO. several years. Articles on planted forests published in *Unasylva*.

Foucard, J.C. 2008. *Filière pépinière : de la production à la plantation*. Tec & Doc Lavoisier.

International Congress on Planted Forests. 2013. Planted forests are a vital resource for future green economies. *Summary Report of the 3rd International Congress on Planted Forests.* *Bordeaux*, Dublin, Porto, Estoril.

ITTO. 1993. *Guidelines for the establishment and sustainable management of planted tropical forests.*

Policy Development Series 4, Yokohama. Japan.

Tiarks, A., Nambiar, E.K.S. & Cossalter, C., 1998. *Site management and productivity in tropical forest plantations.* Occasional Paper no 16, Center for International Forestry Research (CIFOR), Jakarta, Indonesia.

Varmola, M., Florencia, Lee, D., Montagnini, F., Saramäki, J. & y Gautier, D. *Funciones diversificadas de los bosques plantados.*

Wadsworth, F. 2000. *Producción forestal para América tropical.* Departamento de Agricultura de los EE.UU. Servicio Forestal, Manual de Agricultura. IUFRO-SPDC Textbook Project No. 3.

Wormald, T.J. 1992. *Mixed and pure forest plantations in the tropics and subtropics.* FAO forestry paper 103. Rome, Italy.

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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