Food and Agriculture Organization of the United Nations

The Challenge of

Sustainable Forest Management

What future for the world's forests?

CONTENTS

Preface

Can there be anything left to say on the subject of sustainable forestry? So much has been published on the topic in recent years. Much of the body of literature on the subject has been written in technical terms for an audience of specialists who are not only foresters but also ecologists, sociologists, economists and members of that all-embracing category, the environmentalists. Instead, this book is aimed primarily at a non-technical audience, including decision-makers and the concerned general public. It will, however, be of value to those foresters whose professional education was completed before the concept of sustainability was expanded beyond the sustained supply of timber to include all of the goods and services provided by the forest.

The idea for this book arose from the Paris Declaration, which was issued at the end of the Tenth World Forestry Congress (1991). The declaration called on the world's decision-makes to- raise awareness and inform the public so that forest issues could be better understood and appreciated. One of the issues identified by the Congress as being of key importance for forestry as a whole was the concept of sustainable management.

Greater public awareness by itself will not result in the management of forests on a sustainable basis. The public has to be involved in the debate and decisions on the development of systems of management for all types of land use. Pressure from an informed public can make a major contribution to policy formulation and political commitment. The development of national forest policies and the involvement of people was discussed in Foresters and politics at the Ninth World Forestry Congress (Mexico City) in 1985(1). The Stockholm Conference on the Human Environment of 1972, the Seventh World Forestry Congress of 1972 (Buenos Aires) and the Eighth World Forestry Congress of 1978 (Jakarta) have all implicitly or explicitly called upon governments to encourage the sustainable management of forests. All congresses since the eighth have emphasized the need to involve people in forest policy development.

The requirements for sustainable forest management include not only the involvement of people but also the availability of appropriate techniques and adequate finance. In addition, ways must be found to solve or alleviate the many economic and social problems which, although arising outside the forests, have major impacts on the forest resource. Far-reaching changes in the political environment mean that now there is a chance that people in many more countries may be given the opportunity to participate in forest ownership and management. We believe that sustainable forest management is technically possible, although some of the techniques still require improvement and refining.

Forestry is still a low priority in most countries, and when budgets are drawn up, funds are generally still in very short supply. There are now, however, new and improved methods of assessing the values of services provided by forests, which coupled with an increasing awareness of the indirect benefits they bestow should greatly improve the prospects of meeting the funding needs for sustainable forest management.

We all recognize that the loss and degradation of the world's forests could have far-reaching consequences for humanity. This book is a contribution not only to increasing public awareness of the issues involved but also eventually to the implementation of sustainable forest management and of sustainable land use.

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CHAPTER 5

Forest management can be defined as "deciding what one wishes to do with a forest, taking into account what one can do with it and deducing what one should do with it" (FAO, 1991c) (FN 1). The objectives of management are represented by what one wishes to do, the physical and socio-economic context by what one can do and the prescriptions for the conservation and use of the forest by what one should do.

Forests can be managed in many ways and for many purposes. The technique used in each case will depend on the objectives, the type of forest, the available capacities and resources and the local conditions and constraints.

CLARIFYING OBJECTIVES

The United Nations Conference on Environment and Development (UNCED) comprehensively described sustainable forest management. One of the key conference documents (UNCED, 1992) states that it encompasses the*. . . policies, methods, and mechanisms adopted to support and develop the multiple ecological, economic, social and cultural roles of trees, forests and forest lands. . .* the measures and approaches required at a national level to improve and harmonize policy formulation, planning and programming; legislative measures and instruments; development patterns; participation of the general public, especially women and indigenous people; involvement of youth; roles of the private sector, local organizations, non-governmental organizations and cooperatives; development of technical and multidisciplinary skills and quality of human resources; forestry extension and public education; research capability and support; administrative structures and mechanisms, including intersectoral coordination, decentralization and responsibility and incentive systems; and dissemination of information and public relations. This is especially important to ensure a rational and holistic approach to the sustainable and environmentally sound development of forests.

Such an encyclopedic description risks itemizing every aspect of forest management but focusing on none of them. It is not a practical guide for individual cases. Forest management does not comprise everything desirable that might be done but is rather a matter of selecting and prioritizing the tasks that can and should be carried out for a particular area (FN 2).

Above all, it is important to be clear about exactly what the forest management is expected to achieve. If, for example, the required result is a large quantity of pulpwood, then the most obvious management option may be a plantation. If, on the other hand, the aim is to produce a wide range of forest products for local or international consumption, then natural forest management may be the most appropriate option.

Management objectives will vary substantially according to whether the forest is publicly, privately or communally owned. It has to be borne in mind that extreme objectives, although perfectly legitimate in their own right, are usually incompatible. Obtaining the highest possible sustainable timber yield will probably be incompatible with preserving the maximum biodiversity in the same location. It is only when there is a clear set of achievable objectives, analysed for compatibility and ranked in order of priority, that firm decisions can be made on the management methods to be adopted.

It is also necessary to accept the limitations to what can be achieved in any particular area. Because of the pressures of development and land scarcity, the forests of the developing world, in most areas, will not be left untouched. Management for sustainable timber yield, if it can be effectively carried out, can offer an economically productive alternative to clearing for agriculture.

Conservation of forest resources through sustained yield management is not the same as preservation through a policy of non-interference. In neither case can alteration be prevented. Ecosystems will continue to change even if left completely untouched by humankind. Management intervention in a forest, however, no matter how carefully or lightly carried out, inevitably alters the structure and ecology more quickly and in different directions than a policy of preservation; furthermore, if it is poorly carried out it runs the risk of causing serious and permanent damage. But sustainable yield management and total preservation are rarely the alternatives. More often the stark choice is between placing a forest under some form of management or clearing it for agriculture.

MANAGEMENT APPROACHES

Forest management is not carried out in a vacuum. The method adopted must be appropriate to the physical conditions as well as to the socio-economic and institutional context in which it will be implemented.

Technical approaches that are, suitable for the slow-growing temperate and boreal forests, with their limited number

of species, may not be applicable to the much richer but often more ecologically fragile rain forests. The tropical dry forests, with their own special characteristics and vulnerability, will require yet another approach.

The techniques adopted must be compatible with the technical and financial resources available. In the high-wage economies of the industrialized world, with their strong industrial infrastructures and relatively easily available investment capital, forest management tends to be heavily based on mechanization. In many parts of the developing world, where wage rates are low, labour abundant and investment capital extremely scarce, the management techniques of the industrialized world are likely to be inappropriate and even counter-productive.

Management must not be seen as something imposed from the outside by governments or forest services. Large areas of forest are under the management of the people living in and around them. Many such traditional management systems have worked well for long periods, and where this is the case the optimum approach may well be to avoid any external interference. When the traditional system appears to be breaking down or is subjected to new demands that it cannot meet, it does not necessarily mean that the system has failed completely and should be abandoned. The most effective approach will often be to reinforce the existing system or to help it to adapt to the new circumstances.

Where management has multiple objectives, depending on what they are, it may be possible to meet these simultaneously from particular areas of forest. The sustained yield of timber can be compatible with the social objectives of rural development. Protecting a watershed is usually compatible with the conservation of wildlife. In other cases, where such multipurpose management is not possible, the best alternative may be to set aside areas of forest to be managed for different purposes. One part may therefore be managed intensively for timber, another part may be left under the control of local people for the less intensive production of other outputs such as fodder or medicines, while other areas may be conserved for ecological or other environmental reasons.

There is no universal management prescription. What is essential in all cases is clarity about objectives and about who is responsible for pursuing them and under what conditions. Only when these are properly defined and established and priorities are assigned is it possible to develop a strategy that will enable the objectives to be realized.

FOREST MANAGEMENT IN PROGRESS

Once the management objectives have been clarified, the task is to decide on the management and silvicultural techniques to be used.

Temperate and boreal forests

The main management focus in the temperate and boreal forests is upon sustained timber yield. In many areas, this is carried out in a manner that is compatible with the use of forests for watershed protection, recreation and other uses. In recent years, increasing attention, especially in the United States, has been focused on issues of biodiversity and the conservation of endangered species and ecosystems.

Methods of managing the temperate and boreal forests for sustained timber production have long existed. Increasing the area of these forests under such management depends more on political commitment and available funds than on acquiring new knowledge about what needs to be done.

Many of these forests are comparatively simple in structure and species composition. This is particularly the case in Europe, where selection and management over centuries have increased the concentration of timber-and wood-producing species and the degree of uniformity in the forests.

Because of the relatively high density of commercial trees, especially in forests that have been under long-term management, most of the trees are cut during harvesting. Conifer forests are generally clear felled. In broadleaf or mixed forests, however, there is an increasing tendency to carry out selective felling.

There are well-tested methods for ensuring that regeneration takes place after harvesting. These are recognized as good forestry practice and are generally accepted and implemented by the timber industry. They include taking steps to guarantee natural regeneration and sowing or planting of seedlings. In other cases, an area may be completely cleared and replanted.

The temperate and boreal forests are not only managed for timber; cork, naval stores (FN 3) and mushrooms are examples of important commercial products from temperate forests under sustainable management, and many of the temperate forests in industrialized countries are managed for recreation or amenities as well as for forest products.

In general, the temperate and boreal forests are fairly robust systems as far as forest management practices are

concerned. The soils are not particularly fragile and are not endangered by logging, provided that the proper precautions are taken over the construction of roads and that felling is avoided on the steeper slopes. The threats to the temperate, and possibly to the boreal, forests arise more from the effects of pollution and fire than from mismanagement.

Moist tropical forests

The main focus of concern over the moist tropical forests is their rapid rate of depletion. Most of this is caused by clearing for agriculture and is therefore outside the scope of forestry management or silvicultural remedy. Questions of rural development and land-use planning are involved as well as decisions and action by a broad spectrum of authorities and expertise both inside and outside the forestry sector.

Practical management interventions have been limited in most countries, and only a small proportion of the tropical moist forests is subject to effective management. In most other cases the only activities are supervision of logging in support of royalty collection.

Sustainable yield management offers the prospect of realizing the economic potential of the moist tropical forests while at the same time maintaining their basic structure as well as their capacity to deliver a variety of other goods and services. It is, however, considerably more difficult than in the temperate and boreal forests.

The tropical moist forests are inherently complex systems. Because relatively long rotation periods are involved and because sustained yield management is comparatively recent in most areas, some uncertainties about optimum techniques and exact yields and outcomes inevitably remain. The indications are, nevertheless, that management of the great majority of these forests for sustained output of wood is technically feasible.

The main obstacles to the more widespread application of sustainable yield management are economic. Far from being a uniform and bountiful source of easy financial gain, as is often popularly supposed, the tropical moist forests tend to share a number of features that make profitable logging, let alone sustained yield management, difficult to achieve.

The problems of managing these forests include the large number of species, many of which are non-commercial; the rapid and luxuriant growth of vines and creepers in the open spaces created by felling; the general fragility of the soils and their vulnerability if fully exposed; the difficulties of access; difficulties in inducing natural regeneration; and the extremely arduous working conditions, especially in the wetter tropics. Harvesting operations are therefore expensive, and logging companies tend to demonstrate strong resistance to any increase in logging expenditures to reduce damage to the remaining stand or to the soil, especially when the companies involved are small and undercapitalized and the prospects for long-term investment are unfavourable.

The first step towards the sustainable management of an area of forest is to draw up a management plan. A forest management plan prescribes the activities required to meet its objectives. The prescriptions may be simple or complex. A detailed plan requires a considerable amount of information such as an inventory of the standing stock and of its condition and age or size composition, as well as an assessment of the soils, slopes and other factors that affect the way in which the silvicultural and logging operations should be carried out. This demands a substantial amount of work which may simply be impossible for a poorly funded and understaffed forest service. But even a simple working plan, based on cautious assumptions, can provide a basis for sustainable yield management.

The working plan lays down the conditions that logging concessionaires are expected to follow. Access roads are supposed to be constructed in a way that minimizes forest damage and the risks of erosion. The numbers, species and sizes of trees as well as the methods of felling and extraction are specified to limit the damage to the remaining forest. It is particularly important to prevent "creaming" of the forest, in which only one or very few species with the best form are removed, making it more difficult to manage the area on a sustainable yield basis (FN 4).

The design and construction of roads is critical. They may occupy up to one-sixth of the total forest area in European forests, although less in tropical forests. Roads can be a major cause of forest damage. One estimate is that 90 percent of the soil erosion associated with logging is directly attributable to roads. Studies have shown that when proper attention is paid to the overall planning of the road layout and logging operations, fewer saleable trees are left behind, there is less damage to other trees during felling and there are fewer accidents. Costs are lower and the amount of damage to the forest environment is substantially reduced.

Harvesting should be seen as a silvicultural operation, linked to the initial inventory. The most critical element in the implementation of the working plan is therefore the degree of control and supervision exercised over logging operations. This is a major area of weakness in most developing countries. When foresters are poorly trained, ill-equipped and underpaid, the control exercised over logging tends to be weak at best and is often absent. It is hard to expect otherwise when foresters may have to depend entirely on the logging companies for their transport, accommodation and living requirements. Where there is no commitment to the enforcement of regulations in

political circles and the upper ranks of the forest service, logging is effectively uncontrolled and drawing up working plans is more or less meaningless,

The final management task is to ensure that the forest regenerates in a manner that will permit it to be reharvested in due course. Monocyclic management methods are based on a single harvesting after which the forest is left until ready again. In polycyclic management systems, there are intermediate harvests in which the faster-growing trees are extracted. Within these broad categories a wide variety of techniques are used, based upon the information provided by the first and subsequent inventories.

One of the main difficulties in putting into effect management for sustained yield in tropical forests is the small proportion of commercially valuable species that are harvested. This is at first sight paradoxical, but is explained by the fact that once the relatively few commercial trees have been removed, the open areas are quickly covered with creepers and are invaded by other pioneer species. If the desired species are not pioneers then their natural regeneration in the face of this intense biological competition is slow and uncertain. The management challenge is to find ways of manipulating the natural processes of forest regrowth so that the commercially valuable species are encouraged to regenerate and preferably so that their numbers relative to the non-commercial species are increased.

Sometimes the area being managed is enriched by planting seeds or saplings of the commercial species in the logged area. This requires a considerable amount of labour in planting and weeding and is expensive. A cheaper alternative is to rely on natural seeding, when possible, and on improving the growth of the younger commercial trees by techniques such as liberation thinning the elimination of competing species in the immediate vicinity of immature commercial trees, leaving areas where there are no commercial trees undisturbed -and climber cutting.

Whether natural regeneration or enrichment planting is used, measures are usually taken to reduce the competition to the desirable seedlings and to the advance growth. Formerly these objectives were met by killing some of the surrounding non-commercial trees either by girdling or by poisoning with arboricides such as sodium arsenite. The elimination of trees is becoming rarer as experience shows that species regarded as non-commercial at a particular time may become saleable within a decade or two. Liberation thinning reduces disruption of the forest structure as well as costs.

A particularly effective technique for enrichment planting was developed in Uganda during the 1960s. Charcoal makers were allowed into the logged forest areas and were encouraged to convert those species not used for timber into charcoal. This opened up the forest for the growth of the commercial species, which were planted in the cleared areas. Using the trees unwanted by the timber trade for charcoal avoided the cost and waste involved in poisoning while providing employment and meeting fuel needs.

A method developed in Côte d'Ivoire during the 1930s involves limited clearing of the forest after logging, followed by close planting of desirable species. As these grow, the non-commercial trees are gradually poisoned around them. This gives good results but requires a considerable amount of labour. Another management system, begun in Trinidad in 1926, was originally based almost entirely upon regeneration by planting but has been gradually changed in the light of experience and now relies completely on natural regeneration.

An experimental technique at present being developed and tested in Peru is particularly interesting in that it involves the active engagement of the local community. Although clear felling is used, it is only carried out in narrow strips running along the contours of the land. This reduces the danger of damage from erosion and facilitates regeneration from the adjacent uncut forest. To maximize local employment, the logging operations are mainly based on hand labour and the use of oxen, although in some cases portable sawmills are used on site to improve the rate of utilization and the marketability of the timber.

The management system chosen and the degree of intensity with which it is applied will vary depending on local conditions and the objectives. If maximum production of commercial timber is the aim, one of the more intensive management systems or complete replanting after logging is likely to be the most appropriate. Where a limited harvest of top-quality timber for veneers and other high-value uses is the objective, less intensive methods may be best.

In all cases, a critical requirement is that the management method chosen should be related to the implementation capabilities available. This requires a realistic appraisal of the technical and managerial skills available, the financial resources obtainable and the degree of political and administrative commitment to forest management. There is no point in adopting a highly elaborate management plan if there is no way it can be carried out. It is far better to have a simple system that provides some degree of control than an ambitious one that exists only on paper.

The management approach instituted in the Congo, for example, has been deliberately chosen to match the size of the existing staff of the forest service. Under the system, the forest service has simply defined the areas that can be logged and has set conservative limits on the numbers, sizes and species of trees that can be taken from them. Control is exercised by inspection of the logs being extracted. No silvicultural treatment is involved, and road

construction and harvesting practices are subject to spot checks. Once logging has taken place, access is restricted until the area has recovered. The system is geared to the capacities available and, in practice, provides a substantial amount of control. As the human and material capacities of the forest service increase, the control system can be improved and silvicultural treatments can be introduced.

This section has concentrated on the management of moist tropical forests for the production of timber. There are, however, many other products harvested from moist tropical forests. Rattans are of great economic importance for Indonesia (which produces 80 percent of the world's annual consumption), Malaysia, the Philippines and several other countries. Cardamom *(Elettaria* sp.) is grown in southern India under the shade of tropical moist forest. Another important non-wood forest product from India (albeit from the moist deciduous forests) is lac, which comes from the protective covering of an insect that infests the young shoots of *Schleichera* spp., *Zizyphus* spp. and other host plants. From the forests of Brazil come natural rubber, gums, nuts (including the Brazil nut, *Bertholletia excelsa)* and palm hearts.

Details of management techniques for mangrove forests have not been considered, but the basic principles of forest management apply also to these types, which provide, in addition to wood products (such as timber, fuelwood, poles and pulp), also great range of non-wood forest a products which include tannin, nipa palms, shellfish, honey, crocodiles (from crocodile farming), agriculture, salt, ecotourism and coastal protection (FAO, 1993i).

Dry tropical forests

The dry tropical forests pose management challenges very different from those of the moist tropics. Most of the native tree species are slow growing and drought tolerant. During hot dry spells, biological activity is reduced to a minimum as a means of survival. Fire is an important hazard.

The wood produced is usually hard and durable and with few exceptions is generally only commercial on a local basis. Regeneration often relies on grazing animals eating the pods and excreting the seeds; otherwise the seeds are able to survive for years in the soil. A high proportion of the tree species coppice, producing vigorous new growth when the main trunk is cut. Many of the species are fire resistant when larger than pole size.

Wildlife is a significant element in the management of these areas. It is extremely important at a local level as a source of meat and other animal products. It is also of major significance in the tourist trade of countries such as Kenya, the United Republic of Tanzania and Zimbabwe.

Where rainfall is scarce but reliable, sustained yield management is technically feasible. This is usually based on replacement or enrichment planting. The drier the area or more erratic the rainfall, the poorer the record of replacement planting tends to be. In some areas, studies have shown that the yield from exotics may be less than that of the indigenous forest cleared to make place for them.

The management emphasis in the drier areas has consequently been shifting towards the regeneration management of existing forests with indigenous species and the forestation of degraded or even completely barren areas. In a number of countries, demonstration plots in which cutting and grazing have been forbidden and fire has been excluded for a number of years have shown a remarkable ability to regenerate both from coppice and from seed that has lain dormant in the soil. There is no doubt that this suggests a management method capable of restoring and sustaining the productive capacities of large areas of forest in these areas.

Important non-wood products from dry forests include gums (such as gum arabic), fodder, honey and grazing, whose production is included in the objects of management of some forests. The management objectives of other forests include maintenance of populations of wild animals, either for hunting or in support of the tourist trade.

The main problem in implementing forest management schemes in most of the dry forest areas is the intensity of existing land use. Even in badly degraded areas, people may rely completely on what is left of the forests for browse and fuel. Closing off areas for regeneration, even though it will produce long-term gains, can impose intolerable short-term burdens upon people. Where lands are in common ownership there may also be difficulties in arriving at satisfactory methods of sharing out the various benefits and costs involved.

Conserving genetic resources and biodiversity

This section concentrates on the conservation of plant biodiversity and plant genetic resources, but in fact the same principles apply to the animals in the forest ecosystems.

Although conserving biodiversity and conserving genetic resources are frequently seen as the same thing, they are different in that action is focused at different levels: within the ecosystem or within the species. It is, for example, entirely possible to conserve an ecosystem or a species in it but to lose genetic diversity; likewise, it is possible to

conserve genetic diversity while the number of species in the ecosystem may decrease.

Conservation of genetic resources aims at ensuring that the widest possible range of genetic variation for a given target species is identified and conserved. This will usually include surveys, demarcation, management and monitoring of conservation areas and the collection and storage of seeds or tissue. Management may imply the elimination of competitors or the opening of the forest canopy to promote the growth of the target species.

On-site conservation of genetic resources requires planned and systematic management of clearly defined target species in a network of conservation areas and managed resource areas. It should be aimed at the maintenance or enhancement of the within-species variation found in these species. The primary challenge for the conservation of genetic resources is thus not to select, set aside and guard protected areas containing genetic resources; rather it is to maintain the genetic variability of the target species within a mosaic of economically and socially acceptable land-use options. These may include strictly protected areas as well as multiple-use reserves, managed forests and agro-ecosystems. While, in general, the conservation of genetic resources outside protected areas in places used for wood production (for example) will require more intensive management and the monitoring of target species, such areas are not inherently less compatible with genetic conservation of the species being harvested in a sustainable manner, or of associated species, than are strictly protected areas. It should thus be possible to harmonize conservation of genetic resources with sustainable use of much of the land area of a country by including concerns for genetic conservation of target species as a major component in land-use planning and management strategies (FAO, 1991a).

Conservation of biodiversity is concerned with the full range of plant and animal species and their interrelationships. The objectives can easily become blurred, since natural ecosystems are in a constant state of change in which new species are evolving or being introduced while others decline. For instance, the number of species in the climax forest is considerably less than in intermediate successional stages. It is therefore important to specify whether the management system is intended to attempt to freeze biodiversity at its present level, to achieve a different balance or to allow nature to take its course.

Most national parks, to take a practical example, are protected against forest fires. This reduces the competitive advantage of pioneer and fire-resistant tree species. Over time, the balance of tree species, as well as the populations of birds, mammals and other animals, changes. The forest will tend to become more vulnerable to fire damage as the undergrowth thickens and the number of old and decaying trees increases. In this case, protection against forest fires, which may appear to preserve biodiversity, is an interference which will ultimately result in an "unnatural" forest.

Thus, clear objectives are necessary in developing strategies for conserving biodiversity, just as they are in the management of forest areas for any other purpose. Simply protecting an area may result in a reduction in biodiversity and the elimination of plant or animal species that are unable to adapt to the inevitably changing conditions of today's world. Protecting endangered species or maintaining what is felt to be a desirable balance between species may require substantial outside interference in the natural working of the ecosystem.

In all cases, the assent and cooperation of local people will be required if the management of forest areas to conserve biodiversity and genetic resources, however these are defined, is to be successful in the long term. Attempting to drive people out of areas on which they rely for food, fuel or other goods is almost certain to fail. Local people must be involved in the initial planning and final implementation of the management system and must derive tangible benefits from it. Where people are required to give up existing benefits or access rights, they must be adequately compensated.

An example of the conservation of biodiversity is the establishment of a 77 000 ha national nature reserve in Niger. The reserve was proposed in 1982 and was formally established in 1988. The local inhabitants were consulted at all stages to ensure their cooperation. A wildlife sanctuary occupying 12 percent of the area was created in a part of the reserve rarely visited by people. The establishment of the reserve was associated with a rural development programme which provided health training, adult literacy classes. help with well digging and other assistance to the community. Another example is from Peru, where a village community from an area west of the Huascaran National Park has established an in *situ* conservation area of 0.15 ha of *Alnus jorullensis.* A nursery has been established which produces this species for planting in association with agricultural crops to fix nitrogen and to provide fuelwood and soil protection (FN 5)

Trees in the landscape, agroforestry and urban forestry

Sustainable forestry management is not only concerned with trees growing in large blocks but in its broadest sense involves trees growing in the rural landscape, including those on agricultural land, and trees in urban areas.

In most settled farming societies, trees in the landscape provide a number of products (for example, fuelwood, poles, animal fodder, fruit and fibres) and perform several important functions (such as shading, protecting from the wind and decreasing soil erosion).

The numbers of trees in the rural landscape are, however, falling in many areas. Among the immediate causes are shorter fallow periods, agricultural mechanization, increasing grazing pressures which prevent natural regeneration, the breakdown of traditional communal farming systems and increased fuelwood cutting - especially that carried out to meet urban demand. These increased pressures on wood resources reflect the complex and rapid social, economic and cultural changes taking place in the societies involved. In attempting to promote increased tree growing by farmers or by rural communities, it is therefore essential to understand why trees are disappearing, why they are not being replaced and what the local needs are that trees can fulfil. Many of the early tree growing campaigns failed because they focused almost exclusively on growing trees for fuel, which is rarely a priority among rural people. People are often more likely to plant or manage trees for the production of higher-value products, such as timber, poles, fruit or fodder, or even for a service, such as boundary demarcation, shade or ornament, with fuel regarded as a by-product.

Various approaches are now being used in different parts of the developing world to encourage tree growing by farmers. They include educational campaigns, the provision of free or subsidized seedlings, training for farmers in setting up commercial nurseries and support for NGOs that promote tree growing. The results are mixed, indicating that in many cases the campaigns are still not addressing real concerns or that problems of land tenure and tree ownership, which are often the underlying cause of the depletion, have not been resolved.

Agroforestry represents the integration of agriculture and forestry to increase the productivity or sustainability of the farming system and/or to increase farm income. The definition adopted by the International Council for Research in Agroforestry (ICRAF) is as follows: "Agroforestry is a collective name for land-use systems and practices where woody perennials are deliberately integrated with crops and/or animals on the same land management unit. The integration can be either in spatial mixture or temporal sequence. There are normally both ecological and economic interactions between the woody and non-woody components in agroforestry."

Agroforestry includes a wide variety of land-use systems, ranging from those in which trees are planted and managed on agricultural lands to those in which agriculture is practised on forest lands without resulting in deforestation. Many traditional systems have been developed over time through trial and error by farmers and reflect local environmental and socio-economic conditions. The home gardens of Indonesia are one example, while another is the maintenance of naturally occurring *Faidherbia albida* (formerly *Acacia albidu)* in agricultural fields in semi-arid Africa. The contribution of these trees to agricultural production is widely recognized, and these trees are often protected by traditional laws.

Considerable work has been done over the last 15 years to develop agroforestry systems, by devising approaches for research and extension, and to test new systems. Agroforestry, however, is still a new science, and far more has yet to be done to develop systems that are not only biologically and economically viable but socially acceptable as well. The integration of trees into agricultural systems is not the only way in which trees are incorporated in the landscape. Trees have long been used to beautify and ameliorate the urban environment, but in view of the prediction that half of the world's population is expected to be living in urban areas by the year 2000, the need for urban forestry (FN 6) is increasingly recognized. For instance, the green cover (trees and shrubs) of the city of Beijing has increased from 3 percent in 1949 to 26 percent today, or about 6 m^2 per person (Dembner, 1993); in contrast, the green cover of Mexico City is 2 percent, not quite 2 m^2 per person (Cabellero Deloya, 1993). Both cities are aware of the benefits of urban forestry and are attempting, despite considerable difficulties, to increase the area of green cover.

The role of trees in cities lies in the provision of aesthetic and environmental benefits [the latter including climate modification, energy conservation, noise level reduction and improvement of air quality (see e.g. Nowak and McPherson, 1993) and possibly in the provision of wood products and foodstuffs. The development of techniques for the sustainable management of urban trees and forests will, like the sustainable management of forest plantations, be complementary to the development of sustainable management strategies for the world's natural and semi-natural forests.

Protecting forests against fire, insects and disease

Fire, insects and disease are integral to forest ecosystems. However, under certain conditions they can cause widespread damage and disrupt the flow of goods and services that forests provide. They can affect the growth and survival of trees, water quality and yield, wildlife habitats, species diversity, the supply of forage and fodder and recreational, scenic and cultural benefits. Consequently measures to protect forests from fire, insects and disease are an essential part of forest management if sustainable levels of goods and services are to be assured.

Natural fire has influenced plant communities over evolutionary periods of time. In semi-arid regions, where fires are frequent, forests and woodlands have evolved with fire and plants have developed adaptive traits which ensure their survival or enable them to compete with less fire-tolerant species.

Fire can also be an agent of destruction; a low ground fire burning in a forest of fire-tolerant trees will kill regeneration and understorey vegetation. Fire-tolerant trees can sustain injury from fire which makes them more

susceptible to attack by insects or fungi. More intense fires can kill all the vegetation on a site. Years of growth may be destroyed in a matter of hours and endangered habitats may be lost. Destruction of vegetation by fire may cause soil erosion, especially on steep slopes, leading to siltation of water supplies. Human property and life may be lost. In addition, when forests burn, carbon that is stored in woody tissue is released into the atmosphere as carbon dioxide and other greenhouse gases. Increases in atmospheric levels of these gases is causing concern because of their potential influence on global climate.

Fire is also a valuable tool in land management. It is used to prepare land for agriculture. Much of the tropical deforestation and associated burning are done to support shifting cultivation, which is practised by some 200 million people on 300 to 500 million hectares worldwide. Fire is an important silvicultural tool in forestry operations and is used for slash disposal, fuel reduction and the preparation of sites for planting or natural regeneration.

It is estimated that 12 to 13 million hectares of forest and other wooded lands are damaged annually by wildfire. When conditions are favourable, catastrophic wild fires can occur. In 1982-83, following a severe drought, some 3.6 million hectares of primary and secondary rain forest were destroyed in East Kalimantan, the Indonesian portion of the island of Borneo. In 1983, the "Ash Wednesday" fire burned over 340 000 ha in southern Australia; it destroyed 300 000 farm animals, damaged 2 500 homes, injured 3 500 people and killed 75. During 1987, over one million hectares burned in northern China, and in 1988, fires in Yellowstone National Park in. Montana and Wyoming in the United States burned over 320 000 ha.

Wildland fire management is an essential element of sustainable forest management and consists of prevention, presuppression planning and suppression. Measures to prevent forest fires focus on education, legislation, the reduction of the volume of combustible fuels and the construction of fire breaks. For suppression, resources have to be provided for fire-fighting equipment and the recruitment and training of fire-fighters.

The role of natural fire in the dynamics of forest ecosystems must be considered when designing fire management programmes. Exclusion of fire from ecosystems where fire has a natural role can result in changes in vegetation, accumulations of fuels, increased risk of pest outbreaks and, ultimately, the risk of a catastrophic fire.

Insects and disease can also cause extensive forest damage. Every part of a tree - the foliage, buds, flowers, seeds, stem, bark, wood and roots - can serve as host material for these agents. Trees of all ages, from seedlings to mature trees, are subject to attack. In addition, insects and pests affect logs and wood products.

The ecological, social and economic impacts of insects and disease are far-reaching. Pest activity can significantly reduce yields of wood products. In the United States, bark beetles alone kill trees with a volume of 25.5 million cubic metres of sawtimber and pulpwood annually. The yield of fruit, mast or other food products on which wildlife, livestock or humans may depend can also be significantly reduced. Defoliating insects cause a decrease in the availability of fodder derived from hardwoods in India and many other countries. Recreational and scenic values of forests are reduced where extensive areas of forest have been damaged by defoliating or tree-killing insects, and trees weakened or killed by insects and disease in forest recreation areas are a safety hazard. Dead trees left behind in the wake of pest outbreaks increase the volume of combustible fuels. Consequently, when a fire occurs in pest-damaged forest it will burn with greater intensity and will be more destructive and more difficult to extinguish.

In the United States, fungi that cause decay in living trees account for more loss in sawtimber than fire, insects, weather or any other disease agent. Decay of wood products is also significant. Approximately 10 percent of the timber harvested annually in the United States is utilized to replace wood that has deteriorated because of decay caused by fungi. In the tropics and subtropics, insects such as termites are capable of causing extensive damage to living trees, homes and other wooden structures.

Pests that are accidentally introduced can eliminate a host plant from an ecosystem and reduce species diversity. Chestnut blight *(Endothia parasitica)* eliminated American chestnut *(Castanea dentata)* as a major component of the hardwood forests of the eastern United States. This tree was once highly prized for its attractive, decay-resistant wood and for its nuts which were used by wildlife. More recent accidental introductions of insects such as cypress aphid *(Cinara cupressi)* in eastern Africa, Leucaena psyllid *(Heteropsylla cubana)* in Asia and the Pacific and European pine shoot moth *(Rhyacionia buoliana)* and a European wood wasp *(Sirex noctilio)* into South America threaten the future viability of large areas of exotic, fast-growing plantations (FN 7). The natural defence mechanisms of trees and the natural enemies of pest species usually keep the damage to trees at low levels. When trees are weakened by drought, inadequate management, pollution or other factors, the risk of pest damage increases. The decline currently affecting many tree species in Europe and North America is believed to be the result of a combination of these factors. Single-species plantations and natural forests in the boreal and temperate zones which contain only a few species tend to be more susceptible to build-up of pests than tropical forests, in which several hundred plant species may grow on a single hectare.

The protection of forests from attack by insects and disease is best addressed under the concept of integrated pest management (IPM). IPM is a process of decision-making and action that takes into consideration the ecology of pests and their hosts and the ecological, social and economic consequences of pest damage and pest

management actions. Emphasis is placed on pest monitoring, on understanding the underlying causes of outbreaks and on maintaining or improving the health of forests rather than on controlling pests.

IPM involves the use of one or more tactics to reduce losses caused by pests to a level that permits immediate and future management objectives to be met. These tactics include silvicultural action to prevent pest build-up, regulation to prevent pest introductions, the use of predators, parasites and diseases to reduce pest populations, and genetic selection of pest-resistant strains.

Concerns about the potentially negative side effects of chemical pesticides, such as environmental contamination and hazards to human health, have made their use less desirable. In addition, chemicals are expensive and are often not economically justified, especially in developing countries. Despite these drawbacks, chemicals are still considered a part of IPM, but only if they are used selectively and as a last resort, and short-lived compounds are preferred.

IPM is a dynamic process under which new approaches and new technologies are continuously tested and evaluated. Those that prove effective are quickly integrated into ongoing programmes.

Plantations

Plantation forestry is a well established form of intensive forest management. It is estimated that plantations provide 7 to 10 percent of the world's present commercial wood production. There are roughly 100 million hectares of forest plantations in the world (Gauthier, 1991).

Statistics on plantations must be treated with caution. Sometimes the figures are based on the accumulated area planted without any deductions for the areas felled. When estimates are made of the areas planted by local communities or farmers, the margin of error is even larger. Often the figures are based simply on the numbers of seedlings distributed and not on the numbers planted or surviving. On the other hand, the figures may omit the numbers of trees planted by farmers from their own seedlings.

The net area of forest plantations (taking into account the estimated survival rates) in the tropical countries in 1990 was estimated to be about 30 million hectares, counting industrial and community plantations but not including trees planted by farmers themselves on their own lands (Pandey, 1992). It has been calculated that plantations were established at an average rate of around 2.6 million hectares per year during the 1980s and the present rate may be as high as 3 million hectares per year.

The world's rubber, coconut and oil palm plantations are not included in the area of forest plantations. These are mainly in Asia and the wood obtained from them is increasingly important. Their total planted area is about 14 million hectares, of which about 7.2 million are planted to rubber, 4.2 million to coconut and 2.7 million to oil-palm.

One of the oldest methods of plantation management is the taungya system. This was introduced in Myanmar (then Burma) in the 1850s for teak plantations and has since been used in many other areas. After logging, the forest is replanted. Farmers are allowed to grow crops in the planted areas in exchange for protecting the saplings and weeding the plot. In a few years, when the new trees are so large that food crops can no longer be grown in the shade they cast, the process is repeated in another area. Although the system offers a low-cost means of plantation establishment, it is not necessarily sustainable, since it relies on a shortage of permanent agricultural land and a supply of people willing to take part.

Plantations can be highly productive. The increment of timber from a tropical plantation may be 30 m^3 per hectare per year (or more) compared with 2 to 8m^3 from a managed natural forest (FN 8). But such figures need to be treated with caution Experience shows that the yields assumed at the planning stage of many plantations are overestimated, often by a factor of two or more. This was the case, for example, in the dendrothermal programme in the Philippines, which intended to use wood from rapidly growing plantations as fuel for electric power stations. The fact that yields turned out to be half those planned or less was one of the reasons for the failure of the programme.

Other aspects of plantation forestry, especially in the tropics, also leave much room for improvement. There are numerous examples of plantations that have failed or sites that have been degraded by ill-chosen exotic species. A review of tropical plantations (Pandey, 1992) observed that planning is generally poor, particularly in relation to vital issues such as the matching of species to the site. It also noted that plantation projects are often designed in haste, with scant attention paid to important issues because of time or financial constraints.

In the developing world, the main physical constraint to the future contribution of plantation forestry is the availability of land. With expanding farming populations using all the available unforested land for food production, the areas available for plantations are becoming ever more restricted. The experience of the past two decades has shown that degraded or "waste" land may be the only resource available to poor people.

There are, however, large areas where the natural forest has been badly degraded or where the soil fertility has been lost through overcultivation, which could be used for plantations. Such schemes could provide a source of employment and long-term income, provided the existence and needs of local people are recognized from the beginning. There are also large areas of salt-affected land; the total in the developing world is estimated to be about 150 million hectares. Much of this land could be brought into productive use by planting it with salt-tolerant trees. But even here there could be competition from agriculture; major efforts are being made in some areas to rehabilitate these lands or to use them for salt-tolerant crops.

As investments, the main feature of plantations is their long production cycle. Tropical timber plantations have rotations ranging from 15 to 20 years up to 60 to 80 years. In the temperate zones, the rotation periods are even longer. Because broadleaf species such as oak are now being used in response to the popular reaction against uniform conifer plantations in some European countries, some of the plantations now being established will have a rotation period of up to 150 years.

A highly ambitious global forestry programme was included in the Noordwijk Declaration (Noordwijk Ministerial Conference, 1989), the resolution of a ministerial-level, global meeting convened to discuss the problems of atmospheric pollution and climate change. Among the aims set out in the declaration were a world net forest growth of 12 million hectares per year by the turn of the century. It was not anticipated that all of the net forest growth would come from forestation of currently treeless land, but nevertheless a high proportion of the increase would be new plantations.

At present, there appears to be little prospect that the required planting rate will be achieved Plantation forestry nevertheless can continue to make a significant and expanding contribution to the needs of the world for wood. Without plantations, supplies can only be drawn from the natural forests. It is therefore important that governments continue to invest in plantations. It is also highly desirable that private-sector investments be encouraged.

Because the returns from plantations are subject to a variety of long-term risks ranging from price collapses to natural calamities, as well as having long payback periods, it is essential that governments provide the necessary incentives to communal and private investors - with proper controls.

Plantations generally have one major objective for their establishment; often it is the production of wood, but some plantations are created for shelter and protection. Sometimes, however, plantations can supply both wood and non-wood products. Examples are the growing of cardamom under the shade of eucalypts in India, or the raising of mushrooms in *Pinus radiata* plantations in Chile (FAO, 1993a).

There can be no pretence that plantations can provide the full range of goods and services supplied by a natural forest. They comprise tree crops, analogous to agricultural crops, with a simplified ecology of one or at most a few species usually chosen for their yield and ease of management. The primary purpose of most plantations is to produce wood or other products quickly and cheaply. Their role, which is a highly valuable one, is as a complementary element in national or global forestry management strategies.

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1. The following is quoted from the same paper (FAO, 1991c): "In the broadest sense, forest management deals with the overall administrative, economic, legal, social, technical and scientific aspects involved with the handling of conservation and use of forests. It implies various degrees of deliberate human interventions, ranging from action aimed at safeguarding and maintaining the forest ecosystem and its functions, to favouring given socially or economically valuable species or groups of species for the improved production of goods and environmental services."

2. "Forest ecosystems are managed for a variety of objectives related to the many goods (wood and non-wood products) and services (e.g. soil and water conservation, conservation of biological diversity) which they can provide. In most cases they are managed for more than one objective. Even in the case when a single objective is declared, forest management may achieve other purposes which may or may not be clearly expressed. For instance, if sustained timber production is the only explicit objective, forests continue to provide other services such as those of soil and water conservation.

"Prioritization of the objectives of multipurpose management is needed in order to facilitate the choice among the conflicting demands put on the forests under management. In particular, one main objective must be given priority over the others. However, in striving to achieve this objective, forest managers must see to it that all the other objectives remain fulfilled, at least partially" (FAO, 1991c).

3. The term "naval stores" refers to the products of the resin industry in the United States, particularly to turpentine and rosin but also to pine tars and pitch.

4. "While harvesting of mature trees of good quality is among the stated objectives of forest management aimed at the production of timber, pressing market demands coupled with inadequate forest management practices may lead to highly selective harvesting having negative (dysgenic) effects on the future development of the stand. Silviculture rightly calls for harvesting of 'the best', but this must not be done without due consideration to regeneration potential and the quality of the next generation crop" (FAO, 1993b).

5. "West of the Huascaran National Park the community Ramon Castilla has established an in *situ* conservation area of 0.15 ha of *Alnus jorullensis.* Also here a nursery has been established producing *Alnus jorullensis* for planting on terrace risers thus 1) fixing nitrogen to benefit agricultural crops 2) providing firewood and 3) providing soil protection. These activities are considered an example of an optimal strategy of *in situ* conservation. The small natural, remnant stand of *Alnus,* belonging to the community, was being over exploited for wood, posts and poles, and its management was being totally neglected. By demonstrating to the campesinos that food production - a day-to-day concern to them -could be greatly improved by using material originating in the *Alnus* stand, planting *Alnus* seedlings along the contour lines of agricultural fields, the value of this earlier-neglected stand suddenly increased by many orders of magnitude. At the same time. demonstrations were made to show that although the stand could, and should, continue to be used also for the provision of wood and wood products for day-to-day use by the community, management (including ensuring regeneration by careful felling and extraction) visibly improved it and was apt to ensure the availability of such material also in the future. The locals have come to realize the practical value of this stand in their daily life, as well as being aware of the fact that the stand is also of importance to 'the Government' (translating into the value of conserving the genetic resources of this specific stand, as one component of a network of *in situ* conservation areas of *Alnus jorullensis).*

"The management of natural, remnant *Alnus* stands and growing and utilization of seedlings with materials originating in such stands has already spontaneously spread to other, neighbouring communities" (FAO, 1990b).

6. Urban forestry has been defined as "a specialized branch of forestry that has as its objectives the cultivation and management of trees for their present and potential contribution to the physiological, sociological and economic well-being of urban society. In its broadest sense, urban forestry embraces a multimanagerial system that includes municipal watersheds, wildlife habitats, outdoor recreation opportunities, landscape design, recycling of municipal wastes, tree care in general and the production of wood fiber as a raw material" (Kuchelmeister and Braatz, 1993).

7. *Cinara cupressi* attacks the tree species *Cupressus lusitanica. Heterospylla cubana* attacks the tree species Leucaena *leucocephala. Rhyacionia buoliana* occurs on pines in its native European range but has recently been discovered attacking *Pinus radiata* plantations in Chile; *Sirex noctilio,* native to southern Europe, has attacked *P. radiata* plantations in New Zealand and is now attacking *P. radiata, P. taeda* and other introduced pines in Argentina, Brazil and Uruguay.

8. The experience of the Aracruz Florestal, responsible for the plantations of Aracruz Celulose, a Brazilian paper pulp company, provides an example of the potential of plantations for the production of industrial roundwood. The annual increment of the first plantations of eucalypts was 28 m^3 /ha per year, but natural hybrids, mainly between Eucalyptus grandis and *E. urophylla,* increased this to 45 m^3/ha and synthetic hybrids of *E. grandis x E. urophylla* now yield 70 m^3/ha annually (FAO, 1993j).