Long-Term Sustainability of Natural Regeneration

Sustainable use relies on the forest retaining its capacity to regenerate after harvesting. A very large proportion of tropical rainforest trees are dependent on animals for pollination and seed dispersal. Logging can disrupt animal communities in ways which have an impact on tree regeneration. Reduced pollination may lead to reduced seed-set or greater prevalence of inbreeding. Seeds which fall close to a parent tree are often found to suffer greater predation losses than those that are well dispersed. Similarly, seedling survival increases away from the pests and pathogens associated with a parent. Although there are indications that both pollination and dispersal may limit regeneration in forest fragments, there is as yet no clear evidence of impacts on seedling populations in large-production forests. However, seed predation rates have been found to be sufficiently high in logged forest to prevent regeneration of some tree species. Logging removes a significant proportion of the large seed-producing adults of commercial species and the residual seed trees become the focus of all predation.

Fire is becoming an increasing problem in many logged tropical rainforests and has a particularly severe impact on seedling populations. Almost no climax rainforest tree species have fire-tolerant seedlings and even lightly burned forests have been shown to be devoid of natural regeneration of anything other than pioneer species.

See also: **Harvesting**: Forest Operations in the Tropics, Reduced Impact Logging. **Silviculture**: Forest Dynamics; Forest Rehabilitation; Natural Stand Regeneration; Treatments in Tropical Silviculture. **Tropical Ecosystems**: Dipterocarps; Swietenia (American mahogany); Tropical Moist Forests,

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Managing for Tropical Non-timber Forest Products

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Introduction

Interest in the management of non-timber forest products (NTFPs) in the tropics has increased dramatically over the past 20 years. This process reflects observations that:

1. Some economically or culturally significant NTFP resources are being overexploited.
2. NTFPs can provide a raw material resource for local enterprise and income development.
3. NTFPs may be the only harvestable commodities left in degraded forests.
4. NTFPs have significant subsistence and cultural values to local peoples.

Although these concerns are most commonly associated with development forestry in the tropics, all of them are increasingly recognized as present and significant in temperate forests and rural economies (e.g., in the Pacific Northwest of the USA, Eastern Europe, and the UK).

Increasing interest in the poverty and development relevance of NTFPs has engendered work on the promotion of income generating enterprises based on them. Because this has a social focus much of this work has been undertaken by socially orientated advisors and hence on management systems based on participatory rural appraisal and other social science

techniques. The development of the ecological or autecological basis for species management has only recently become of more concern and suitable protocols for ecological investigation of the multifarious species of NTFPs are only now being developed. Good management should be based on sound ecological knowledge whether this is the result of extended observation and encapsulated in local knowledge or the result of biometric investigations. This article considers how this knowledge has been used to develop NTFP management or silvicultural systems in the tropics.

What is a Non-Timber Forest Product?

For millennia people have used forests as a source of sustenance, raw materials for craft and industry, and as a home. Ethnological surveys demonstrate that roughly 60–70% of any flora and a lower percentage of the fauna are utilized by traditional forest-dwelling societies as food, clothing, shelter, tools, and medicines (**Figure 1**). The advent of sedentary farming, industrialization, and colonialism removed people from the forest, made them less reliant on wild resources and focused attention on the exploitation of forests for timber primarily for export. However, this did not mean that the other products were entirely disregarded. Harvesting of several wild products developed into large-scale export enterprises (e.g., cocoa, coffee, rubber, chicle, and palm oil) though many of the plants from which these were derived were eventually brought into plantation cultivation. By the middle of the twentieth century, the majority of managed tropical forests were a focus for the production of export quality timber. The continued reliance of local people on other products was considered to be insignificant and largely irrelevant and they were termed 'minor,' 'non-timber,' and 'non-wood' and all lumped together – often with less tangible forest 'benefits' and 'services.'

Figure 1 Many NTFPs are used as medicines. This lady is a wholesaler of medicinal plants in the Durban herb market. She is selling parts of wild plants collected from indigenous forest and montane land in South Africa and neighboring countries. Many of these plants are becoming threatened by this trade. Shortages may compromise access to healthcare by poorer members of society. There is an urgent need to institute sustainable management for these resources. Photograph courtesy of Jenny Wong.

Although these terms are in common usage among foresters they do not have currency outside the profession. There is no accepted term for non-timber forest products that is recognized by all disciplines interested in managing forests. This is unfortunate as the successful management of NTFPs by foresters would benefit greatly from cross-disciplinary exchange with wildlife managers (especially as wildlife is considered an NTFP), ethnobotanists, human ecologists, and conservation biologists, none of whom use or recognize the term NTFP.

An examination of the NTFP literature reveals that the term is used to describe wild and semicultivated plants from natural, managed, and modified forests and also semidomesticated forest plants (e.g., trees for fruit or understory plants such as Marantaceae) even where these are not in a forest environment (e.g., in agroforestry systems). Furthermore, some NTFPs are wild products taken from artificial forest environments (e.g., mushrooms from pine plantations in southern Africa and snails from oil palm plantations in Cameroon). The NTFPs themselves may also be cultivated using artificial techniques such as *in vitro* propagation. Careful examination of the actual products and environments covered in the NTFP literature suggests that we can map the area of interest as shown as the shaded areas in **Figure 2**.

Although the rhetoric suggests that animals should be considered as NTFPs there is very little evidence that foresters have done much work in this area. However, there is substantial work on sustainable management of animals in the conservation world especially in Latin America which is not often referenced in the forestry literature.

In a further complication, the term NTFP has been more literally interpreted as including products made from wood but which cannot be classed as 'timber' including the derivation of chemical feedstock from

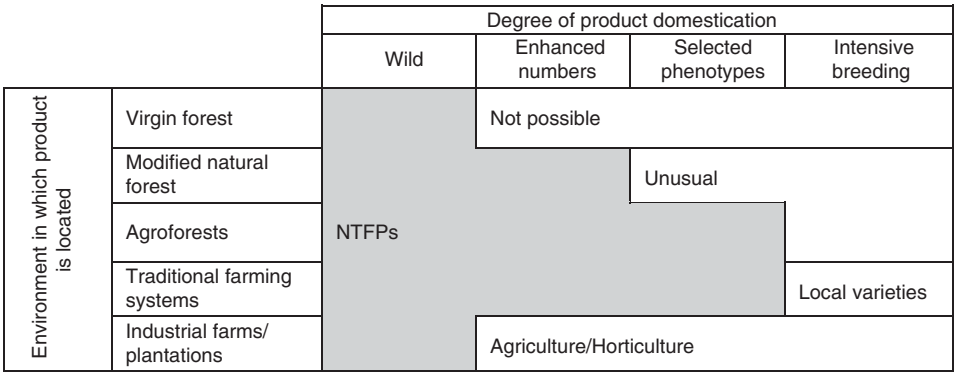

Figure 2 Map of products termed NTFPs.

wood. This latter interpretation is ignored for the remainder of this article as silviculture for wood-based products is the same as for maximizing wood volume which is dealt with elsewhere (*see* **Silviculture**: Silvicultural Systems).

What is NTFP Silviculture?

Before answering this question we have first to consider what is meant by silviculture. Silviculture is the art and science of controlling the establishment, growth, composition, health, and quality of forests and woodlands. Silviculture entails the manipulation of forest and woodland vegetation in stands and landscapes to meet the diverse needs and values of landowners and society on a sustainable basis.

In principle this definition includes the proactive management of NTFPs. However, silvics is the study of the life history and dynamics of forest trees. Although including other forest plants seems reasonable, stretching it to include animals seems unreasonable. However, the principle of developing an understanding of a species and then manipulating its environment to produce desirable products is one that applies to sustainable management of any NTFPs.

Proactive manipulation of a species to increase the quantity or quality of a product often begins with harvesting regulations and ends in the domestication of the species with production in monoculture far from the forests which were its original home. Cocoa and oil palm were both once harvested from the wild and ended as highly modified plants in monocultures. Other products such as locust bean (*Parkia biglobosa*) are halfway along this road and although not yet extensively modified by selective breeding are hardly present in the wild. Yet others, such as Brazil nuts (*Bertholettia excelsa*), are closer to the beginning and have properties that make them difficult to domesticate. Once a species has been recognized as an NTFP it seems to retain this title as it becomes progressively domesticated and increasingly characteristic of farmland. The line between NTFP silviculture and horticulture is indistinct.

Identifying a product as an NTFPs depends on the plant or animal being found in a forest or being produced by a tree more or less regardless of location. The only exceptions are orchards or fruit tree plantations. This means that wild-harvested products from different habitats, such as veld or desert, are not included. However, the similarities between the management systems required by these products are such that they are increasingly classed as NTFPs in the literature even though they have little to do with 'forests' (e.g., devil's claw (*Harpagophytum procumbens*) in Botswana).

So a pragmatic definition of NTFP silviculture would need to include the development of cultural systems for all wild and semidomesticated non-timber tree products, regardless of where they are located, and anything found in a forest environment.

Although the issues included in NTFP silviculture represent a continuum which is rather poorly defined, it is possible to recognize three areas that have distinct silvicultural and management features. The regulation of harvesting from wild populations has a very long history and is known in the Americas as 'extractivism.' The semidomestication of trees in traditional farming systems across the tropics likewise has a long history, and has resulted in distinct anthropogenic landscapes such as the African savanna parklands, the agroforests of Indonesia, and the home gardens of Nigeria. A third trend is for cultivation of wild products leading eventually to full domestication, this being a more recent phenomenon.

Harvesting Natural Forests

This section describes the silvicultural systems that are used to harvest 'wild' products, i.e., those in the third column of **Figure 1**. Most silviculture for

wild products in natural forest takes the form of harvesting rules. These are most often concerned with one or more of the following:

- prescribed harvesting methods
- exploitation of only a portion of the species range in any year (coupes)
- a fixed harvesting interval.

Wild products are also exploited from farm and plantation habitats where they often occur as weeds or by serendipity. Silviculture in such environments may be the same as for natural forests but, in these anthropogenic situations, there is much more scope for proactive intervention such as the tending of plants and the promotion of suitable habitats for wildlife.

Traditional Systems

Local people who have depended on NTFPs for many generations have a vast repository of knowledge of the plants, animals, and ecosystems in their locales. This experience is very often encoded into myths, taboos, rules, and decision-making processes which maintain a balance between exploitation and productivity.

NTFP protection and harvesting restrictions feature in many cultures. In some African parklands, for example, anyone felling the soil-improving *Faidherbia albida* could traditionally face execution! In other instances, all a community's trees of a key species might be owned by the chief, regardless of who farmed beneath them (*Parkia biglobosa*), or the community could harvest fruit only when the chief declared the season open (*Sclerocarya birrea*).

The use of traditional management practices has in many cases provided a sustainable resource for local use for many generations. However, as the market economy takes hold, favored products enter commercial trade and the equilibrium between traditional rules, expectations, and market demand is disrupted. Almost inevitably unchecked, these processes lead to either overexploitation or the domestication of the species, both to the detriment of the local economy.

The advent of participatory forest management initiatives such as Joint Forest Management in Nepal has provided a basis for the integration of traditional knowledge with modern forest management planning. The silvicultural elements of this exchange are exemplified in Oaxaca in Mexcio with the development of what has been termed 'barefoot silviculture.' The origins of such systems is indigenous knowledge which can give rise to systems which can be recognized as conforming to single and multicohort stand management. Within such systems NTFPs are managed alongside the trees as an integral part of the silvicultural system.

Extractivism

Extractivism is a term used, mostly in the Americas, to describe any gathering of natural products, whether of mineral (mining), animal (skins, meat, fats), or plant (woods, leaves, fruits etc.) origin. In the forests of Amazonia, large stocks of nuts and rubber resulted in the establishment of a harvesting system based on wild collection using indentured labor. In time this system collapsed but the nut collectors and tappers remained and have found themselves in conflict with forest clearance for large-scale ranching. The outcome has been the formal recognition of extractive reserves in Brazilian law. By April 1994, nine extractive reserves had been established for harvesting of babaçu (*Orbignya phalerata* – fruit), açai (*Euterpe oleracea* – fruit), rubber (*Hevea brasiliensis* – latex), Brazil nuts (*Bertholletia excelsa*), and copaiba (*Copaifera langsdorffii* – oil) though each reserve is managed for multiple use.

An example of the type of silviculture proposed in the utilization plans is that for babaçu in the Frexal Extractive Reserve. Babaçu is a palm which grows in dense monospecific stands in which fruit productivity can be restricted by overcrowding. It is therefore suggested that unproductive trees should be removed and the density of immature plants controlled by thinning. It is also suggested that the babaçu forests could be combined with perennial crops adapted to the region. In effect, this is a move towards a more managed landscape with the wild trees treated as a plantation crop.

The management planning and social elements of extractive reserves make them uniquely suitable for the Forest Strewardship Council type of certification. Recently Brazil nuts and chicle (edible tree latex) have been successfully certified as being derived from sustainably managed forests.

Sustainable Harvesting Plans

The development of a management system for NTFPs is basically the same as that for timber with the following recommended sequence of activities:

- inventory
- growth and yield determination
- determination of harvesting methods and yields (perhaps using some form of growth modeling)
- monitoring.

Although much of this information is often available as local knowledge, there is increasing interest in the scientific appraisal of such knowledge and biometric

approaches to data collection. A review of the available biometric methods for NTFPs revealed a dearth of tried and tested protocols. However, in many cases the use of conventional forest inventory techniques is prohibitively expensive for use with NTFPs. There is a need to develop cheaper, statistically efficient means of inventoring NTFPs.

The scarcity of good resource and growth data for many NTFPs means that taking an adaptive management approach is desirable. Adaptive management accepts that decisions have to be based on imperfect information. Management prescriptions are therefore based on the precautionary principle and monitoring systems put in place to learn from experience. The monitoring itself therefore becomes both an instrument for research and feedback to ensure that management improves with each reiteration which should therefore take place at regular intervals.

Wild Products from Farmed Landscapes

Farmed landscapes with trees retained from the natural ecosystems originally cleared, sometimes as much as 200 years earlier, cover millions of square kilometers of the tropics. They support tens of millions of people in Africa alone and supply a wide range of NTFPs produced under varying degrees of management. These environments constitute an outstanding example of the way that NTFPs are integrated into the daily life and vital needs of rural communities on an extensive scale, primarily from indigenous trees.

Parkland Systems

Since the 1960s the farmed landscapes of the savanna regions of sub-Saharan Africa, especially, have been described and studied in some detail. The farmed landscape with trees (widely called 'parkland') is a refinement of the natural vegetation of the area. Tree removal is effected to enable annual crops to be grown but the removal is highly selective. Impact is less on the populations of species valued for NTFPs and, favored by measures taken to tend crops, the individual trees retained commonly display enhanced growth and vigor. Products sought from the trees have significance as dietary essentials (e.g., vitamin C in the fruit flesh of *Sclerocarya birrea* and *Ziziphus mauritiana*), positive seasonal impact as nutrient rich fruit pulp and seeds in the mid- and late dry season when alternatives are few (e.g., *Adansonia digitata*), and options for making cash income (e.g., tapped sap from the palm *Borassus aethiopum* or the fresh fruits of *Lannea microcarpa*). Complementing these rewarding but routine uses of the most highly regarded species is the availability of others with food security roles exploited when circumstances dictate. Among these 'famine' foods are proteinaceous meal from the kernels of *Balanites aegyptiaca*, palm kernels (*Hyphaene thebaica*), foliage of *Ficus* spp., and young shoots of *Borassus aethiopum*.

Keystone Species

Particularly significant NTFP tree species retained in farmed landscapes are the keystone species – those which are so abundant that the ecosystems are named from them. Parklands of *Faidherbia albida* (fodder, including fruit for livestock), *Vitellaria paradoxa* (edible oil from fruit), *Parkia biglobosa* (seeds for seasoning), and *Adansonia digitata* (leaves as a vegetable) are examples (**Figure 3**). Tendencies towards gregariousness are reinforced by selective removal of unwanted species, and a high proportion of the trees left may be of the keystone species. Thus, *Vitellaria paradoxa* (the shea butter tree) commonly accounts for 70–90% of the mature trees in large areas of farmed landscapes but under 20% of those in natural woodland.

Because of their significant nutritional values, dominant among the NTFP tree species of farmed landscapes are the fruit trees. Some of these are the basis of considerable specialized activity involving restricted sections of the local communities, generally defined by gender and/or age. Those NTFPs of outstanding local importance ultimately result in processed output. The cooking oil (shea butter) extracted from the seeds of *Vitellaria paradoxa* and the fermented seed meal (soumbala) of *Parkia biglobosa* are the best-known West African examples, and in many parts of southern Africa fermented drinks are processed from the fruit pulp of *Sclerocarya birrea*.

Management

In an established farming setting, the tree cover is the product of considerable conscious selection when individuals for retention are identified, as well as management actions at system and tree level. Selection goes well beyond choice of species and removal of moribund or unhealthy individuals. Over a period of several years as the farming system is introduced, the farmer also applies a wealth of indigenous knowledge equivalent to infraspecific taxonomy, with varieties recognized within the local culture being valued differently and individuals of the less attractive ones likely to be removed. In central Burkina Faso, for example, several varieties of *Parkia biglobosa* are locally distinguished, the so-called 'black' type (dark bark; black seed coat) being favored as superior for seeds used in cooking.

Figure 3 The dry season aspect of typical agroforestry parkland in northern Nigeria. Prominent in the foreground is the spreading, heavily branched crown of a large *Parkia biglobosa* tree. To the right, further back, is a baobab tree (*Adansonia digitata*), the pale bole a consequence of bark removal for fiber. Photograph courtesy of Fergus Sinclair.

Other than undertaking selection, the principle thrust of the management of farmed landscape NTFPs is the imposition of pruning practices. Despite the impression of stability given by scattered large trees in crop land the system is highly dynamic. The enhanced growth rates arising in the favorable environment of a well-tended crop brings a need to prune trees which progress to a widely spreading form in old age (such as *Ficus* spp. and *Parkia biglobosa*), which would otherwise cast excessive shade. An alternative, used more to compensate for the growth in species with more compact crowns (e.g., *Vitellaria paradoxa*) is thinning of the tree population. With increasing demand for fodder and wood products, particularly fuelwood, poles, and wood for tool handles, pruning tends to meet more than one need. Nevertheless unless pruning intensity is modest (with half or more of the crown left in place) fruit production may be severely depressed for several seasons – to a mere 5–10% of a mature tree's full fruit crop in *Faidherbia albida* (typical yield 125 kg), *Parkia biglobosa* (typical yield 70 kg), and *Vitellaria paradoxa* (typical yield 50 kg).

Whilst presently minor elements of management, two further measures, fire protection and planting, merit comment. Fire protection is mainly achieved opportunistically because after crops are harvested, and livestock brought to feed on the residues, there is no fuel bed at the period when fire risk is high. However, in many farmed landscapes fallow phases remain an integral part of the land use system and are associated with increasing frequencies and intensities of wildfire. It is traditionally recognized that NTFP yields from trees exposed to intense fire are lowered (e.g., with *Parkia biglobosa*), and that smoke and other particulate matter released in an untimely fire will reduce pollination efficiency in species with dry season flowering (e.g., *Vitellaria paradoxa*). Individual trees considered of exceptional value may be protected with a firebreak, usually an area of cleared ground. Assuming wildfires will become increasingly problematic, active fire protection will be routinely needed in farmed landscapes for efficient NTFP production.

Much attention has been drawn to the lack of planting of indigenous NTFP trees in farmed areas and the population structures of NTFP tree species emphasizes this and has prompted forestry extension services to address the problem. There are two main difficulties. The first is complacency, since in most tree populations there is a vigorous core of mature trees with a projected productive life of decades. Nevertheless, the combined impact of natural mortality, removal of trees of declining productivity and of further trees to create crop space and emergency fellings for fuelwood indicate accelerating change and a need for the reinvigoration of the populations. The second difficulty is opposition to planting indigenous trees based on cultural beliefs which have been reported for various societies. It does not apply everywhere, nor to all species, however, and there are also traditions which encourage planting, as with

Adansonia digitata. The *Sclerocarya birrea* population in Namibia has also been attributed to planting germplasm brought from what is now Angola, and suggestions have also been made that planting and introduction could explain aspects of the regional variation of *Vitellaria paradoxa*.

Commerce

There has been a long history of trade in more easily handled NTFPs from farmed landscapes, where processing is relatively simple and storage difficulties are minor. Foremost among these are exudates tapped directly from the trees (e.g., gum arabic, *Acacia senegal*) or collected from insects, such as lac, from, for example, *Butea monosperma* in India. Another significant NTFP from farmed landscapes is the leaf of *Diospyros melanoxylon*, used to wrap cheroots, through which upwards of 1 million people find employment even though serving the internal market of India rather than international consumers.

Today, commercial interests based on NTFPs from farmed landscapes are expanding and diversifying as technological advance has created opportunities to utilize the qualities of fruit products in the cosmetics and food sectors, notably with *Sclerocarya birrea* and *Vitellaria paradoxa*. There is also growing willingness to support processed and packaged products from these species released in local markets, together with those from other keystone species (e.g., food seasoning cubes from *Parkia biglobosa*; cosmetics and drinks based on *Adansonia digitata*).

The Road to Domestication

All domesticated plants and animals were at one time wild. Presumably some proved so useful or amenable that they were domesticated and eventually rendered dependent on cultivation. This process of taming, and later modifying, species for more intimate use by humans is a continuous one and there are many species presently in the process of being domesticated. However, there are several forms that such a transformation can take as shown in columns four and five of **Figure 1**, a few of these are described below.

Farming the Forest

The first stage in domestication is often the manipulation of a wild species *in situ* to improve productivity. This often involves an increase in the number and density of the target species either by protecting juveniles, creating conditions for enhance recruitment or transplanting wild plants to create gardens of the species. In America this process of 'farming' wild plants *in situ* is termed 'woods grown' and is applied to understory herbs such as American ginseng and goldenseal. In Japan similar techniques are used to grow indigenous saprophytic mushrooms (e.g., shi-take) using stacks of cut logs as a substrate within the forest.

Rescue from Extinction

For a great variety of reasons many NTFP species end up being overharvested to the extent that they are at risk of becoming locally extirpated and perhaps even threatened with extinction. In these circumstances the only option is to undertake *ex situ* conservation and if market demand remains high to proactively domesticate the species. An example of such a process for a tropical species is that for eru (*Gnetum africanum*) in Cameroon. This is a climbing plant from which the leaves are harvested, for use as a vegetable. It is becoming increasingly rare in the wild and has been the subject of intensive cultivation trials at the Limbe Botantical Gardens in Cameroon.

Figure 4 This is a wild coffee (*Coffea* sp.) that grows in the forests of Uganda. In the past young plants were collected and used to establish coffee farms outside the forest. Since the introduction of cultivars this practice has all but ceased. The world coffee market is swamped with large volumes of cultivated coffee but the speciality market is always receptive to additional varieties. Wild coffee could potentially be sold to the speciality market and its reintroduction into coffee farms in Uganda could bolster farm incomes. Photograph courtesy of Jenny Wong.

Trials have been successful and local communities and farmers' groups are now successfully cultivating the plant and obtaining a good income from sales locally and export to Nigeria. Silviculture in these cases is synonymous with horticulture.

The Market Takes Over

When market demand is for consistent quality, reliable large volumes, and a product which is a profitable export, it is often only a matter of time before production becomes industrialized (**Figure 4**). At this point market forces take over and capital is invested in large-scale or at least farm-scale production which almost inevitably takes the production process away from small-scale farmers, gatherers, and the poor. This is the end of the road to domestication; from this point onwards agriculture and horticulture take over. However, through long association, the tag NTFP may still remain as evidenced by articles in the *Journal of Non-Timber Forest Products* covering *in vitro* propagation of trees and provenance trials for common farm trees (e.g., neem).

Although often advocated, and in many instances necessary, captive production or cultivation (*ex situ*) is not without its conservation risks. Domestication can lead to environmental degradation, pollution, and reduction in genetic diversity as well as loss of incentives to conserve wild populations.

See also: **Biodiversity**: Plant Diversity in Forests. **Ecology**: Human Influences on Tropical Forest Wildlife. **Medicinal, Food and Aromatic Plants**: Edible Products from the Forest; Forest Biodiversity Prospecting; Medicinal and Aromatic Plants: Ethnobotany and Conservation Status; Medicinal Plants and Human Health; Tribal Medicine and Medicinal Plants. **Non-wood Products**: Resins, Latex and Palm Oil; Rubber Trees. **Sustainable Forest Management**: Definitions, Good Practices and Certification.

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Unevenaged Silviculture

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Introduction

Uneven-aged silviculture may be defined as the tending and regeneration of woodlands or forests which contain trees of several age classes in intimate mixture. In terms of silvicultural systems (*see* **Silviculture**: Silvicultural Systems) this would, strictly speaking, include only selection and group selection systems. A looser interpretation might include stands of trees with only two or three age classes, such as coppice-with-standards or even-aged crops which have been underplanted with younger trees. However, these will either be managed as overlapping even-aged crops, which will be maintained as such, or as the first stage towards a truly multiaged stand.

Stands of trees which are basically even-aged may also go through a period when some of the older trees are retained while younger trees become established, as in shelterwood systems, so that the stand will be temporarily uneven-aged to some degree, but the silviculture which is involved will remain essentially even-aged. Similarly, areas of forest may, for various reasons, be divided into smaller units, but the silviculture of these units would still be described as even-aged if each is managed with reference to its age and area, even if each unit is very small. The essential difference, in silvicultural terms, between even- and uneven-aged silviculture is that the latter does not take any direct account of the age of the trees or the area which is occupied by each age class. Age and area, as such, are ignored. This involves a fundamentally different approach, both in theory and in practice.