# Management of tropical moist forests in Africa

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# FOREWORD

The potential for sustained management of natural forests in the humid tropics continues to be a subject of concern and uncertainty among tropical foresters. The destruction of roughly 7.5 million ha of tropical rain forest annually, in addition to about 4 million ha of open and savanna woodlands, has heightened the importance of managing tropical rain forests (FAO/UNEP, 1981). The virtual disappearance of commercially productive tropical rain forests is imminent in some countries; in others, this is happening at a slower pace, usually because of inaccessibility.

Amongst the principle causes of this deforestation are rural poverty, population growth, and poor organization and funding of forestry institutions. Managing tropical forests for economic production is a key element in conserving tropical forests. Despite many writings on this topic, some of them based on significant and well conceived field programmes, only a very small proportion of existing tropical rain forests are currently managed in any real sense of the term.

This paper considers natural forest management in a restricted sense which may be thought of as controlled and regulated harvesting, combined with silvicultural and protective measures to sustain or increase the commercial value of subsequent stands, all relying on natural regeneration of native species. In a model management programme, negative ecological impacts of harvesting or alternative lands uses can be minimized, and the overall operation is productive and profitable while maintaining the essential ecological character of the forest. The paper also considers plantation management systems on tropical moist forest sites.

A key factor in forest management is political will to institute effective management programmes. The stakes here are enormous: the quality of life of millions of people will depend on sustainable, productive land use; ecosystem conservation and the conservation and management of genetic resources are inseparably tied to sustainable development; small and large-scale forest industries in tropical countries, a mainstay of national economies and many local communities, will only contribute to development if they can be assured a continuing supply of forest resources.

FAO will continue to assign highest priority to the conservation and sustained use of tropical forests, in support of national development programmes; and to provide a forum for technical and policy-level discussions furthering the management of this valuable resource.

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## ACKNOWLEDGEMENTS

In this study of forest management in Africa, M.S. Philip prepared a review and analysis of tropical moist forest management in the Anglophone countires of Africa with contributions on Uganda from P.K. Karani (1985), and on Nigeria and other countries from P.R.O. Kio et al. (1985). R. Catinot prepared a review and analysis of tropical moist forest management in the Francophone countries of Africa. R.L. Willan then consolidated these studies to produce the present synthesis. FAO wishes to acknowledge the excellent work of all of these individuals; and the individuals and institutes in the countries concerned which provided the basic information for review and discussion.

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# CHAPTER I

## 1. INTRODUCTION

1. Effective management of the Tropical Moist Forests (TMF) is one way to prevent their disappearance. This, however, requires a good knowledge of existing practices. The Forestry Department of FAO has commissioned several studies on tropical forest management (FAO Forestry Papers on Intensive Multiple-Use Forest Management in Kerala (India) [No. 53], Intensive Multiple-Use Forest Management in the Tropics, Analysis of Case Studies from India, Africa, Latin America and the Caribbean [No. 55]), and Review of Forest Management Systems of Tropical Asia: Case Studies of natural forest management for timber production in India, Malaysia and the Philippines (FAO 1988b). The present study applies to TMF in Africa.

2. This study covers mainly the lowland TMF, but has been extended to include the semi-deciduous tropical forest at rather higher altitudes in Uganda. Mention is also made of the montane closed forests of Kenya and Tanzania.

3. "Management" can be defined in various ways. The management manual of the Office National des Forêts in France, quoted in Vannière (1975), defines it as follows: "Management consists in deciding what we wish to do with the forest, to take account of what we can do with it, and hence to deduce what we should do with it". Philip (1986a) defines management of a forest, as of any other enterprise as, "The allocation and organization of scarce resources to meet defined objects, goals or ends". Both these definitions stress the fact that management must be a compromise between the ideal and the possible; that it requires clearly defined objectives; that the objectives must be realistic and may need to be modified in the light of biological, social, economic or political constraints; and that management must make the best use of available resources in achieving the objectives.

4. "Forest management" is also conceived as the practical application of various techniques, as day-to-day operations, over extensive areas of forest. In this sense, a perfectly "managed" research plot of 5 hectares, inspected daily by an experienced researcher, does not constitute an example of forest management. Management prescriptions should be codified and readily applicable by independent operators working in widely separated forests. As stated in the Foreword, natural forest management may be thought of as controlled and regulated harvesting, combined with silvicultural and protective measures to sustain or increase the commercial value of subsequent stands, all relying on natural regeneration of native species.

5. Because of the long life of most TMF trees, management operations need to be planned well in advance. Thus any management system worthy of the name should be incorporated in written management or working plans for each major forest, with details of the programme of operations, resource inputs, produce outputs, provision for checking actual achievements against plans and, where necessary, for modifying the plan in the light of changing circumstances. Where a

crop has already passed successfully through one or more rotations, as is the case with many tropical fuelwood plantations of eucalypts or with cypress timber plantations in Kenya, it is justifiable to talk of a proven management system; operations, yields, costs and returns from new plantations can be based on experience in the old. No management system for natural TMF is proven in this sense, since rotation age is expected to be anything between 60 and 90 years; existing management systems are provisional. In the case of some plantations of e.g. Aucoumea, Terminalia, the management system can be based on more reliable data, since a number of stands have reached the expected rotation age of 35-45 years. As will be seen, management systems are designed for certain social and economic benefits, and when social and economic conditions change rapidly, as they often have in Africa in recent times, then management systems must be adapted rapidly if they are to function properly.

6. The present paper covers all management systems which retain TMF sites for forestry purposes. It therefore includes management of the mixed natural forests using natural regeneration, use of enrichment planting in combination with natural regeneration, and conversion of the natural forest to even-aged monoculture forest plantations. Conversion to non-forest crops, such as annual rice and maize or long-lived oil palm and rubber, may be a perfectly valid management system on some sites, but is outside the scope of this paper.

7. Classical forest management teaching was concerned with the organization of the forest viewed mainly as an ecological system (Philip, 1986a). The classical forest management or working plan described the forest under a set of headings such as:

(1) location;

(2) ownership;

(3) altitute, climate, topography;

(4) geology and soil;

(5) description, history and ecology of the forest:

(a) inventory of the growing stock;

(b) calculation of rate of growth;

(c) produce of the forest, demand, markets, prices, etc.

8. The plan then prescribed the silvicultural system, rotation, rate of felling and level of production expected. It set up an organization to ensure that either the prescriptions were followed or the plan was revised. A lot of emphasis was placed on the concept of sustained yield and on matching growth and harvest.

9. In many respects this has been an admirable system, as the ecological situation in each forest was carefully analyzed, and the function of the forest within, and as part of, the national forest estate was assessed in relation to the forest policy of the country. Recent developments in the science of forest management imply changes, especially changes in emphasis.

10. Foresters have always recognized that frequently the life span of their crops exceeds that of man - but two new facets of modern times have introduced a new dimension to forest planning. These are:

(1) the exponential growth rate of many human populations;

(2) the accelerating rate of change in technology, not only in that of harvesting and processing but in every sphere of modern society from food processing to transport and communications.

11. These two facets of the management environment affect planning in different ways. Increasing populations exert enormous pressure on land in developing countries through their increased demands for the most essential products of that land - food and wood fuel. The forests and agricultural lands will certainly be unable to sustain this increasing pressure and supply essential products and services unless some form of family planning can be effective in stabilizing populations. Changing technology implies changing demands and patterns in demand, especially for more sophisticated or highly manufactured wood products. Thus:

(1) the demand for building poles may be substituted by a demand for sawn wood;

(2) the demand for small round wood for fuel may be substituted by a demand for charcoal;

(3) traditional minor products used by rural communities may be substituted by a demand for recreation from town dwellers.

However, the major change is the tremendous and constantly growing increase in demand for all the products and benefits of the forest, both traditional and modern.

12. These changes have clarified the role of the forest and the role of foresters. In the early days of the colonial regimes, foresters, often aptly named "conservators of forests", were elite technocrats who were not directly answerable to the people. In these circumstances the technocracy often failed to distinguish and cater adequately for the "felt" needs of the people who lived beside the forest. The tendancy was to concentrate on the more extensive needs of the nation and of unborn generations to come.

13. This duality of responsibility was well understood and found expression through the distinction between national and local forest administrations and reserves. Often, however, the distribution of the productive forest and dense population coincided. Then population increases exacerbated the conflict between local interests wishing to satisfy their immediate needs for more land to grow more food, as well as for more wood fuel, and the longer term national needs for sustained forest production.

14. Increases in the demand for the more sophisticated products of the forest, especially for wood suited to pulp, chip and fibre technology, have also arisen and paralleled the rise in demand for fuel and food. Hence the scarce resources of fertile land and productive forest have become relatively more scarce, and pressure on productive forest boundaries has mounted in the face of the demand for immediate needs.

15. Consequently the environment of modern forest management in the tropics is dominated by people and their needs. Full understanding of the physical and ecological factors are still as vital as ever, but no management diagnosis that excludes a detailed analysis of the local and national social and political elements has any practical relevance. Prediction of future trends in these elements has become a necessary but difficult and risky task.

16. The total management environment of a forest enterprise can, therefore, be considered under four major heads:

(1) Physical, biological, ecological and environmental factors;

(2) Social - including the political and cultural facets as well as local and national needs;

(3) Economic - including constraints on the capital and recurrent budgets, rate of return, costs, prices, trade and markets;

(4) Technological factors and their rate of change in silviculture, harvesting and wood processing.

The synthesis of an appropriate management system must consider all these. Similarly any review of systems employed in the past must also consider all the relevant facts.

17. Therefore a complete management system can be viewed as an iterative, recursive, dynamic organization collecting processing and storing information. It is driven by the defined objects, limited by constraints and fuelled with new information. This new information must reflect, without distortion, changes in the total environment of management. Such a management system is illustrated in Figure 1.

18. Of the four major headings listed in paragraph 16, the first three (physical/biological/ecological environmental, social and economic) are largely beyond the control of the forest manager. They are discussed in Chapter 2, "The environment of forest management". The fourth, technological factors, includes such things as inventory, harvesting and silviculture. These are, to a considerable extent, within the control of the manager and, in effect, they constitute the tools of forest management. They are discussed in Chapter 3, "Recent developments in the principal components of forest management". The general synthesis of Part I is completed by Chapter 4 on "Current management needs in African Tropical Moist Forest".

19. The synthesis in the first part of the paper is complemented by three Case Studies; Case Study No. 1 is an Analysis of the development of management systems in the TMF of Uganda; No. 2 is an Analysis of the development of management systems in the TMF of Nigeria; No. 3 is on Management possibilities derived from studies on the development of closed forest in Côte d'Ivoire after various silvicultural treatments.

Figure I. Diagrammatic layout of a management system.

INFORMATION BLOCK

Physical, biological, ecological and environmental factors

Social factors - political
legal
cultural
national needs
local demands

Economic factors - capital & recurrent budgets
costs & prices
returns
trade
markets

Technological factors
- silvicultural
harvesting
processing in other sectors - e.g. agriculture

THE MANAGEMENT SYSTEM

- POLICY - objects & goals
- PLANNING - analyzing the factors of the environment, synthesizing options, choosing best
- PROGRAMMING
- BUDGETING
- CONTROL

# CHAPTER II

## 2. THE ENVIRONMENT OF FOREST MANAGEMENT

### 2.1 The Extent and Classification of Tropical Moist Forests in Africa

20. The land areas, areas of TMF, populations and population densities of the African countries which possess significant areas of TMF are given in Table 1.

Table 1. Countries with Significant Areas of Tropical Moist Forest in Africa

| Country | Area km² Total | Area km² Tropical Moist Forest | 1980 Estimate of Population $10^6$ | 1980 Estimate of Population Persons km² |
|---|---|---|---|---|
| (West Africa) | | | | |
| Cameroon | 475,442 | 179,200 | 7.1 | 15 |
| Côte d'Ivoire | 322,463 | 44,580 | 8.0 | 25 |
| Gabon | 267,670 | 205,000 | 0.5 | 2 |
| Ghana | 238,538 | 17,180 | 11.4 | 48 |
| Liberia | 96,320 | 20,000 | 2.0 | 21 |
| Nigeria | 923,768 | 59,500 | 85.0 | 92 |
| Sierra Leone | 73,326 | 7,400 | 3.4 | 46 |
| (Central Africa) | | | | |
| Central African Republic | 622,984 | 35,900 | 2.0 | 3 |
| Dem. Rep. of Congo | 342,000 | 213,400 | 1.5 | 4 |
| Zaire | 2,344,885 | 1,057,500 | 27.9 | 12 |
| (East Africa) | | | | |
| Kenya | 580,367 | 11,050 1/ | 15.7 | 27 |
| Tanzania | 939,702 | 14,400 | 18.0 | 19 |
| Uganda | 196,840 | 7,650 2/ | 13.2 | 67 |

Source: FAO/UNEP, 1981.

1/ Including bamboo and coniferous forest.
2/ Including bamboo.

21. An excellent detailed botanical account of the African forests is given in "The Vegetation of Africa" (White, 1983) published by Unesco. The main TMF types of Africa are described briefly in paragraphs 29-43. From the economic aspect, however, it is widely recognized that the pattern of wood harvesting has a dominant effect on the future structure and tending of the forest (Catinot, 1986; Philip, 1986a). Hence two important factors when categorizing the TMF of Africa for management purposes are their distance from a sea port that can facilitate export sales, and the strength of the local markets that can absorb the less valuable products. This latter factor is associated with population density; where these are high they are associated with correspondingly high pressure on the land surrounding the forest and, often, a demand to convert the forest land to other uses. A third basis of categorization is the forest itself, especially:

(1) its volume of species that are internationally marketable and hence of high value;

(2) the degree that the forest has been disturbed either by agriculture or by harvesting activities;

(3) its ecological status.

22. Catinot (1986) has pointed out the broad distinction between West Africa (e.g. Côte d'Ivoire, Ghana, Nigeria) and Central Africa (e.g. Congo, Zaire) in respect of access and population density. For the most part the West African forests have already been harvested, depleted or converted to agriculture. There are substantial areas of forests which have already been logged. Relative proximity to ports and strong local markets increase the possibilities of utilizing both the prime timbers and a wide range of secondary species. More efficient utilization can and should lead to more efficient management. On the other hand, the high population density (as high as 92 persons $km^{-2}$ in Nigeria, see Table 1), which increases local demand for wood and encourages better utilization, also leads to political pressures to destroy the forest ecosystem entirely and convert it to agriculture or other uses.

23. In most of Central Africa, in contrast, there are still large areas of forest not yet commercially exploited, populations are low (less than 5 $km^{-2}$ in e.g. Gabon, Congo) and distance to ports considerable. There is therefore little pressure for permanent deforestation. On the other hand, the reduced wood demand can lead to a highly selective type of harvesting, "creaming" of a very few exceptionally valuable trees per ha. Once certain species are depleted, it is very difficult and expensive to regenerate or reintroduce them.

24. Differences also occur within countries. Case Study 1 makes it clear that management of the lakeshore forests in Uganda, in areas where the population density is high, presents quite different problems and opportunities from that of the western Uganda forests, where human density is low but elephant density high. Table 2 summarizes the classification of African TMF by criteria of ecology, access and population density.

## 2.2 Physical, Biological, Ecological and Environmental Factors

25. The TMF of Africa are typically at low (or relatively low) altitudes. In West Africa these forests lie near the coast in the high rainfall belt below 500 m in altitude. They merge through the Congo basin with the eastern outliers in western Uganda where they occur at over 1,000 m.

26. The climate ranges from equatorial in character, with an annual total rainfall of over 1,500 mm, to that characteristic of the inter-tropical belt with one or two short dry seasons. In some years these cause soil water deficits sufficient to cause wilting in the understorey.

Table 2. A Broad Classification of Tropical Moist Forests in Africa

| Ecology / Access | Evergreen with low exploitable volumes | | Semi-deciduous with higher exploitable volumes | |
|---|---|---|---|---|
| Accessible, relatively close to a sea port | coastal forests of W. Africa | | inland forests of W. Africa | |
| | Population | | density | |
| | low | high | low | high |
| eg | Liberia | Nigeria | //// | Nigeria |
| Distant from ports and rather inaccessible | inland forests of Central Africa | | Uganda's forests | |
| | Population | | density | |
| | low | high | low | high |
| eg | Cen. Afr. Rep. Congo | //// | Western Uganda | Uganda Lakeshore forests |

27. The soils have a nutrient cycling potential that tends to vary with the extent of the dry seasons. Under the equatorial rainfall regime, downward movement of water through the soil profile is continuous and results in high potential leaching. Many of the soils are extremely nutrient poor - for example the Benin sands in Nigeria. Where the rainfall is interrupted, reddish, low base status, kaolinitic soils are common. Hall (1977) has shown some correlation between species distribution and soil parent material. Throughout these areas the soils tend to have a low base exchange capacity and to be heavily leached.

28. The soils of these African forests exhibit a narrower range of types than those of the Far East (Whitmore, 1975), lacking soil types derived from extensive areas of limestone and ultra basic rocks. Soils with saline or brackish ground water exist near the coasts and are colonized by mangroves. Fresh water and seasonal swamp forests are common along the slow-moving rivers and low-lying ground. Especially in those areas with a marked dry season, the distribution of many of the forest types and associations reflect relative topography and drainage patterns.

29. The main TMF types of tropical Africa are:

(1) evergreen rain forest;

(2) semi-deciduous forest;

(3) fresh water swamp forest;

(4) seasonal swamp forest;

(5) riparian forest;

(6) forest remnants in the derived savanna zone;

(7) moist montane forest.

30. The evergreen rain forest and the semi-deciduous forest are the two most extensive types. The physiognomy of these forests has been described in detail many times (Aubreville, 1938; Eggeling, 1947; Lanly, 1966; Longman & Janik, 1974; Hall, 1977). The features of greatest relevance to forest management are:

(1) the large number of species present per unit area;

(2) the layered and storeyed nature of the forest, each layer containing species whose height at maturity is limited as well as species typical of the layers above;

(3) the fine bole form of many of the stems in the highest layer of the canopy, including the emergents that may attain a total height of 50 m or more;

(4) the frequency of buttresses;

(5) the presence of strangling figs (Ficus spp.) and epiphytes;

(6) the abundance of herbaceous and woody climbers (lianes), especially in disturbed forest;

(7) the complex spatial patterns of species distributions that often resemble a mosaic of associations super-imposed over a coarser pattern derived from the topography and drainage.

31. The seasonal and permanent swamp forests are far less varied. Typically they have a more open and less marked layered structure, and a lower standing volume per hectare. Several species characteristic of the permanent, fresh water swamps have special adaptations to cope with the lack of aeration in the soil - for example the pneumatophores of Nauclea diderrichii.

32. The lower moist montane forest also has a slightly more simple structure. It is not as tall as the forest at lower elevations and lacks the prominent emergents that dominate that type.

33. In those regions with a marked dry season, the deciduous habit of the forest is apparent because the leaf fall of the different species tends to coincide. In the dry season the undecayed layer of litter is obvious, dry and crackles underfoot. A sparse flush of inflorescences of small herbaceous plants such as Haemanthus and various genera in the Acanthaceae and Primulaceae, for example, appear.

34. The ecology of these forests is still surprisingly little understood; this must in part be due to the pattern of variation which is so extensive in both time and space. Particularly in West Africa, where the recorded history of occupation is longer and the population density very much higher than in Central or East Africa, much of the forest is a patchwork following partial clearing for subsistence agriculture that includes the culture of fruit trees such as the cola nut. Hence the seral stages and, indeed, age of the forest are difficult to determine.

35. A different picture is presented in the forests around Lake Victoria in Uganda, where a relatively dense population was forced to move away during a sleeping sickness epidemic that occurred at the end of the 19th centry. Some of the forests on the islands in the lake appear young, even-aged and to date from this period.

36. Observations of the ecology of the TMF in Budongo, western Uganda, have been made since M.T. Dawe visited it in 1905. Throughout this century the climate has permitted the spread of the forest into the surrounding grasslands of Pennisetum purpureum that had established on abandoned fields, after the population had fled at the end of the 19th century, following slave raiding, epidemics of small pox and wars of succession in the Kingdom of Bunyoro. The pattern of succession around the rim of this large block of nearly 500 $km^2$ is more obvious than elsewhere.

37. Generalizing on the evidence from the derived savanna zone in West Africa and from the forests of Uganda, a common seral succession includes:

(1) fire susceptible grassland;

(2) fire resistent colonizing scrub;

(3) colonizing forest;

(4) mixed forest with emergents;

(5) stable associations dominated by shade tolerant species with heavy crowns.

However, this general pattern of succession is being constantly modified either by human interference, or by the death and collapse within the forest of one or more large trees, or through more extensive storm damage when winds exceed some 100 km per hour. Such a storm hit the northern shore of Lake Victoria around 1962 and destroyed many square kilometers of mixed forest. Such gaps are immediately colonized by clasmophytes and species characteristic of earlier seral stages, and these contribute to the overall mosaic of stages and species associations.

38. In areas where the forest is bordered by grassland, fires sweep towards the forest edge. In some areas herbaceous climbers root beneath woody shrubs and spread out over the grass heads to provide a fire resistent belt beyond the edge of the trees. Thus protected, woodland genera such as Acalypha, Alchornea, Acanthus, Maesa, Harungana, etc. grow tall and start off the forest succession.

39. Colonizing forest is characterized by tree species that exhibit many or all of the following characteristics:

(1) very shade intolerant and with rapid height growth in the sapling and adolescent stage;

(2) single stems with strong apical dominance and ephemeral side branches throughout the adolescent stage;

(3) large spreading mature crowns;

(4) effective seed dispersal mechanisms;

(5) wood of a low density which is straight grained and consequently easy to work.

Species exhibiting many of these characters are Triplochiton scleroxylon, Terminalia spp., Cordia spp., Albizia spp., Croton spp., Olea welwitschii, Maesopsis eminii, and at higher elevations Catha edulis.

40. Rather different are the much shorter lived clasmophytes that follow any temporary clearing in the forest. Notable tree species are Trema orientalis, Macaranga spp. and Musanga cecropioides.

41. The TMF of Africa exhibit a fully developed multi-storeyed structure and carry a high growing stock, partly because of the height and bole length of the emergents. Notable among these are many genera and species of the Meliaceae that yield high quality cabinet timbers similar to the West Indian and Central American mahoganies of the genus Swietenia. African genera include Khaya, Entandrophragma, Lovoa, Guarea, Carapa, etc. These forests exhibit the species richness, characteristic of continental TMF; commonly over 50 species may be found in the lower, middle and upper canopy layers of the forest within an area of 100 hectares, though many of the species will occur only infrequently.

42. In Uganda and the western Congo (for example the Ituri forest) the rain forest appears to be replaced by less species rich associations dominated by Cynometra, Celtis, Strychnos, etc. These species occur in relatively extensive consociations or in more mixed associations. They are characterized by the abundance of the established regeneration of the same species in the lower storeys.

43. The role and ecology of woody climbers, or lianes, in West Africa was studied by Jones (1950). One of the major differences between the forests of West and East Africa is in the influence and density of woody climbers in the organization and dynamics of the forest flora. In both regions they are a common, even universally present, constituent of the forest; large populations of their seedlings occur at ground level apparently waiting for sufficient light to start their ascent to the canopy top. In East Africa, although they can create climber towers on adolescent advance growth in gaps, they do not seem to prevent the re-development of the canopy; whereas in parts of West Africa they persist and severely impede the growth of younger trees. This difference in behaviour may be due to:

(1) the past history of interference and partial clearing in West Africa that has left the canopy very broken and already bound together by invading climber towers;

(2) a more vigorous invasion by clasmophytes in East Africa; these re-establish a dense canopy of small trees quite near the ground. This is progressively raised as the ephemerals are replaced by those living longer and of a greater stature.

44. Catinot (1986) has contrasted the African TMF with both the temperate forests and with the TMF of south-east Asia. Most temperate forests are comparatively simple both in structure and in species composition. In Europe selection and management over several centuries has further increased the uniformity of the forests, and the use of relatively few and well known species has contributed to the stability of their markets. Well tested methods of regeneration, e.g. retention of a number of seed bearers for restocking an area after the remainder of the mature crop has been felled, are recognized and accepted by the timber trade as an essential part of good forest management.

45. In south-east Asia the forests are even richer in species than the African moist forests, and the family Dipterocarpaceae is prominent. For many years, silvicultural and management systems have been devised, practised and revised in several countries in the region (FAO, 1988; in press). A similarity of wood properties in the Dipterocarpaceae has allowed volumes of 50-150 $m^3$ per ha to be removed at one time. With careful harvesting and silvicultural practices this has resulted in successful regeneration in some areas. In others, much forest destruction has resulted.

46. The TMF of Africa have a much lower stocking of valuable species. Although a few species, notably in the Meliaceae, have won a well-deserved reputation on world timber markets, they occur only sparsely and are greatly outnumbered by secondary species of limited local use or no known use other than fuelwood. The great variation in wood properties among the many species has made it difficult to group them into a few categories, each with fairly uniform properties and end uses, as has been done for the dipterocarps. Species were harvested and exported separately, and for the first half of this century very few were in demand. In Côte d'Ivoire *Khaya ivorensis* was the only species exported from about 1905 until the late nineteen twenties, while single species export applied also to Gabon (*Aucoumea klaineana*), Zaire and Congo (*Terminalia superba*) until the nineteen fifties. Because of the paucity of commercial species, the exploitable volume per ha has usually varied between 5 and 35 $m^3$ per ha (Catinot, 1986; Lowe, 1984). This low level of felling per ha resulted in only a modest opening in the canopy, insufficient for any significant increase in growth among the younger stems of the light-demanders which include most of the valuable species.

47. Although the contrast between the TMF of Africa and other forest types is generally valid, it should not be allowed to obscure the great variation which exists within those forests and which must affect the details of management in different areas. Not enough is known about either the autecology of species or the synecology of types for clear distinctions to be drawn between the many different associations. Two generalizations may, however, be made. First, the semi-deciduous forest tends to be somewhat richer in commercial timbers than the evergreen rain forests. An example of this is available from three forests in Côte d'Ivoire (Catinot, 1986). Irobo is evergreen forest; La Téné, about 200 km north-west of Irobo, is semi-deciduous forest; Mopri, about 50 km north-west of Irobo, is a transition (to savannah) type. From Table 3 it can be seen that, while the evergreen forest has a higher total of stems per ha and nearly as high a total basal area per ha as La Téné, in terms of preferred species it has less than half the basal area (and so less than half the volume) per ha contained in the semi-deciduous forest. Secondly, within a given area, climax forest tends to have fewer species than the later seral stages, from which it is thought to have developed, and the typical climax species are less valuable than the preceding seral species. In Budongo forest in Uganda, for example, the dominant species in the climax forest, Cynometra alexandri, is of little value compared with constituents of the mixed secondary forest such as the Meliaceae, Moraceae and Sapotaceae.

Table 3. Stocking in Three Forest Types in Côte d'Ivoire

| | Semi-deciduous Forest La Téné | | Evergreen Forest Irobo | | Transition Forest Mopri | |
|---|---|---|---|---|---|---|
| Species | No. of stems $ha^{-1}$ | Basal Area ($m^2$ $ha^{-1}$) | No. of stems $ha^{-1}$ | Basal Area ($m^2$ $ha^{-1}$) | No. of stems $ha^{-1}$ | Basal Area ($m^2$ $ha^{-1}$) |
| Preferred Species | 208 | 20,5 | 106 | 8,6 | 169 | 13,5 |
| Less Desirable Species | 186 | 7,4 | 347 | 15,9 | 192 | 9,1 |
| Total | 394 | 27,9 | 453 | 24,5 | 361 | 22,6 |

### 2.2.1 Non-Wood Resources and Constraints on Forest Management

48. The forest contains more than trees and produces more than wood. Local communities use forests in a myriad of ways, for medicine, food (from plants and animals), vines for construction and domestic use, tannin, etc. The most important benefits of the forest, other than wood and other products are the conservation of:

1) the flora and fauna (including genetic conservation);
2) soil;
3) water resources.

These benefits, and the production of wood, depend upon the integrated functioning of the forest ecosystem. Management modifies and directs this, but within certain limits, if the system is to continue functioning. Where the exact nature of these limits is not precisely known, it is necessary to experiment with constant and considerable care.

49. The forest flora produce edible fruits, medicinal products and other non-wood forest products which may be locally of great importance. Management for wood production should be planned so as to be complementary with the production of these other goods.

50. Faunal populations and their conservation are particularly important in Africa. The wildlife on the East African plains and savannahs is world renowned. But the forests of many of the countries listed in Table 1 contain important wildlife populations. These animals are important for conservation values, and also many of the more common species are important for nutritional value for the local people. Even in the densely populated areas where large mammals are very uncommon consumption of forest animals for food is important.

51. Conservation of the indigenous flora and fauna is now widely viewed as of critical importance. What is an adequate area to conserve a species or a range of species is less certain, and the requirements are clearly different for migratory animals or plant species, especially those with a sparse or discontinuous distribution. Tropical Forest Ecosystems (Unesco, 1978) records "We know that protected natural forests assist gene flow preservation, preserve representative ecosystems for research, maintain hydrologic flows and soil stability, provide opportunities for recreation and tourism, and safeguard scenic resources. Nevertheless, it still requires considerable basic and applied research before the true significance of each of these objectives can be measured". How different types of natural forest management systems quantitatively effect gene pools and natural populations is not known. It is known that techniques can be developed to manage genetic as well as other resources, and that forest areas not under productive utilization run the risk of being converted to other uses. Reserves with the primary purpose of conserving natural populations and genetic resources have been established throughout Africa (IUCN, 1987) and conservation is extremely important to the ecology and economy of the continent.

52. Soil conservation against erosion is a most obvious need in the montane forests where the altitudinal range is large and the slopes are often steep. Most in need of conservation are the volcanic soils such as on Mount Meru in Tanzania. These soils have a low water absorption capacity from surface wetting, lose their structure when dry and become powdery, and are extremely vulnerable and liable to gully erosion from intense rain after exposure and drying. However, this is an extreme example. Just as important are the kaolinitic soils whose low base exchange capacity and fragile structure make them prone to leaching under the equatorial rainfall regimes. Even in areas with some drier periods, such soils are liable to degrade if exposed and cleared of vegetation, through irreversible changes in the form of the iron hydroxides: these may be precipitated on drying out, cement the parent rock fragments in the soil and impede drainage.

53. Many of these tropical mixed forests lie on important water catchments. Particularly in the lowlands, population concentration in towns of over a million people places heavy demands on domestic and industrial water supplies. Consequently the role of the forest in maintaining even flows of high quality water is now, and is likely to become even more, vital.

## 2.3 Social Factors

### 2.3.1 Political Factors

54. In some of the African TMF areas, unified independent kingdoms had developed before any marked impact of European culture. In Uganda the Kingdoms of Buganda, Koki, Ankole and Bunyoro had a remembered history going back many generations, whereas kingdoms in West Africa, such as the Yoruba, Beni and Ashanti, for example, were much older.

55. Many of these people also had a common heritage in the use of dugout or sewn canoes as a means of transport on the inland rivers and lakes and coastal waterways. At first trade was the dominant activity, with palm oil, wood, minerals and later cash crops such as cocoa in West Africa and coffee, cotton and tea in East Africa, becoming increasingly important following the establishment of colonial regimes. Investments, particularly in the railways and in industry, gathered momentum at the very end of the 19th century and during the first decade of the 20th century. Liberia had a different history, the modern state originating from the return migration of slaves to Africa from America, commencing in 1821.

56. Most African TMF countries gained independence in the late 1950s or early 1960s. Since then, the political panorama includes great progress in economic development and education in many countries and tragic violence and instability in others. The extremely complex political situation is outside the scope of this study. However, increasing populations universally exert greatly increasing demands on forest products and benefits of all kinds.

### 2.3.2 Legal Factors

57. Forest policy and forest law in colonial Africa were based on experience from continental Europe. In francophone Africa it was derived directly from France or Belgium and the long experience of temperate forestry in those countries.

58. In British colonies, the early administrators followed the pattern of reservation of forest lands adopted in India under the influence of several distinguished German foresters who served in that country during the nineteenth century. The foresters of the day were mainly concerned to establish within a legal framework what was termed a "permanent forest estate" whose boundaries and use could only be amended by the highest authority in the land. The roots of this strategy can be traced back to feudal Europe. Forest policies based on these concepts were declared by Governments, Forest Ordinances were passed by the Legislatures, and Forest Regulations or Rules were adopted.

59. Typical examples of forest policy statements and of the laws which reflected them in British colonial Africa are those of Uganda and Nigeria referred to in Case Studies 1 and 2.

60. In these policy statements there is a common preoccupation with three vital factors, namely:

(1) needs of the population and of posterity;

(2) allocation of land for agriculture;

(3) the environmental benefits of maintaining forest cover.

What was lacking is any acknowledgement of the rate of change in the environment of management and any attempt to integrate forest policy with the policies of other sectors such as agriculture, urban development, etc. This weakness is recognized clearly by both Karani (1985) and Kio (1985).

61. None of the policy statements that have been reviewed faced up in a realistic way to the interactions of population increases, urbanization, and varied demands for production from the limited land resource.

62. In francophone Africa foresters were similarly concerned to control and reduce the rate of destruction of the forest by man and to conserve sufficient forest land to supply the needs of posterity (Catinot, 1986). Thus the first Inter-African Forestry Conference at Abidjan in 1951 emphasized the imperative need to constitute and preserve a permanent forest estate ("Domaine classé"), which would be totally protected against forest clearance but in which certain traditional users' rights were allowed under strict control. Harvesting of timber species under licence was permissible but clearing for agriculture was forbidden.

63. Formulation of successful and effective forest policy and legislation is a complex matter. As a minimum, they should:

(1) Ensure that both the total size and distribution of the forest estate is adequate for the needs of the country;

(2) ensure that the law is enforceable;

(3) ensure that the local population generally approves of maintaining the land under forest;

(4) define relative priority of domestic and export production and processing;

(5) take account of possible changes in demands and conditions far into the future.

64. Although the size of the permanent forest estate was rarely as big as the foresters would have wished, it still covered a substantial part of the land surface in many countries. In Nigeria the aim at one time was 25%, but in practice the final achievement was 10% (Lowe, 1984). On the whole distribution was reasonably good, with adequate

emphasis on reservation of conservation forests on watersheds and steep slopes. Enforcement of the law has varied greatly according to the population density and pressure for land, the attitude of the government, the strength of forest staff and the accessibility of the forests. In some areas, regular cutting of boundary lines and maintenance of boundary beacons, frequent patrolling and rigorous prosecution of forest offenders had the effect of maintaining the reserves under forest cover. Sometimes plantations were established close within the forest boundaries as an indication that the forests were being actively managed. In many areas the ability to maintain forest reserves under forest cover has been minimal. Catinot (1986) has noted that Côte d'Ivoire has lost about 85% of its moist forests and that all the reserved forest estate is threatened.

65. The aspect most neglected by colonial governments was the winning of local support for reservation. A forest reserve, an undoubted asset to the nation and to posterity, was perceived at the local level as a liability and a nuisance. It has to be stressed that the reservation of forest land was most unpopular with local inhabitants who treated the uniformed cadre of foresters with dislike and often overt enmity. As a result, on gaining Independance some gazetted forest lands were immediately handed over to farmers. With hindsight, Philip (1986b) sees the establishment of a protected forest estate as justified; it is also clear that much too little was done to gain the confidence of the elders and the understanding of the young. The accounts of the early history of forestry in the montane areas in Kenya clearly show the urgency of protecting them from fire. Draconian measures were essential but with the inevitable result of promoting opposition from the people living near the forest who perceived no problem. In contrast the recent, more acutely "felt" problems of firewood supply to urban centres, or to rural communities in semi-arid areas almost bare of trees, are more amenable to solution with local agreement and participation.

### 2.3.3 National Needs

66. Until the energy crisis early in the 1970s few, including foresters, fully appreciated the enormous consumption of wood for fuel in Africa, and most expected its relatively rapid replacement by oil and gas in the more arid parts. This view has now changed dramatically.

67. Study after study of fuel consumption concludes that a figure of around 1 $m^3$ of wood is used per person per year - less in areas where trees are scarce and more in well forested parts. This demand for domestic wood now dominates national predictions of consumption.

68. Previously predictions had concentrated on the more elaborately processed demands, namely for:

(1) sawn wood;

(2) veneers & plywood;

(3) particle board and other panel products;

(4) pulp wood and paper.

In most of the coastal countries developments in wood processing have followed similar patterns, and interior countries have exported fewer logs and processed products.

69. The common pattern has been from simple hand hewing and adzing for dugout canoes and squares, to pit sawn planks and simple belt driven circular saw mills powered by steam. Later, after the second World War, the mills introduced band saws and electric power units. Most countries in West Africa maintained a strong export trade in round logs up to the late 1960s and some continue this trade today.

70. These later investments in sawmilling have been complemented by a degree of vertical integration into building, plywood and veneer production, parquet flooring mills, door and furniture shops and, in East Africa, the production of tea chests for shipping this important export crop. These investments have been fostered by governments as:

(1) a means of substituting imports and saving foreign currency;

(2) a means of earning foreign currency, especially by adding value to a previously exported raw product;

(3) a vehicle to promote development and raise national incomes through industrialization.

Most countries have experienced considerable difficulty, during recent times, in servicing the capital, maintaining the level of investment, ensuring the effectiveness of the industries through an adequate provision of spares, and adopting modern technology.

71. Neil (1981) suggests that the development of tropical forest management in Africa is unique because of the strong interaction with the supply of food for its relatively large population that lives both alongside the forest and in the neighbouring savanna areas. In East Africa, endowed with magnificent wild life resources which are the base of a strong tourist industry, there is some competition between production forestry, tourism and recreation.

### 2.3.4 Local Needs

72. The important local needs are for:

(1) land on which to grow food and cash crops;

(2) fuelwood and roundwood for building and sawn timber;

(3) other traditional products of the forest such as food (from plants and animals), medicines, vines, barks and other products;

(4) elements with a value derived from local culture.

Karani (1985) attributes the failure of forest policies in Uganda to meet the needs of the nation to the lack of effective land planning. Unfortunately, countries in Africa share a common factor that greatly complicates effective land allocation; this is the rapid rate of increase in their populations. Table 1 (paragraph 20) shows the considerable variation in population density between the countries. In high population density countries people will clear land unsuited to permanent agriculture because they have no alternative. Local people often see the land not as a source of a sustained supply of wood products for posterity, but as a reservoir of land for growing food or cash crops.

73. Land management to maximize the production of food, wood, and other products, while conserving the natural resource base, is an urgent need. However, no scientific land use planning has been or can be implemented without the approval of the rural people. This requires the harmonious development of agrisilvicultural techniques for some areas, and comprehensive extension programmes which stress two way communication between land users and land use planners. Building up such institutional strength takes political committment, time and substantial funds. Ultimately, there is no solution which does not include an element of family planning, and effective models adapted to African conditions must be found.

### 2.3.5 Interactions with Agriculture

74. Much of the subsistence agriculture practised in the wetter areas of Uganda at the turn of the century was a form of agri-silviculture (Karani, 1985). The scale of farms was small and many of the indigenous tree species were protected or even cultivated along with food crops. The same was true in West Africa. Fruit trees, palm oil trees, bark cloth figs etc. were raised deliberately and, as well, the forest provided food (snails, bush meat, fruits) and many other products such as fibres, medicines, fuel and shelter.

75. The introduction of some, but not all, of the cash crops such as cocoa, coffee and to a degree, tea strengthened the ties between arboriculture and agriculture by the use of trees to shade the lower storey. This practice contrasts dramatically with the crudest forms of slash and burn and bush fallow commonly practised for cereal production in the forest, savanna and miombo areas of both East and West Africa.

76. Urbanization had a strong influence on agriculture and this also affected forestry, albeit indirectly. Towns depended upon food surpluses grown in the rural areas as a cash crop. The massive explosion of urban areas, particularly in West Africa after the Second World War, caused a demand for food that was met by a revolution in the scale of agriculture, although the methods remained conservative. Where the urbanization took place within the TMF zone, the transferred pressure on the forest resulted in wholesale destruction, especially along the roads and other lines of access. At the same time the access roads created by the sawmillers opened up previously inaccessible areas to settlement and agriculture. In many regions large areas of forest have been completely cleared for extensive and, possibly, short term unsustainable production of maize and dryland rice.

77. The traditional system of agriculture in many of the countries in Africa involves the clearing of small areas of forest or woodland and burning the debris. The area cleared is farmed for a few years, the duration depending upon the soil fertility, climate and build up of weeds, and then abandoned. The abandoned farm land is then recolonized by woody vegetation. The development varies greatly with the type of vegetation, but invasion by pioneer species, colonization by shrubs and climbers and regrowth from coppice and suckers may all play a part in the re-establishment of the forest fallow. Many years later the cycle may be repeated.

78. Agronomists and soil scientists have maintained that this system has proved to be well adapted to the environmental conditions of much of tropical Africa, provided that the population density does not exceed a critical value, so that the fallow period is sufficiently long to restore completely the nutrient store in the biomass and soil (Nye and Greenland, 1980). However, populations denser than this threshhold value result in shorter fallow periods and a drop in the production potential (Kio, 1980). Shifting agriculture has felled large areas of mature TMF in this century. The area of bush fallow in the moist forest zone of the 13 countries, shown in Table 1, is given as 480,000 km² (FAO/UNEP, 1981) compared with 1.87 million km² of remaining forest. UNEP (1980) estimated that an additional 4,000 km² of forest is felled for shifting agriculture every year.

## 2.4 Economic Factors

### 2.4.1 Trade in Wood Products

79. East Africa's trade in wood products is of little significance in the global scene. It is an importer of most of the more sophisticated processed wood products, but this has little impact on the management of the mixed tropical forest; neither are exports more than of marginal significance either to the countries of origin or to the recipients. Since the early 1960s, Kenya has established 150,000 ha of plantations of exotic softwoods in areas of montane forest, while Uganda has concentrated its forest activities on the natural regeneration of its hardwoods, except for relatively small areas of softwood plantations established in the West - mainly in grasslands (Logan, 1962).

80. In contrast, all the countries along the coast of West Africa have been involved in the trade in high quality tropical hardwoods since before the turn of the century. Originally, shipments were restricted to the cabinet woods *Entandraphragma cylindricum*, *E. utile*, *Khaya ivorensis*, *Chlorophora excelsa*, etc., but the list grew after the Second World War and included, especially, relatively low density white woods such as *Triplochiton scleroxylon* the *Terminalias* and *Nauclea diderrichii* which were found to be suitable for furniture and plywood manufacture.

81. Originally most of the exports were in the form of logs, but both Ghana and Nigeria have banned the exports of logs since the mid 1970s. However, although Liberia has made the establishment of wood based industries a strict condition prior to the granting of new timber concessions, export of logs is still a very important element in trade in that country. Similarly, log exports from Côte d'Ivoire, Congo, Cameroon and Gabon, in 1984, were still at least two thirds of the level they had been a decade before (FAO, 1986). More recently Nigeria has imposed restrictions on the export of processed timber in order to conserve the supplies.

82. Now Nigeria and, probably, Ghana are net importers of wood based products. Table 4 gives the import values of veneers, plywood and particle board for the years 1963-80 for Nigeria, and these data show the steep rise in imports in the late 1970s. Nigeria imports 90% of its paper products (Baykal, 1979).

Table 4. Import Values (Naira) of Veneer, Plywood & Particle Board for the Years 1963 to 1980. Source Nigerian Trade Summary, Federal Office of Statistics

| Year | Veneers | Plywood | Particle Board |
|---|---|---|---|
| 1963 | 88,972 | 621,484 | 120,648 |
| 1964 | 58,672 | 468,670 | 191,363 |
| 1965 | 30,330 | 276,910 | 279,412 |
| 1966 | 15,030 | 55,458 | 244,372 |
| 1967 | 15,414 | 114,958 | 189,346 |
| 1968 | 16,576 | 6,530 | 13,392 |
| 1969 | 30,050 | 17,660 | 27,300 |
| 1970 | 85,742 | 36,396 | 129,820 |
| 1971 | 94,564 | 13,396 | 44,116 |
| 1972 | 10,460 | 49,252 | 91,170 |
| 1973 | 62,121 | 119,111 | 84,147 |
| 1974 | 81,926 | 41,086 | 301,533 |
| 1975 | 161,812 | 1,245,885 | 347,378 |
| 1976 | 333,360 | 7,382,870 | 1,096,386 |
| 1977 | 513,509 | 13,519,584 | 1,845,394 |
| 1978 | 855,375 | 11,775,579 | 1,080,693 |
| 1979 | 426,410 | 5,878,675 | |
| 1980 | 1,685,783 | 11,763,593 | |

### 2.4.2 Capital and Recurrent Budgets

83. Mention is made in the early Uganda policy statement of the rate of return on the capital invested. This is rarely repeated in such statements for other countries and may reflect an early influence of W.E. Hiley who, later (1950) advocated a financially autonomous Forestry Board for Kenya. The rule has been for forestry to be an integral part of the state finances. In colonial times these were part of annual budgets in which capital and recurrent expenditures were rarely distinguishable.

84. Now when the finances of these countries are complemented by funds from bilateral and multilateral sources, allocations are more specific and a distinction is made between capital investments and recurrent expenditures. Kio et al. (1985) state "Budget allocation to forestry in the English speaking West African states is always paltry. This stems from the unfortunate grouping of forestry under the broad category of agriculture. Within agriculture, forestry often ranks a poor third after food crops and livestock. Sometimes it is beaten into the fourth position by the fisheries sub-sector". Again "Perhaps the most important set-back to forestry development is the method of release of allocated funds. Funds in most countries are released piecemeal and usually after they are needed for critical operations such as site preparation, planting or weeding. These operations are time specific and cannot be postponed without serious distortions of planned programmes. The consequences of late fund release, for example, have been:

(1) large tracts of land are cleared, laid bare and remain unplanted for long periods;

(2) large stocks of seedlings are annually left unplanted because there are no funds for site preparation;

(3) young plantations are not weeded, thus creating a fire hazard;

(4) natural forests are left unmanaged and unprotected creating opportunities for illegal felling".

Obviously, the budget allocated for forestry is part of the total available to the state. There is no easy escape from the constraint of supply of capital. Although international investment funds may be available for forestry, project appraisals must demonstrate clearly a net benefit from investment and be ranked by their importance within the integrated national development plan. They cannot be viewed independently.

85. Forest planners and managers must be aware of movements in costs and prices. Baykal (1979) concludes that the results of investment in forestry for wood-based industrial development are more sensitive to changes in product prices than to changes in costs. However, this may well be more a characteristic of the simulation model than of reality.

# CHAPTER III

## 3. RECENT DEVELOPMENTS IN THE PRINCIPAL COMPONENTS OF FOREST MANAGEMENT

### 3.1 Policy

86. In recent years some governments have come to realize that forests are not simply a legacy from nature, to be squandered at will, but a resource for the future which can only be developed by investment now. In countries such as Kenya and Tanzania where the forest services had long been considered as primarily, or solely, revenue earners for the Treasury, there was a swing towards investing in foresty, so that those services became net spenders on a considerable scale. This trend was encouraged by the new possibilities of external financial aid which came with independence. However, most of this investment has been in plantations, sometimes planted on montane grasslands (Sao Hill, Tanzania) or in savanna woodland (Congo) at some distance from the TMF; elsewhere massive conversion of TMF to plantations is planned, as in Nigeria. There has been little increased investment in the management of natural TMF as such. Moreover there are still too many countries in which politicians and administrators continue to regard the forests as a source of timber to earn revenue and land for agriculture, rather than as a renewable resource which demands dynamic management.

87. Catinot (1986), while drawing attention to the urgency of the threat to the survival of TMF in an increasing number of countries, lists several factors which give some grounds for hope. Hitherto they have been appreciated most by foresters and ecologists, but there is a gradual trend towards realization by top government administrators. Some of the main positive trends are summarized below.

(1) Forest which is seen to be under active management is less likely to be subject to clearance for agriculture. While forest management can only be practised if the forest is conserved, it can in itself promote conservation.

(2) Worldwide concern about environmental dangers, such as the loss of TMF, increasing desertification and increasing risks of famine in Africa, already exerts a considerable influence on governments and sometimes provides financial help.

(3) Loggers and millers now realize that their long-term livelihood depends on the renewal of the forest resource, which is only possible through forest management. Similarly, government economists realize that continuing revenue from the forest resource depends on its renewal.

(4) Agricultural research offers the possibility of a more stable system of agriculture, combining trees, food crops and livestock in an agro-sylvo-pastoral systems which should maintain soil fertility as well as providing a satisfactory yield of mixed produce. Promising species of

nitrogen-fixing trees could be introduced into these systems, as well as being used in bush fallows to induce a more rapid restoration of fertility.

(5) The assignment, at least in part, of the revenue and other benefits of the forest to the neighbouring rural communities would encourage them to protect it effectively. Planning should first and foremost consider the needs of communities living near the forest for the good of both.

(6) Species and provenance research can identify those best adapted to local conditions, which could then be planted by private persons in local communities.

(7) Soil survey and soil mapping of agricultural land could lead to more rational land use, based on soil potential; again with effective programmes to generate approval and support from local communities.

## 3.2 Forest Inventory

88. The techniques for the inventory of the TMF have probably shown more progress in the past 30-40 years than those for any other component of management. Catinot (1986) has outlined some of the steps taken in francophone Africa during this period.

(1) In an initial period, inventory was confined to harvesting coupes of limited area. 100% enumeration was carried out of all stems to be exploited, i.e. of very few commercial species above the current minimum exploitable girth limit.

(2) From 1945, use was made of aerial photographs, first in Gabon, then in Congo, Central African Republic and Côte d'Ivoire. They were used both for determining and mapping the boundaries of forest blocks and also for identifying forest areas rich in species easily recognizable by their distinctive crowns, e.g. Aucoumea klaineana, Triplochiton scleroxylon, Terminalia superba.

(3) 100% enumeration of all species and size classes was first carried out in silvicultural plots in Gabon in 1947.

(4) Forest enumeration by low percentage systematic sampling was first carried out in Gabon and Central African Republic in 1947-1949. It sampled the 8-10 species then saleable at a sampling percentage of 10%.

(5) The first low percentage randomized sampling, with possibilities of calculating sampling error and confidence limits for the enumeration figures, was carried out over 100,000 ha in Gabon in 1962, and over 460,000 ha in Central African Republic in 1963. It applied to commercial species expected to reach exploitable size within the next 10 years and was intended to provide guidance to the authorities on the issue of felling licences in the areas.

89. Since 1962 inventories have been carried out over a very large area of francophone countries (total over 400,000 km²), as shown in the attached table (Table 5).

Table 5. Forest Inventories in Six Francophone African Countries

| Country | Area of Inventory ha | Observations |
| --- | --- | --- |
| Cameroon | 9,950,000 | 9/10 sample (two stages)<br>100,000 ha for paper production |
| Central African Republic | 1,550,000 | complete sample (one stage) |
| Congo | 3,500,000 | 1/2 sample (two stages)<br>1/2 sample (one stage) |
| Côte d'Ivoire | 15,000,000 | 3/4 sample (two stages)<br>100,000 ha for paper production |
| Gabon | 6,100,000 | 3/4 sample (two stages)<br>100,000 ha for paper production |
| Zaire | 5,500,000 | apparently one stage sampling |
| Total | 41,600,000 | about 3/4 sampled at two stages<br>300,000 ha for paper production |

Source: OAB (Organisation Africaine des Bois).

Catinot (1986) has pointed out that more than 50% of these inventories date back to over 15 years ago. The results, reliable at the time of inventory, will have become partially outdated because of natural increment and, to a still greater degree, by the intervening operations of harvesting and clearance for agriculture.

90. Forest inventory in anglophone countries developed along similar lines. Early experiments in Uganda (Dawkins, 1952) led to the development of inexpensive methods of low percentage enumeration, using a stratified random sample of transects. Such methods were extended from closed forest to open woodland, for example in Tanzania where percentage sampling was adapted to three different levels of stocking by adjusting the size or spacing of the sampled plots (Parry, 1966). Aerial photography as an aid to inventory was first used in Nigeria in 1948. The most extensive inventory in TMF in that country, carried out in 1973-77, covered 13,300 km² of reserved forests.

91. There is now a great deal of agreement on the various types of inventory needed to fulfil the aims of forest management, each supplying information of different kinds or at different levels of precision (Catinot, 1986; Philip, 1986b). Detailed consideration of inventory techniques is available in FAO (1981a). The main stages are described below.

(1) National forest resource surveys require individualized design depending on what information is required for forest policy formulation or revision at the national or provincial level.

Remote sensing techniques can be of great assistance at this stage. Imagery capable of resolving objects of 10-40 m in diameter provides excellent means of stratifying the forest by forest types, and is also an aid to topographical mapping which is often a time-consuming part of forest surveys. The theory of "general variables" and "regional variables" also offers a possibility of increasing the statistical efficiency of inventories, but has not yet gone beyond the stage of experimental simulation (Catinot, 1986).

(2) Determination of harvestable quantities of timber on forest blocks of 2,500 to about 20,000 ha, of sufficient precision to decide the terms for granting long-term, exclusive harvesting licences. A sampling level of 5-6% is usually sufficient for management decisions, i.e. estimates for two or three groups of species within ± 15% of the true figure. A higher sampling level of about 10% is considered necessary to provide concessionaires with sufficiently precise information on available volumes for them to dispense with the 100% enumeration described under (3) below. A recommended method of carrying out this type of inventory is shown in Appendix 1.

(3) Inventory carried out by a concessionaire at the level of the annual coupe, in order to plan his harvesting operations, usually 100% of commercial species of harvestable size.

(4) Diagnostic sampling, done by means of a systematic sample of parallel equidistant transects 500-1,000 m apart, and at a sampling level of 2-4%; this should give a sampling error not exceeding 15-20% for "desirables" including 15-20 species. The purpose is to determine the stocking and silvicultural condition of young stems of desirable species below the exploitable girth limit. This may be done at any time before or after the main felling, but is usually carried out soon after felling so that only the advance growth which survives the felling undamaged is considered.

92. One major problem, especially for the harvester, is to convert numbers of stems and diameter classes into saleable volume. Conversion to gross stem volume sometimes involves the problem of buttresses, but this is minor compared to converting gross volume to net saleable volume, and good modern textbooks are available (FAO, 1980; Philip, 1983). Factors which reduce the gross stem volume on an area to a considerably lower net saleable volume include local difficulties of topography and access, defect, and fluctuations in local markets. Since 1969 CTFT has developed a method of estimating appropriate conversion factors from gross volume to net saleable

volume. This was based on qualitative estimates, made at the time of the inventory, on the proportion of gross volume in each of several "saleability classes"; these were later checked against the volume actually found saleable by the harvester, and adjusted as necessary. Similarly, in the Indicative High Forest Inventory (I.H.F.I.) in Nigeria, volume estimates were analyzed into six species groups, based on timber characteristics and quality, and five grades of log quality (Kio et al., 1985). One difficulty is that, even in a single area, the conversion factor changes in accordance with the changing state of the market. The conversion of stocking or basal area into net saleable volume remains one of the more intractable problems in inventory.

93. The above provides information on the static condition of the forest. There is also general agreement that this must be supplemented by information on forest dynamics, by recurrent measurements of increment on the same clearly identifiable trees. In Nigeria at least 50 permanent sample plots are to be established in the TMF. These "continuous inventory plots" should be truly representative of the rest of the forest and must not therefore be given any special treatment. Soil samples will be taken from each plot and analyzed to monitor soil changes under current management, whether as managed TMF or after conversion to plantations (Kio et al., 1985).

## 3.3 Silviculture

94. In contrast to the steady progress and general consensus in the field of inventory, silviculture of TMF over the last half century has been a thing of fits and starts. Practices have varied greatly from country to country and even within countries, and opinions have often oscillated within a decade between the relative advantages of natural and artificial regeneration, or of monocyclic and polycyclic felling systems. The complexity of the forest, its diversity in both place and time, an ignorance of the silvicultural requirements of individual species and a preponderance of harvesting over silvicultural considerations have all contributed to this situation.

95. Catinot (1986) has outlined the history of TMF silviculture in francophone Africa. The complexity of the natural ecosystem, the paucity of seed-bearers of desirable species, most of which were removed in commercial harvesting, and the lack of valuable regeneration which was presumed to result led foresters to concentrate early efforts on artificial regeneration. In the first instance felling concessionaires were obliged to plant 3 to 10 plants of the same species for every one which they had felled. This was soon abandoned as a failure; no proven planting technique had been developed and control of operations scattered sparsely over thousands of hectares was impossible.

96. Forest Services then started to make their own compensatory plantations or enrichment plantings on an experimental scale, in Côte d'Ivoire from 1930, in Cameroon and Gabon from 1935 and in Zaire from 1935. Eventually substantial areas were planted, for example

13,000 ha in Côte d'Ivoire between 1932 and 1950, 500 to 3,000 ha a year of Aucoumea in Gabon, 500 ha a year of Terminalia superba in Congo, 10,000 ha in Zaire by 1950. At the same time attempts to manage the natural forests concentrated on improvement thinnings in immature stands e.g. the methods of "Uniformisation par le haut", "Normalisation" and "Amélioration des peuplements d'okoumé".

97. After the Second World War, there was a swing towards natural regeneration. Some of the enrichment plantings by the "Méthode des layons" had given disappointing results because the amount of light, reaching the young plants through a barely disturbed canopy, was inadequate to maintain acceptable growth rates; an early misconception that all TMF species were strong or at least partial shade demanders had led to this technique which amounted almost to underplanting. At the same time concern had been aroused at what was thought to be the excessive cost of close planting after clearing TMF, and early reports on natural regeneration obtained by the Tropical Shelterwood System in Nigeria were enthusiastic.

98. Natural regeneration techniques prevailed in the decade 1950-1960, especially in Côte d'Ivoire and (from 1947) in parts of Cameroon. But, by 1960, results from natural regeneration had been judged as generally disappointing and the pendulum swung back to plantations.

99. Between 1960 and 1980 artificial regeneration was virtually the only method of regeneration practised in francophone TMF countries. Planting techniques were characterized by a progressive increase in the intensity of canopy removal, and culminated in the system of complete forest clearing and replanting now practised by SODEFOR in Côte d'Ivoire. At the same time, mechanized methods of clearing and tending gradually replaced manual methods. During the same period, the use of fast-growing species such as pines and eucalypts for pulp production was introduced, first on an experiemental and then on an industrial scale, e.g. on savanna sites at Pte. Noire, Congo. The main timber species planted were: teak and Cedrela (Côte d'Ivoire), Aucoumea (Gabon and Cameroon), Terminalia ivorensis (Cameroon and Côte d'Ivoire), T. superba (Congo and Côte d'Ivoire) and Triplochiton (Côte d'Ivoire).

100. Since 1977, large scale research on the effects of deadening non-commercial species with arboricide in previously harvested forest has been carried out in Côte d'Ivoire. This research is described in Case Study No. 3. Early results are most promising and have once again stimulated interest in the possibilities of natural regeneration as the basis of a TMF management system, with particular reference to forest cut over some years previously. Catinot (1986) has observed that, with the newer techniques of a much more radical opening of the canopy by felling or deadening, some of the older methods of enrichment planting (Yangambi "Méthode de placeaux" or gap planting, planting in wide cleared strips), which failed before because of inadequate light, might be reintroduced with success.

101. Some of the older plantations are now 35 to 50 years old and provide evidence of the yields to be expected. Tables 6 and 7 give some representative figures from different sites. It can be concluded that with the best African timber species on good sites, a mean annual increment of 8 $m^3$ $ha^{-1}$ $yr^{-1}$ may be expected at age 30-45 years. However, the high establishment cost of US$ 1,000-2,000 per ha renders the profitability of the system arguable, especially if thinnings are unsaleable. It compares with a cost of US$ 200-250 per ha for deadening/improvement of natural forest which appears to produce a mean annual increment of 3-3.5 $m^3$ $ha^{-1}$ $yr^{-1}$ in the years immediately after treatment. However, it remains to be seen whether that increment can be sustained over the 30-40 years which correspond to the rotation in a plantation, without the need for one or more additional treatments.

Table 6. Yields for African Species in Plantation

| Species<br>Parameters | *Aucoumea klaineana* | *Nauclea diderichii* | *Terminalia ivorensis* | *T. superba* |
|---|---|---|---|---|
| Final Density/ha | 120 | 80 | 70 | 75 |
| Age (yrs) | 44 | 48 | 34 | 36 |
| Basal Area ($m^2$) | 34 | 22.5 | 20 | 21 |
| Stem Volume ($m^3$ $ha^{-1}$) | 350 | 270 | 250 | 260 |
| Productivity ($m^3$ $ha^{-1}$ $yr^{-1}$) | 8 | 5.8 | 7.5 | 7.5 |

102. The estimated areas of plantations planted in francophone countries are shown in Table 8. Even if all the plantations are not fully stocked, they still represent a substantial asset.

103. Philip (1986a) has indicated equally diverse and changing attitudes within anglophone countries to the relative merits of natural and artificial regeneration. The first recorded elements of silviculture in TMF were concerned with artificial regeneration by planting. In Nigeria, in 1906, new timber rules were drawn up by which licence holders had the option of either planting a certain number of plants, to replace those that had been felled, or tending the natural regeneration by weeding, thinning and cleaning. This attempt to involve loggers with silviculture was a failure, just as in francophone Africa. Karani (1985) records that as early as 1916 attempts were being made to regenerate the *Podocarpus latifolius* forest on the shores of Lake Victoria in Uganda by planting seedlings. Similarly, perhaps the most famous research plots in anglophone West Africa - the Kennedy plots at Sapoba - were in part artificially established. Further details of plantings in Uganda and Nigeria will be found in Case Studies 1 and 2.

Table 7. Management Schedules for Terminalia superba and Aucoumea klaineana

| | | SPECIES | |
|---|---|---|---|
| | | T. superba | A. klaineana |
| Planting Density (stems $ha^{-1}$) | | 625 to 950 | 950 |
| Spacing (m x m) | | 4 x 4 and 3.5 x3 | 4 x 3 to 3.5 x 3 |
| Cleaning | Age | 3 to 4 yrs | 4 to 5 yrs |
| | Stems $ha^{-1}$ | 310 | 350 |
| | Average diameter | 10 cm | 7 cm |
| Thinnings | | | |
| 1st | Age | 7 to 8 yrs | 8 to 10 yrs |
| | Stems $ha^{-1}$ | 220 | 200 |
| | Average diameter | 17 cm | 15 cm |
| 2nd | Age | 12 yrs | 15 to 17 yrs |
| | Stems $ha^{-1}$ | 150 | 150 |
| | Average diameter | 25 cm | 26 cm |
| 3rd | Age | 17 yrs | -- |
| | Stems $ha^{-1}$ | 85 | -- |
| | Average diameter | 32 cm | -- |
| Final harvest | Age | 35-45 yrs | 40-50 yrs |
| | Stems $ha^{-1}$ | 70 | 100 |
| | Average diameter | 60 cm | 60 cm |
| Basal area $m^2$ $ha^{-1}$ | | 20 | 28 |
| Stem volume harvested $m^3$ $ha^{-1}$ | | 220 | 300 |

Table 8. Estimated Plantation Areas in Six African Francophone Countries

| Purpose / Country | Timber (ha) | Cellulose, Panel Board, etc. (ha) |
|---|---|---|
| Cameroon | 5,000 | 500 |
| Congo | 15,000 | 12,000 |
| Côte d'Ivoire | 50,000 | 500 |
| Gabon | 26,500 | 1,000 |
| Central Afr. Rep. | 500 | -- |
| Zaire | 10,000 | -- |

104. Perhaps regrettably, but certainly inevitably, natural forest silviculture was at the mercy of current harvesting techniques and, therefore, of current markets. When harvesting was very selective, natural regeneration appeared sparse and was certainly slow growing. Attempts were therefore made to improve the stocking of young desirable species by some form of enrichment planting e.g. in the South Mengo forests of Uganda by line-group plantings of two year old striplings of Khaya and Entandrophragma spp. (groups of 3-5 plants at spacings of 9 x 45 m). Later experience, as in francophone Africa, indicated that most of the early plantings received far too little light from the low intensity selective fellings and that much more severe disruption of the forest canopy was needed to promote growth rates, whether of natural advance growth or of planted seedlings.

105. Karani (1985) reported that in Uganda until 1950 little attention had been paid to natural regeneration. "During the 1950s it was found out that, generally, the natural forests of Uganda regenerate fairly well, but the natural regeneration meets a lot of competition from the standing trees which are never felled by the saw millers - the so-called undesirable species. The majority of the original stand was left and this shaded the forest floor and prevented the establishment of the seedlings and their development into a pole crop. They were suppressed from the very moment that they germinated".

106. It was observed and confirmed by experiment that when the forest canopy was open so that light reached the forest floor, the rapid growth of seedlings of both trees and climbers alike was stimulated. After five to ten years the climbers, many of which in Uganda are herbaceous and short lived, decline and the tree species are able to grow on. Dawkins (1953) at first suggested that gradual opening of the canopy was the best method of encouraging natural regeneration. Later this opinion was revised in favour of a more sudden and vigorous break-up of the canopy. These observations coincided with successful trials of inexpensive techniques using arboricides instead of felling to remove so-called "weed trees". This helped to change the method of renewing the crops in the mixed forests of Uganda from artificial to natural regeneration.

107. During the late 1960s and 1970s, the demand for charcoal enabled the Forest Department in Uganda to reduce and finally eliminate arboricide treatments. Previously much of the charcoal burning had been done on public and private lands outside the forest reserves. However, these sources became depleted and the Department was successful in attracting operators into some of the forest reserves to utilize the wood left after felling operations. In this way the removal of the canopy was achieved both more effectively and more economically in terms of both wood resources and cash while supplying a very useful product for local consumption and commerce. Some enrichment planting with both indigenous and exotic tropical hardwoods has been done in areas cleared for the charcoal kilns and wherever advance regeneration is inadequate. Recently political uncertainty and the practical halting in investment in the wood processing industries in Uganda have reduced the areas being harvested and such regeneration activities have slowed down.

108. In Nigeria, as decribed in Case Study 2, Kio et al. (1985) have noted that up to 1944, although the need to maintain the productivity of the natural forest was realized, there was no real systematic method of regenerating the high forest of Nigeria. Early work mainly involved observations of the ability of various species to regenerate naturally. In the 1930s natural regeneration was stimulated in some reserves by climber cutting and light thinning, together with progressive poisoning with sodium arsenite to remove unwanted trees. Notable among these trials were the natural regeneration experiments laid down by Kennedy at Sapoba, between 1927 and 1936 (Lancaster, 1961; Lowe and Ugbechie, 1975). At the same time artificial regeneration using the "taungya system", with either wide espacements and mixed species or pure, more intensively cultured plantations, was practised with some success and on a considerable scale. Taungya is described in paragraphs 123-124.

109. Very little taungya has been practised in Uganda because there was little shortage of land suited to agriculture. In West Africa, however, the mixed plantations of Nauclea diderrichii raised by taungya in the late 1930s were being thinned for transmission poles in the early 1970s to leave a mixed crop containing many valuable cabinet woods to grow on. Although these plantations were not extensive, they do indicate that such techniques are possible. A total of over 300 $km^2$ of plantations of indigenous hardwoods were raised up to 1976 (Kio et al., 1985).

110. As the scale of harvesting in Nigeria increased after the Second World War, it was found that taungya alone could not cope with the large areas which required to be regenerated each year. Lawton (1978) estimated that there were about 50 $km^2$ of forest in the annual regeneration coupe in Benin alone. This led to the introduction of the Tropical Shelterwood System (TSS) of natural regeneration introduced in the later nineteen forties and described in more detail in Case Study 2. Its sequence of climber cutting, deadening with arboricide and weeding operations was related in time to the principal felling. In the early years, it was associated with a planned felling cycle of 100 years (Collier, 1946), and was presumably conceived as a monocyclic system, but later the felling cycle was reduced to 50 years and in Akure forest a reduction to 25 years was considered possible (Lowe, 1984), based on a polycyclic system.

111. In Ghana the story is not unlike that of Nigeria. Both monocyclic and polycyclic systems have been used in the TMF and plantations of both indigenous and exotic species have been established using taungya practices. The Bobiri forest reserve, some 60 km south-east of Kumasi, contains a notable example of trials of both these systems. Research began in 1945 and the forest was divided into five blocks for management on a 100 year rotation. Two were allocated to treatment by a monocyclic system, with regeneration tended by a form of TSS, the remainder to treatment by a "selection" (polycyclic) system.

112. The progress of the regeneration was monitored by sample plots of 1 ha. Originally all trees of a list of desirable species over 14 cm dbh were recorded but later this was restricted to the four largest in each sub-plot of 0.04 hectares, i.e. the equivalent to the 100 leading desirables in the plot. The total number of tree species

recorded in Bobiri is 163, but of these only a total of 26 species are counted as marketable. Karani (1970), who visited this forest in 1969, was of the opinion that in Bobiri forest TSS had been very successful in that ten years after felling there were nearly 60 stems per hectare of the desirable species over 10 cm dbh. The faster growing species such as Triplochiton scleroxylon and Terminalia spp. were already over-topping the more valuable mahoganies and some individuals had reached over 40 cm dbh. Karani was of the opinion that the total stocking was too high and diameter increment was suffering. He advocated some form of crown release and possibly, later, the removal of the faster growing species to release the slower growing but more valuable mahoganies.

113. Karani postulated that because so few species were marketed, the treatments were expensive. Consequently and in spite of the success of this example of TSS, the TMF in Ghana was being managed under the Selection system. Prior to felling, a coupe was treated by climber cutting to reduce felling damage and by a refining or weeding operation, aimed to reduce the competition acting on the desirable species by removing competitors of the weed species. The weeds were cut if small or killed with arboricide if large. In 1969, 310 $km^2$ were treated. The annual yield was calculated using a 25 year felling cycle and controlled by a minimum diameter (48 cm dbh) and a total annual basal area for removals. The yield calculation was based on the predicted rate of growth between the minimum girth limit and the desired commercial size. A survival figure of 70% was assumed and the final yield adjusted to ensure that the level could be sustained for three cycles or 75 years. The yield was marked after stock mapping, starting with the largest trees, and the marking took into account the aim of spreading the yield amongst all species and retaining as wide a spectrum of desirable species in the forest as possible (see also Baidoe, 1970). Since 1971, the felling cycle in Ghana has been reduced from 25 to 15 years. It is very doubtful that the forest could support this short a cycle in perpetuity. Furthermore, selective fellings without silvicultural treatments will inevitably diminish the representation of commercially valuable species in the forest.

114. Some enrichment of poorly stocked forest and conversion to plantations is practised, often using taungya. A relatively new form of conversion has been described by Masson (1981) and is used in the Subri forest. This system is developing in an area of relatively high population density, with a trend towards industrialization and urbanization. As a result, the forests are being required to maintain the supplies of traditional timbers, to increase the supplies of firewood and contribute to food supplies for the nearby urban population. Also there is a demand for a pulp and paper industry to substitute for imported supplies.

115. The proposed solution to these demands has been the evolution of a flexible system that can be adjusted as conditions change. The stages are:

(i) selection of plantation areas on the bases of soil and site mapping;

(2) marking selected stems from among the regeneration of high value species at an intensity of between 40 and 60 stems per hectare, concentrating on well formed stems in the large pole stage (presumably less than 20 cm dbh);

(3) felling large-crowned stems in the overwood, followed by replacement of any damaged marked stems from additional advance growth;

(4) felling remainder of the stand unmarked for retention;

(5) extraction of sawlogs, followed by reduction of marked stems to 40 per hectare, evenly spaced;

(6) conversion of remaining stem and branchwood to firewood and charcoal;

(7) planting up the felled area with - for example - *Gmelina arborea*, with or without food crops.

116. Various species have been used in trials including *Albizia falcataria*, *Leucaena leucocephala* and, on dry ridge sites with shallow soils, *Cassia siamea*. Plantain has been the common food crop grown but needs planting well in advance of the trees if they are to fruit before canopy closure.

117. Elsewhere in West Africa there has been an equally rapid growth in the demand for pulp and paper. Kio *et al.*, (1985) have noted that: "The importance of paper in every day life, its high foreign exchange costs, and the availability of suitable species that can be grown in the African TMF zone as a whole have made the establishment of pulp and paper mills very attractive to most African nations in this region. Many West African countries from Angola to Senegal have undertaken initiatives to implement their own pulp and paper production with varying degrees of success. There are now eleven such mills in West Africa".

118. In response to this demand, 14,200 ha of *Gmelina* plantations had been established in Nigeria between 1979 and 1981; the 4th National Development Plan for 1981-85 called for an annual rate of establishment of 3,200 ha of *Gmelina* plantations in Ogun and Ondo States under an IBRD assisted pulpwood development programme, as well as 900 ha of bamboo and pine plantations in other states.

119. Such developments involving the large-scale conversion of the TMF to even-aged monocultures similar to those of many other temperate, sub-tropical and tropical countries open a new phase in the management of areas that were mixed tropical forest ecosystems.

120. In East Africa, neither Kenya nor Tanzania have paid as much attention to the regeneration of TMF as Uganda. Their areas of lowland TMF are small and, while the areas of montane forests are somewhat larger, management objectives concentrate on conservation of soil and water supplies. Kenya led the way in the introduction of fast growing exotic species in the genera *Pinus*, *Cupressus*, *Eucalyptus* and *Acacia*, and in the increased scale of planting of conifers after

the Second World War. Supplies of the native softwoods Podocarpus and Juniperus were soon depleted, and the species were difficult to regenerate and slow growing under the conditions of the natural forest. Conversion of suitable areas (on more gentle slopes) of montane forests to even-aged plantations of exotic cypress and pine was found to be an effective means of replacing the indigenous softwoods. There are now about 150,000 ha of exotic conifers planted in Kenya, and they help supply a pulp mill and a diversified wood-processing industry. These plantations have been largely productive and successful, but the Kenya Forest Department is aware that management in these forests could still be greatly improved and efforts are continuing in this direction. Elsewhere, for example in the Sao Hill pulpwood project in Tanzania, the plantations were established on montane grasslands. Where possible, the forests converted to exotic plantations were mixed forests lacking the important hardwood, Ocotea usambarensis.

121. The wetter forests dominated by Ocotea were maintained as natural forest for protection purposes and to regenerate the main species. Ocotea in certain localities, e.g. S. Kilimanjaro and W. Usambara in Tanzania, regenerates profusely from root suckers after felling. A good deal of effort was directed at cleaning and thinning the sucker regrowth to promote diameter increment (Mugasha, 1980). Overall, however, attempts at natural regeneration of TMF in Kenya and Tanzania have been very limited in comparison with the scale of investment in plantations, including conversion of natural forests. Kenya has the biggest area of exotic timber plantations in East Africa, while in Tanzania in recent years management aims have switched in a most dramatic manner to providing firewood supplies to rural communities in the drier areas outside the TMF.

### 3.3.1 Artificial Methods of Regeneration in TMF

122. A number of methods of artificial regeneration have been developed in TMF. Some have been used to establish plantations on an operational scale over thousands of hectares, others have not developed beyond the stage of research or pilot trials. They have been summarized by Catinot (1986).

#### Taungya Method

123. The oldest, simplest and often the cheapest of plantation establishment methods: it consists of planting trees in mixture with agricultural crops, so that the farmer tends the trees at the same time as his own crops (hoeing, weeding, etc.). Depending on the growth rate of the trees, their initial spacing and the consequent competition they offer to the agricultural crops, the latter are abandoned one, two or three years after the trees are planted, after which any further tending of the trees must be carried out by the forest service. The cost of establishment (nurseries, planting and tending after farmers cease to cultivate) may vary from 20 to 40/50 man-days ha$^{-1}$ (Catinot, 1986). It is a valuable method of planting after complete removal of pre-existing forest. It is suited to light-demanding species which quickly form a closed stand, with natural pruning, e.g. Tectona, Gmelina, Nauclea, Cedrela, Terminalia.

Numerous accounts of the "taungya system" have appeared: for Nigeria in Redhead (1960a), King (1968), Lowe (1975), Umeh (1978), Ball & Umeh (1981); for Ghana in Brookman-Amissah (1977); for Kenya FAO (1974); for Tanzania Hofstad (1978), Lundgren (1978) to mention just a few. FAO (1984a) "Changes in shifting cultivation in Africa" also contains sections on taungya.

124. In some countries taungya has been developed into a well-defined system, with clear obligations assumed by both farmer and forest service. Under the Kenya "shamba" system, resident farmers contract to work at least 270 days a year for the forest service, as well as to clear forest each year for agriculture and to weed the planted trees, with their crops, for two years after they are planted. Normally each farmer has four "shambas" of about 0.6 ha each, one recently allocated with forest being cleared, one with agricultural crops and no trees, two with agricultural crops with trees 0-2 years old. In return, the Forest Department:

(1) guarantees the resident farmer a permanent salary for 270 days of labour a year;

(2) provides housing and land for cultivation;

(3) fells the large trees in the uncleared forest allocated for cultivation;

(4) allows the farmers to grow their own crops (maize, potatoes, beans, peas and other vegetables);

(5) allows each farmer to graze 15 sheep free of charge;

(6) provides Welfare Centres, Schools, etc. (FAO, 1974).

The Kenya Shamba System has worked successfully on montane forest sites. Successful methods have also been applied in lowland TMF, e.g. mixtures of bananas and Aucoumea or Terminalia over several thousand hectares in Zaire, Congo and Gabon, and the "Departmental Taungya System" of Nigeria.

Plantation under Shelterwood (Méthode Martineau)

125. First adopted in Côte d'Ivoire around 1930, it consisted of close planting (1,500-2,500 seedlings per ha) in natural forest, in which the understorey of trees less than 10 cm in diameter had been previously removed and the overstorey was gradually killed by girdling or with arboricide treatment over the subsequent 10 years. The method was found to be expensive in labour (185 man-days per ha) but gave excellent results with Tarrietia and Khaya. Further research may indicate ways of reducing cost (more intensive felling of understorey up to 20-25 cm diameter by chainsaw, girdling/arboricide treatment in two stages only, reduction of initial planting rate to 1,000-1,200 per ha).

Line Planting (Méthode des Layons)

126. In Côte d'Ivoire this method consisted of planting in parallel strips of 3-4 m in width, cleared in closed forest which needed to be enriched. Although the method was carried out over 13,000 ha, it gave disappointing results (poor and irregular growth, need for endless tending). Later research showed that growth could be considerably increased by giving the plants more light through widening the cleared strips to 5 m and girdling the overstorey between the lines, but the improved method was still too costly (Catinot, 1986).

127. Line planting under a full or even partial upper canopy has always given disappointing results. Dawkins, quoted by Lamb (1969), proposed five necessary conditions which must be present for line planting (defined as the establishment of a tree crop to be closed at rotation age, in lines spaced at intervals equal to, or slightly greater than, estimated final-crop crown diameter) to be successful. They are enumerated in paragraph 56 of Case Study No. 1. Probably the most important of all is the combination of fast-growing light demanders with full overhead light from the moment of planting.

Coppice Method (Méthode du Recru)

128. This method was devised after research carried out by CTFT/Gabon had shown that, while the principal species such as Aucoumea needed full overhead light, too much lateral light (as in plantations established after complete forest clearing) produced excessive development of side branches which could lead to defects and stem deformation. The operations consisted in manual felling of all understorey trees up to 20 cm diameter and arboricide treatment of all stems of greater diameter. These created a dense regrowth of coppice shoots from the small felled trees which progressively enclosed the planted trees, while the shade from the overstorey disappeared more or less rapidly as a result of the arboricide treatment. The method required 90-100 man-days per ha plus 130 litres per ha of diesel/phytohormone mixture. It was used in Gabon, Cameroon and to a lesser extent in Côte d'Ivoire, and gave results which were technically and financially encouraging, but could not be extended to large areas because of the large labour force which it demanded.

Plantations in Full Light

129. Realization that most of the valuable species in African TMF are light demanders has led to an increasing trend towards planting forest sites after complete removal of the pre-existing forest. This trend was inspired by the early experiences with Aucoumea and Terminalia. A more recent trend, caused by the progressive decrease in the rural labour force available for forest operations, is the increasing use of mechanized methods for:

(1) forest clearance, made wholly or partly by chainsaw or by caterpillar tractor with tree pusher;

(2) tending of plantations. This may be done partly or wholly by hand (by machete along the line of plants) or mechanically (roller drawn by a small caterpillar or an agricultural tractor). If tending is fully mechanical, stumps must be uprooted, partially burnt and windrowed, and the soil levelled.

130. Intensive mechanization, involving heavy machinery (Caterpillar D6 to D8 with tree pusher) substantially increases the cost of establishment, but it has proved almost indispensable for large-scale planting schemes (500 $ha^{-1}$ $yr^{-1}$ or more) where labour is inadequate, and especially when operations must be completed to a strict time schedule in order to take advantage of the optimum planting season.

131. Details of operations in current use in the different variations of clear felling and planting are shown in Table 9. Some additional modifications may occur according to local conditions. Tending of Aucoumea is always done manually, because of the need to maintain its close association with the surrounding coppice regrowth. Species successfully planted by this method, on a scale of several thousand ha per year, include Tectona, Terminalia ivorensis and T. superba, Gmelina, Aucoumea, Cedrela, Nauclea and Triplochiton.

Group Planting (Méthode des Placeaux)

132. The system devised by the Forest Division of INEAC at Yangambi about 1952, was based on the Anderson group method used in temperate forests. The originators have described it as follows: "The principal characteristic of the method consists in planting the enrichment species in small dense groups in the undergrowth, which should be as little disturbed as possible. This method provides optimum ecological conditions at the critical period of establishment. Once the plants are established, the canopy is lightened; treatments are gradual in the early stages, until the groups have closed over, and then more intense". The groups consisted of 25 plants at 1 x 1 m spacing, the groups themselves being at 10 x 10 m or 100 per ha (Dawkins, 1955).

133. Catinot (1986) has noted that this method, first conceived for use in unexploited forest, could have its most important application in exploited or degraded forest. Use of fast-growing light-demanders in small groups, sited in large gaps in the canopy after exploitation, has been used in several countries e.g. Uganda, Tanzania. Usually the groups have fewer trees (3-5) and are at rather wider initial spacing than in the Méthode des Placeaux. Singling of each group, to leave the best stem only, can be done within two or three years after planting if fast-growing species are used. In Kihuhwi-Sigi Forest Reserve (Tanzania) Maesopsis, Cedrela, Terminalia ivorensis and T. superba averaged, over the first 7-10 years, annual increments of 1.5-3 m in height and 1.3-4 cm in diameter (Borota, 1969). Similar growth rates have been achieved in Uganda (see Case Study 1, paragraph 54). The method is of great flexibility, in that it takes advantage of existing gaps without the need to spend money in creating them. However, it has yet to be applied in large scale operations, in which control of field work is less close than in small research plots. More research is needed to consolidate early findings and make them applicable to operational management (Catinot, 1986).

Plantation Methods for Pines and Eucalypts

134. Fully mechanized methods are normally used for these genera. When planted on closed forest sites, it is advisable to select degraded forest where clearing costs will be reduced. For the most part, however, this type of plantation is best suited to "derived savanna" sites with only scattered trees and a ground layer of grass.

Table 9. Forest Plantations under Full Light; List of Operations Characterizing Different Methods

| Manual Method | Semi-Mechanized Method (Limba, Congo) | Semi-Mechanized Method (Aucoumea) | Fully Mechanized Method (Côte d'Ivoire) |
|---|---|---|---|
| - Strip or line clearing<br>- clear felling - ax<br>- chainsaw<br>- Burn at end of dry season<br>- Clearing (trunk removal) along planting lines<br>- Dig planting holes<br>- Plantation<br>- Manual tending | - Strip or line clearing every 50 m<br>- Staking of planting lines<br>- Clear felling - ax<br>- chainsaw<br>- Burn<br>- Bucking trunks<br>- Clear planting line<br>- Bulldozer or<br>- Angledozer<br>- Dig planting holes<br>- Plantation<br>- Tending - manual and/or<br>- mechanized | - Strip or line clearing every 50 m<br>- Staking of planting lines<br>- Cutting of small stems<br>- ax<br>- tractor<br>- Cutting of large stems with chainsaw<br>- Burn<br>- Bucking trunks<br>- Line clearing<br>- Raking windrows<br>- Burn<br>- Final clearing of lines<br>- Plantations<br>- Manual Tending | - Strip or line clearing every 50 m<br>- Staking of planting lines<br>- Harvesting marketable wood<br>- Clear felling with Treepusher<br>- Directional felling of large standing trees<br>- Bucking trunks and slash<br>- First clearing of planting lines with D8 and root rake<br>- Burn planting lines<br>- Second clearing of planting lines with D7<br>- Burn windrows, planting lines<br>- Level ground<br>- Dig planting holes<br>- Plantation<br>- Tending - manual or mechanized |

Source: after H. Maitre, CTFT Support Mission to the Pilot Afforestation Centre in Limba, Congo, Catinot (1986).

Clearing costs are thus reduced. Grass competes severely with young planted trees, it is therefore essential to carry out weeding operations by uprooting and not by slashing, which may encourage a still more vigorous regrowth. Manual hoeing is time-consuming and costly, so it is usually confined to the areas closely surrounding the plants, while inter-row weeding is done mechanically by disc harrows of about 2.5 m in width.

135. The sequence of operations is summarized below.

(1) Mechanical clearing, either by a bull-dozer or tree-pusher with D4 tractor, which pushes over and uproots the woody vegetation, or by a pair of D7 tractors working together about 30 m apart and dragging between them a thick chain which uproots the trees.

(2) Burning, followed by raking of remaining material into piles and reburning.

(3) Soil working with heavy ploughs (e.g. Rome-plow), to improve soil structure and to turn over and bury the grass layer; sub-soiling where necessary to break hard-pan layer; final soil working with light harrows.

(4) Pitting and manual planting.

(5) Tending for 2-3 years by manual hoeing round the trees and mechanical harrowing between the rows.

(6) As an essential protective measure, creation of firebreaks around and between the plantation compartments.

Costs

136. These vary greatly according to local conditions, including the intensity of the clearing operation, the local cost of labour and equipment and the accessibility of the area. An estimate of the wide range of establishment costs at the present time (Catinot, 1986) is:

(1) Timber species on closed forest sites: 1,200-2,000 US$ per ha

(2) Pines and eucalypts on savanna sites: 700-1,000 US$ per ha

Tree Improvement

137. Progress has been most notable for fast growing species and particularly eucalypts and pines. Selection of plus trees and the establishment of seed orchards as a first step in tree improvement programmes, have been carried out in many countries including Congo, Côte d'Ivoire, Kenya, Madagascar, Nigeria, Uganda, Tanzania, Zambia and Zimbabwe. Clonal plantations of high-yielding eucalypt hybrids and of selected *Terminalia superba* are carried out at a large scale in Congo. Among indigenous TMF species, research is in progress on *Terminalia superba* in Congo, Côte d'Ivoire and Cameroon, *Terminalia ivorensis* in Côte d'Ivoire, and *Triplochiton scleroxylon* in Côte d'Ivoire and Nigeria. This work includes provenance trials, plus tree selection and development of reliable methods of vegetative propagation, applicable on a large scale.

## 3.4 Harvesting

138. Both Catinot (1986) and Philip (1986a) have remarked on the spectacular progress made in harvesting techniques during this century. This applies to both the equipment and techniques available for harvesting and to the range of species saleable. There is no tree which current technology could not harvest. On the other hand the high cost of harvesting still constitutes a severe economic constraint to the more efficient utilization of the forest resource. Harvesting, of course, effects the environment and can be a silvicultural operation as well. Poorly planned harvesting with modern machinery can be very destructive to the forest environment and to the residual stand of trees. It is also more expensive and inefficient than well planned harvesting, including road and skid trail lay out. Thus, well planned and carefully controlled harvesting systems are superior economically, environmentally and silviculturally. Such harvesting systems should be fully integrated with the management system, but this has been an elusive goal in the tropics.

139. A number of factors as listed below raise problems in harvesting (Catinot, 1986).

(1) High rainfall (1,500-4,000 mm/yr) with little or no dry season, which makes felling, extraction and transport difficult. Even with a good road system, road transport may be limited to 180-220 days a year because of the climate.

(2) Topography. A significant part of the forests of Congo, Gabon and Zaire, as well as the montane forests of East Africa, are found on steep slopes.

(3) Difficult soils (excessively sandy or excessively clayey) which, in conjunction with high rainfall, make logging and transport difficult.

(4) Large tree sizes.

(5) In some cases, distance of the forests from markets.

(6) Inadequate knowledge of the forest. Although a great part of the forests have been inventoried, the intensity of the inventory is often too low to provide acceptable information on stocking on smaller blocks of less than 20,000 ha (sometimes less than 100,000 ha).

(7) The heterogeneous composition of the forest. Commercial volume varies greatly according to proximity to local markets or to ports for export, the sales policy of the concessionaire and the annual fluctuations in the market.

140. A clear distinction must be made between the gross stem volume per ha, which is most readily available from standard inventories, and the net commercial volume per ha which the harvester is able to sell. Table 10 presents average figures for undisturbed forest in

francophone Africa, extracted from the "Memento du Forestier". They refer to stems of over 70 cm dbh and therefore of harvestable size. It can be seen that, whereas the gross volume of all species is over 100 m³ per ha, the net volume of the preferred species after allowance for defects is only 15 m³ per ha.

Table 10. Stocking and Volumes of Trees of Harvestable Size by Species Groups

| Types of species | No. of species in group | No. of stems $ha^{-1}$ | Bole volume ($m^3$ $ha^{-1}$) | Commercial volume ($m^3$ $ha^{-1}$) |
|---|---|---|---|---|
| Preferred species: | | | | |
| Red wood | 8 | 0.9 | 12.5 | 6.80 |
| Other species | 7 | 1.4 | 15.5 | 8.50 |
| | 15 | 2.3 | 28.0 | 15.30 |
| Less desirable species: | 15 | 1.9 | 16.6 | 9.15 |
| Important complementary species | 19 | 3.0 | 30.4 | 16.70 |
| Sub-Total | 49 | 7.2 | 75.0 | 41.15 |
| Other complementary species | | 4.3 | 36.2 | 19.8 |
| Global Total | | 11.5 | 111.2 | 60.95 |

141. In some countries a high proportion of total production is exported. Table 11 shows that in 1983 exports accounted for an average of 74% over four francophone West African countries. Export markets are highly selective and, if local markets to take secondary species are poorly developed, overdependence on export will lead to harvesting only certain species and a low intensity of felling, which in turn makes silvicultural treatment to regenerate these same species very difficult. The predominance of exports is not universal; in Nigeria they ceased several years ago. But the high local demand (for forest products and forest land) which may replace exports, creates other management challenges.

142. Over the years, there has been a steady and welcome increase in the number of TMF species with a commercial value. In some countries this has led to a shift from the very selective harvesting of the early decades to complete utilization in some areas today. The trend was assisted by research on timber properties conducted at institutes such as the Centre Technique Forestier Tropical in France or the Forest Products Laboratory in U.K., and later by African forest products institutes e.g. at Ibadan, Accra, Moshi, Kampala, CTFT/Gabon and CTFT/Côte d'Ivoire.

Table 11. Production and Exports in four Tropical Moist Forest Countries in 1983

| | Total Log Volume Production ($10^3$x $m^3$) | Log Exports Volume ($10^3$x $m^3$) | Log Exports Percent of Production | Processed Wood-Log Volume Equivalent ($10^3$x $m^3$) | Total exports Log Volume Equivalent ($10^3$x $m^3$) | Total exports Percent of Production |
|---|---|---|---|---|---|---|
| Cameroon | 1,680 | 595 | 35.4% | 250 | 845 | 50.3% |
| Congo | 491 | 221 | 45.0% | 150 | 371 | 75.6% |
| Côte d'Ivoire | 4,075 | 2,267 | 55.6% | 888 | 3,155 | 77.4% |
| Gabon | 1,390 | 938 | 67.5% | 360 | 1,298 | 93.4% |
| Total | 7,636 | 4,021 | 52.6% | 1,648 | 5,669 | 74.2% |

143. As an example, Karani (1985) recorded that by 1939 Uganda could sell as many as 15 timber species. Foreign markets demanded high quality timbers, which Uganda could not find in sufficient quantities to sustain exports, and this helped greatly to develop local markets and to persuade the timber industry to continue to expand the list of timbers placed in that market. Harvesting one species only was tried in the very early days, but abandoned and replaced by grouping species of similar wood properties as a practical policy for developing forest industries in Uganda. Species were also grouped into three, and later four, classes in terms of value. The first class consisted of species of high quality cabinet woods, commonly called furniture species. The second class consisted of general construction timbers, some of which may be used for the cheaper types of furniture. The third class consisted of species which are used for construction but which tend to be less common and/or to have certain disadvantages in processing; they are less readily accepted by the market. The fourth class is of species which are less used because of processing difficulties. Species in this last category may occur in very substantial quantities in the mixed forest - for example Cynometra alexandri in Budongo and Bugoma forests, and Parinari excelsa in the forests of Kibale, Kalinzu and Kasyoha-Kitomi. In the case of Parinari that is a very hard timber containing a lot of silica, the introduction of stellite tipped teeth to saws helped to overcome some of the processing difficulties.

144. By the early 1970s most of the species in the Mabira, West Mengo and Masaka areas (that is in the densely populated areas around Lake Victoria near the industrial centres of Kampala and Jinja) had been distributed to all the four commercial classes. The only exception was one species, Cola gigantea, whose timber is difficult to saw or peel and whose only use is for charcoal.

145. One difficulty is that it is usually impossible to foresee which new species will become marketable and when. Kio et al. (1985) have noted that in Nigeria areas are usually divided into blocks to be worked through in chronological sequence, but many concessions allow the right of re-entry into previously logged coupes. Thus when a

previously unmarketable species that has been left standing is in demand, concessionaires return to coupes that have been transferred for regeneration silvicultural operations. This may negate the efficacy of those operations already executed and designed to promote regeneration or enhance the growth of the residual stand. Certainly in Uganda stems that have been treated with arboricide have later been harvested, and species previously treated as weeds have been promoted to the category of "desirables". Even where there has been little active intervention by silvicultural operations, re-entry for harvesting operations reactivates climber activity and delays the re-establishment of a canopy of tree species that would mitigate against the vigour of the population of lianes.

146. Great developments have been made since the early days of axes, cross-cut saws and short manual haulage. Narrow gauge railways were used for log transport to the mill at an early stage, as in the Sango Bay Podocarpus forest in Uganda (Philip, 1986a). Now sophisticated crawler tractor systems are available, linked by powerful log loading gantries to heavy, multi-axle road vehicles. Felling is commonly done by chainsaws, but tree-shears have also been used experimentally in Gabon (Catinot, 1986). In large concession areas skidding is done by wheeled or caterpillar tractors of 180-200 hp. Mechanical loading is done either by dozer blade or front loaders. Transport may be done by road tractors with articulated trailers capable of carrying loads of 12-35 t. The total weight loaded is from 22-50 t and requires a high standard of roading, with a width of 8 m, a compacted surface over a laterite base and full exposure to sunlight.

147. Often harvesting has been regulated through the terms of exclusive concession agreements, i.e. the licensee has the exclusive right to log the forest within the concession area. In Uganda, for example, the Government started sawmilling in the early years of this century but stopped in 1930. Between 1915 and 1933 exclusive licenses were issued to various companies in different parts of the country, although the forests were not under any formal management plans. The first working plan was written for Budongo forest in 1934 and for other forests of S. Mengo in 1948 (Sangster, 1948). Since that date, most of Uganda's major forest reserves have been operated through exclusive licensing concessions to privately owned companies in accordance with a formal plan.

148. The concessionaire is given information from any inventory done prior to the advertisement - usually the total volume expected and an analysis by species and commercial classes, and, as well, definitions of the area to be harvested and other conditions imposed. Once the harvesting operation is underway, a harvesting plan is devised and agreed with the Forest Authority. Rules are promulgated under the conditions of the licence to control the orderly working of the area, the construction and layout of extraction roads and the measurement of timber. Normally the basis of payment is the volume measured at stump, i.e. after felling. Detailed legal provisions have often been made to regulate the terms of a concession. For example the model "Exclusive Licence to take Trees and Timber", used in Tanzania during the 1950s, contains 59 conditions plus 13 schedules and runs to 18 pages.

149. Most concession agreements are applicable to forest reserves where the Government has full control of the land. In some countries, however, a significant proportion of forest production may come from areas outside the reserves. These areas are often described as "free areas" and are mainly destined for agriculture, but meanwhile they produce a great deal of wood; for example Kio et al. (1985) state that in Nigeria "50% of all logs cut were reported to be from outside the forest reserves".

150. Some indication of the range in harvesting productivity is given in Tables 12 and 13, quoted by Catinot (1986) from the "Mémento du Forestier".

Table 12. Labour Productivity by Harvesting Units (broken topography in Gabon)

| Annual Production of operation $m^3\ yr^{-1}$ | Commercial Volume of forest $m^3\ ha^{-1}$ | Terrain 1/ | Personnel Labour N1 | Personnel Supervision N2 | Productivity $m^3\ man^{-1}\ yr^{-1}$ P1 1/ | Productivity $m^3\ man^{-1}\ yr^{-1}$ P2 2/ |
|---|---|---|---|---|---|---|
| 127,000 | 8 | M/D | 249 | 15 | 510 | 8,500 |
| 65,000 | 9 | M | 150 | 7 | 500 | 10,700 |
| 57,000 | 8 | M/D | 104 | 5 | 550 | 11,400 |
| 91,000 | 8 | M/D | 191 | 8 | 475 | 11,400 |
| 75,000 | 16 | M | 148 | 5 | 505 | 14,900 |
| 31,000 | 10 | D | 83 | 3 | 380 | 10,450 |
| 30,000 | 10 | D | 73 | 4 | 420 | 7,700 |
| 22,000 | 8 | D | 74 | 3 | 295 | 7,300 |
| 81,000 | 11 | E | 130 | 8 | 620 | 10,075 |
| Older operations (1960-1965) | | | | | | |
| 48,000 | 15 | E | 200 | 5-6 | 240 | 8,100 |
| 60,000 | 15 | E | 200 | 5-6 | 300 | 10,500 |
| 42,000 | 10 | D | 147 | 6-7 | 280 | 6,300 |

See notes below Table 13.

151. Comparison of the tables suggests differences in productivity caused by local conditions, especially the effect of local topography. Also the productivity in most of the areas in Côte d'Ivoire/Cameroon/Central African Rep. being felled for the second or third time is higher than the average of the first fellings, providing some evidence that harvesting costs can be expected to diminish with recurrent cycles of a polycyclic system, because the initial roading and logging infrastructure can be restored and reused instead of being created de novo.

152. Precise logging costs are not readily available. Catinot (1986) observes that these are undoubtedly too high. One reason is that in francophone Africa at least half of the supervisory staff are expatriate. The development of a higher and less selective demand for forest products, especially within the producing countries, would certainly lead to a larger harvest of saleable wood per ha and so to reduced costs.

Table 13. Labour Productivity by Harvesting Units
(gentle topography in Côte d'Ivoire, Cameroon, Central African Rep.)

| Annual Production of operation $m^3$ $yr^{-1}$ | Commercial Volume of forest $m^3$ $ha^{-1}$ | Terrain 1/ | Personnel Labour N1 | Personnel Supervision N2 | Productivity ($m^3$ $man^{-1}$ $yr^{-1}$) P1 1/ | Productivity P2 2/ |
|---|---|---|---|---|---|---|
| 61,000 | 10 | E | 118 | 3.5 | 520 | 17,400 |
| 43,000 | 12 | E | 126 | 4 | 340 | 10,700 |
| 84,000 | 13 | E | 111 | 5 | 760 | 16,800 |
| 132,000 (2nd & 3rd cutting) | 4 to 5 | E | 126 | 4 | 1,100 | 33,000 |
| 140,000 ( " " ) | 4 to 5 | E | 204 | 6 | 685 | 22,300 |
| 80,000 ( " " ) | 2 to 3 | E | 80 | 7 | 1,000 | 11,400 |
| 33,000 ( " " ) | 2 to 3 | D | 84 | 1 to 2 | 390 | 18,900 |
| 32,000 ( " " ) | 2 to 3 | M/D | 56 | 2 | 570 | 16,000 |
| Older operations (1960-1965) | | | | | | |
| Total of 7 operations | | E | | | 200 | 9,600 |
| 81,000 | | E | 202 | 5 to 6 | 290 | 14,700 |

Notes for Tables 12 and 13:

1) E = easy
M = medium
D = difficult

2) $$P1 = \frac{Production}{N1}$$

$$P2 = \frac{Production}{N2}$$

## 3.5 Forest Industries

153. Throughout this century there has been steady progress in wood processing techniques leading to the use of a much wider range of species than previously. These developments have followed from research into the wood properties of the different species, machining techniques, seasoning and preservation processes and developments in more sophisticated wood using processes employing modern adhesives and resins. Whereas at the beginning of this century the most sophisticated wood use was in cabinet making and marquetry, now machines for finger jointing, plywood and veneer production, chip board and fibre board are relatively common in some developing countries. Pulp mills are being established as well and, no doubt, the development of technical know-how will continue and new technology such as oriented strand board will follow. Kyrklund & Erfurth (1976) conclude that moist tropical hardwoods can be used successfully for the manufacture of pulp and paper in a technical sense, but problems arise on costs and economic returns.

154. There is, however, a price to pay for this improved technology. These manufacturing processes tend to be capital intensive and the costs of production are sensitive to economies of scale. Markets for these products are international, and success in either import substitution or export is subject to many external influences. They call for high energy inputs and are costly in terms of management expertise, spare parts and some raw materials such as chemicals that may not be available locally. Consequently their adoption is not without risk and the easy access to imported technology has not been, and is not, necessarily beneficial.

155. The extent to which technological progress has actually benefitted forest industries and forest management in Africa is arguable. Philip (1986a) paints a fairly bright picture of the situation in anglophone countries. He cites the conclusions of Kio et al. (1985), that by 1980 there were over 1,000 horizontal band saw mills, each with a capital investment averaging around US$ 50,000. As mentioned in Case Study 2, however, there is good reason to think that many of these mills are under-utilized. In the 1980s an integrated investment stage commenced where most countries pursued total wood utilization. Achieving this is only possible through an integrated approach to wood processing, and saw mills became integrated with veneer, plywood and particle board mills. Integrated pulp and paper mills also came into existence. By 1976, Ghana had some six such integrated plywood and veneer mills while Nigeria had four. By 1980 in Nigeria, the number of plywood and veneer mills had increased to six and two particle board mills had opened. Nigeria also owns a paper mill that used to depend solely on imported pulp for paper manufacture, but recently has been expanded into an integrated pulp and paper mill. Two other mills are now under construction, but costs have escalated and construction and start up have been delayed.

156. The pattern in East Africa has not been dissimilar. Because the natural closed forests of this region were less extensive than in West Africa, there has been a steady expansion of fast growing plantations of exotics mainly pines, cypress and eucalypts. Integrated plywood mills, particle board and fibre board mills were established during the 1960s and 1970s and now, as in West Africa, the emphasis on new investment has shifted to pulp mills.

157. Catinot (1986) paints a less optimistic picture for West African francophone countries, where the markets are still largely dominated by the export trade, as shown by Table 14. He observes that, during the last 20 years in francophone Africa, forest industries have scarcely evolved at all and seem ill prepared to confront the new problems likely to arise in harvesting plantations and natural forest already cut over once or more. In both cases the diameters will be much less than during the initial felling in "virgin" forest.

Table 14. Production and Internal Markets in Four Tropical Moist Forest Countries in 1983

| 1 | 2 | 3 | 4 | 5 | 6 | 7 (6÷4) | 8 (6÷2) |
|---|---|---|---|---|---|---|---|
| Parameters / Country | Total Log Volume ($10^3$ x $m^3$) | Exported Log Volume ($10^3$ x $m^3$) | Locally Processed Log Volume ($10^3$ x $m^3$) | | | Percentage of processed wood sold locally | Percentage of total production sold locally as processed wood |
| | | | Total | Exported | Local Market | | |
| Cameroon | 1,680 | 595 | 1,085 | 250 | 835 | 77 % | 50 % |
| Congo | 491 | 221 | 270 | 150 | 120 | 44 % | 24 % |
| Côte d'Ivoire | 4,075 | 2,267 | 1,808 | 888 | 920 | 50 % | 22 % |
| Gabon | 1,390 | 938 | 452 | 360 | 92 | 20 % | 7 % |
| Total | 7,636 | 4,021 | 3,615 | 1,648 | 1,967 | 54 % | 26 % |

158. Table 14 shows that:

(1) national processing industries absorb less than half of roundwood production ($3.6 \times 10^6$ out of $7.6 \times 10^6$ $m^3$)and over half is exported as logs;

(2) processing industries which feed local markets take only 26% of total roundwood production, ranging from 50% in Cameroon to only 7% in Gabon; the remaining 74% is exported, either as logs or after conversion;

(3) only a little over half (54%) of processed products is absorbed by the local market.

159. The virtual stagnation of local markets (except in Cameroon) has continued to tie forest industries too closely to the export market with its emphasis on high quality and extreme selectivity. There has thus been no inducement towards an increased range of species processed or improved types of equipment in use. Most mills have been forced to concentrate on processing a few primary species as their main source of income. Only in special circumstances (old equipment fully depreciated, close proximity to a large urban market) can a mill rely solely on second category species.

160. When felling was almost confined to overmature trees, the large mills had to install heavy machinery to handle large logs. Since the initial harvesting has now covered most of the forest area, the average diameter of trees felled in the second cut has become progressively less and the existing machinery becomes oversized and uneconomic to operate. Small mills may have equipment better suited to the smaller log size, but much of it is old and the enterprises are often insufficiently capitalized to be able to replace it. Although there are exceptions, this is a common problem.

161. In West Africa, as the availability of export quality logs declines, there is bound to be increasing emphasis on the need to develop local markets and to make better use of the smaller trees still remaining in the natural forest, as well as the plantation thinnings of small size (15-35 cm diameter) but homogeneous wood characteristics which will soon be produced over tens of thousands of hectares. To do this, special equipment will be needed, including:

(1) Peelers and slicers designed specifically for logs of small dimensions, e.g. the Finnish peelers and other machines from Canada and Scandinavia.

(2) Mobile sawmills and planers of small size which could be installed in the felling coupe for production of joists and rafters, which could be further processed in the main mill. The volume of small material expected (150,000 $m^3$ per year of thinnings from Côte d'Ivoire alone) justifies investment in new equipment (Catinot, 1986).

162. Parallel developments are needed in secondary conversion, mainly for joinery, carpentry and furniture making. Development of laminated roof-trusses has been held up for lack of local markets, but there is an increasing demand for locally produced items such as broom handles and curtain rods, especially in Côte d'Ivoire. Actions which could promote the domestic use of wood from local industries are listed below.

(1) Increased care in wood seasoning, which is made difficult by the constant humid climate of the TMF zone. Careful seasoning is particularly important if products are to be sold in the adjacent drier zones of Africa.

(2) Use of plywood products in painted rather than polished form. This can conceal minor blemishes and render cheaply produced material acceptable in appearance.

(3) Use of reconstituted wood (particle board, etc.) for wood panels. This well developed and inexpensive technique for using small waste products could be an essential means of using profitably plantation thinnings and other wood of small dimensions.

163. The above comments refer particularly to West Africa. In Central Africa, where there are still substantial areas of undisturbed forest, the dominance of a highly selective export market is likely to continue for several decades.

## 3.6 Institutions

164. Governments and administrators have traditionally regarded revenue collection as the primary function of the forest service. The forest, they thought, "can grow by itself", therefore expenditure and staff in the forest service should be kept to a minimum.

165. Politically the forest service is often regarded as a source of friction. Rural communities commonly regard forest legislation as oppressive and the forest service as a body of interfering policemen. Prosecutions for hunting, burning and illegal felling offences arouse almost daily a latent hostility which is later expressed openly to the local politicians. Politicians who wish to remain popular are therefore wary of giving too overt support to the forest service when it attempts to enforce the law. Forestry has usually been among the activities least supported by governments.

166. In francophone Africa it has been common practice to have separate organizations for (a) technical operations and (b) application of forest policy, administration, revenue collection (Catinot, 1986). This separation was often found convenient by donors of external funds, both multilateral and bilateral, for adminsitration of technical cooperation projects. In this way organizations were created in all the major francophone forest countries which were responsible specifically for forest operations and were theoretically independent of the forest service. They usually took the form of State Corporations or Boards e.g.:

(1) In Cameroon: the Fonds Forestier National and the CENADEFOR.

(2) In Congo: Unité Industrielle d'Afforestation du Congo.

(3) In Côte d'Ivoire: the Société pour le Développement des Plantations Forestières (SODEFOR).

(4) In Gabon: the Société Technique de la Forêt d'Okoumé (STFO).

167. These organizations are usually administered by a Committee and are given financial autonomy. They come under the aegis of the same Ministry which includes the Service des Eaux et Forêts, the Chief of which is the government representative of the Committee.

168. These technical Corporations provide a suitable administrative mechanism for handling forest management projects. Experience has shown that many of them lack a specialized section on research, planning and control of operations, which would be the appropriate unit to assume responsibility for the organization and coordination of special projects. External aid agencies have often assigned a socio-economist to undertake the work of planning and coordination. This aspect is particularly important in ensuring the success of forest management projects.

169. In anglophone countries, forest departments are commonly responsible for technical operations as well as for revenue collection and administering and protecting the forest estate. Certain forestry projects have been undertaken by the Commonwealth (and previously Colonial) Development Corporation e.g. the Usutu pulpwood plantations in Swaziland and the Njombe wattle (Acacia mearnsii) scheme in Tanzania. In general, however, national forest departments themselves carry out technical operations including plantation establishment and natural forest management. In many cases major schemes of afforestation or management are given the status of a separate project with its own budget.

170. Staff available for forest operations are often insufficient in number and lacking in professional experience. Salaries are often so low that professionals may find it difficult to meet basic needs. Vehicles, fuel and funds are commonly in such short supply that it is difficult for supervisory staff to spend adequate time in the field. Technically capable foresters must be supported in the field, with equipment, transport, adequate salaries and career tracks, before forest management can become a reality. One important deficiency in

training in many countries is in harvesting and processing (Catinot, 1986). Forest management staff find it difficult to talk on equal terms with loggers and sawmillers regarding estimating the commercial volume of standing trees, grading logs and sawnwood or finding markets for secondary species. But forest management demands frequent contacts with timber concessionaires, and it is essential that both understand each other. Thus one important means of improving forest management is to expand the professional training of field foresters in harvesting, processing and marketing tropical woods, so that their control of these operations is based on full technical knowledge. Proper institutional support of field foresters is essential and will not require insignificant funds.

3.7 Economics and Socio-economics

171. Catinot (1986) has observed that no comprehensive economic studies of management options in TMF have been made for francophone Africa. However, limited studies have been made in a number of countries. These vary from generalized discussion of the economics of management of TMF worldwide (e.g. Leslie, 1976, 1987) to more specific accounts of individual countries or sectors. Economic aspects of plantations are better documented than those of natural forest management (e.g. Openshaw, 1982).

172. The principal sectors on which some economic data are available are listed below.

(1) Harvesting costs, with a breakdown by the principal components (reconnaissance, roads, felling, cross-cutting, skidding, transport) and differentiated according to the richness and accessibility of the forest.

(2) Processing costs and returns, as affected by species, type of material, etc.

(3) Costs of transporting material from mill (by rail, river or road) including maintenance stations, intermediate stock-piles, cost of fixed assets, and their efect on returns.

(4) Costs of maritime transport in the case of exports, including any taxes, customs dues, etc. levied on these.

(5) Integrated studies following all production stages from the standing tree to the final user, and including comparison of the rates of return from export of round logs and export of processed lumber.

(6) Studies of national and international markets, in terms of species and customary uses, with the purpose of determining the range of prices obtained in practice. Most of the evidence confirms that the price range between preferred and less desirable species does not vary much and that, when the market becomes depressed, less desirable species become unsaleable on the export market. This situation could, however, be improved by the development of vigorous local markets.

(7) Numerous case studies of the rates of return predicted from specific forestry projects. They have been concerned especially with feasibility studies of pulp and paper projects (e.g. Gabon, Congo, Cameroon, Côte d'Ivoire, Nigeria, Kenya, Tanzania). Some of these projects were conceived as using wood from the natural forests (all species), others as based on existing or future plantations of fast-growing species. This type of feasibility study included almost all the traditional aspects of forestry and also a number of new aspects (e.g. total harvesting of TMF, chipping of large logs, construction of all-season road networks for heavy vehicles, harvesting of plantations over thousands of hectares a year, use and outputs of heavy equipment, etc.). These studies have produced a mass of new data of great value to the forest manager.

(8) Economic studies of forest plantations started around 1945-50, when they first attracted overseas investment. Bilateral or multilateral aid agencies insisted on both prior feasibility studies and subsequent financial and economic monitoring of projects. Up to 1984/85, these studies were incomplete because plantation yields had to be estimated; they can now be measured since the plantations of Aucoumea, Terminalia superba and T. ivorensis have reached harvesting age. Calculations of plantation profitability can now be based on actual volume yields, but are hindered by the lack of agreement on a realistic value per $m^3$ of standing timber. Good access, high volumes of material per ha and homogeneity in both size and quality should all enhance the value of plantation produce. Nevertheless, their financial yield is likely to be low because of the high costs of establishment and maintenance, at least during the first rotation.

(9) A certain number of special studies have been made. The most important, for the future of plantations on TMF sites, has probably been that made by SODEFOR in Côte d'Ivoire on the valuation of plantation thinnings. This study quantified the cost of thinning to waste and also the production cost of material from thinnings, using new equipment designed specially to handle the poles and small logs involved.

(10) In contrast to plantations, economic studies on treatment of natural TMF have been carried out on only a small scale (e.g. forest on Yapo in Côte d'Ivoire) and socio-economic studies are virtually non-existent. The long rotations involved and the difficulty of quantifying growth response to specific treatments in a statistically valid manner make this a formidable task.

## 3.8 Research

173. Early in the century research, nearly always silvicultural research, was carried out through the curiosity and initiative of local forest officers as part of their district forestry work. Catinot (1986) quotes the experiments of Martineau and Aubreville at Banco in Côte d'Ivoire, which started in 1925. In Nigeria, two silviculturists were recruited in the 1920s and started investigations in both natural and artificial regeneration in Sapoba. In many African countries, however, specialist research units started only after the Second World War. A notable exception was the establishment in 1934 of the Forestry Division of INEAC in Zaire, which carried out valuable research in TMF at Yangambi and Luki until about 1960.

174. Organized research started, or was greatly strengthened, with the increases in professional staff which followed the Second World War. Silvicultural research sections were operational in most countries by the late 1940s or early 1950s. Small forest research sections started from 1945 in Côte d'Ivoire, Cameroon, Gabon and Congo. From 1958 research in francophone Africa was greatly strengthened through the foundation in several countries of research stations, which were first outstations of the parent CTFT and later progressively nationalized. CTFT/Gabon and CTFT/Congo were established in 1958, CTFT/Côte d'Ivoire in 1962 and CTFT/Cameroon in 1965. Staff varied from 2 to 10 researchers per station, with the emphasis on silviculture and genetics but with research also on wood technology. Specialist sections on utilization research were often started some time after silvicultural research, partly because of the more expensive capital equipment needed for the former. Utilization research units were set up at Ibadan (Nigeria), Accra (Ghana), Moshi (Tanzania), Kampala (Uganda) and Muguga (Kenya), while wood research workshops and laboratories were incorporated in CTFT/Côte d'Ivoire and CTFT/Gabon. For certain types of research services, reliance has been placed on regional or international research organizations such as the East African Agriculture and Forestry Research Organization, the West African Timber Borer Research Unit, CTFT in France, Oxford Forestry Institute and Forest Products Research Institute in the U.K. Silviculture and utilization have everywhere been the two primary research disciplines, but additional specialists have been recruited in accordance with local problems and priorities, e.g. forest pathologists and entomologists, beeswax officers, tree breeders, forest botanists and ecologists, statisticians, forest economists.

175. Research was first concentrated on the silviculture of indigenous timber species, with trials of both natural and artificial methods of regeneration. Later the species range was extended to exotics such as teak for timber production and to fast-growing species (pines, eucalypts) for pulp production. Most of the silvicultural techniques described previously under 3.3 were evolved after preliminary investigation on a research scale. Research on nursery planting, tending and thinning methods for individual species has been universal. Variations on widespread methods (taungya, enrichment planting) developed as a result of local research, have sometimes received their own specific names e.g. the methods of Uniformisation par le bas (taungya of bananas and Terminalia superba) of Mayumbe in Zaire; the Nigerian departmental taungya, the Kenya shamba system; the

Méthode du recrû for Aucoumea in Gabon, the Méthode du couvert in Côte d'Ivoire, the Méthode des grands layons in Cameroon, the Méthode des placeaux and Méthode de l'Uniformisation par le haut developed by INEAC in Zaire; and the stripling method of line-group planting in Uganda. Much research effort was put into the development of low-cost but statistically reliable methods of forest inventory and of cheap, effective arboricides (sodium arsenite in West Africa, hormonal in Uganda). Tree increment plots have been commonly used to measure the variation between, and the effect of silvicultural treatment on, diameter increment of individual trees. Some attempts have been made to measure the extent of felling damage on adolescent trees of desirable species (e.g. Dawkins, 1958; Redhead, 1960b). More recently some countries have paid much attention to tree improvement as a means of increasing the productivity and wood quality of plantations and hence their profitability. This applies to both compensatory plantations on savanna sites (e.g. pines, eucalypts in Congo, Nigeria) and to TMF species (e.g. Triplochiton in Nigeria, Côte d'Ivoire; Aucoumea in Gabon; Terminalia superba in Congo).

176. A big problem for research, as for management, is the complexity and variability of the TMF. Most species of commercial value occur sparsely. The height of the canopy calls for large plots and large buffer zones. If responses to treatments are to be assessed separately by (a) species and (b) size classes, and if each sub-class is to constitute a statistically adequate sample, the total experiment size becomes very great. This fact has been fully recognized by the designers of the current research project in Côte d'Ivoire, described in Case Study 3, in which a single experiment including surrounds occupies 900 ha. Soils, topography, microclimate and perhaps other factors affect forest growth and response to treatment in ways that are very poorly understood.

177. The advances in computer technology over the last two decades are of great benefit to forest research. Before that, field measurements often generated far more data than could be analyzed and interpreted. Now data processing facilities are often available in forestry organizations within the countries. In addition, many African countries have access to the computing facilities which exist at international centres, such as CTFT at Nogent sur Marne or the Forestry Institute at Oxford. Multi-variate analysis of single trees may reduce the need for large plots.

178. Forest products research has concentrated on:

(1) Determination of physical and mechanical characteristics of TMF species previously little known but shown by inventory to occur at relatively high frequency.

(2) Utilization of methods appropriate to these species, in sawing, peeling and slicing, also in the use of wood for energy production (charcoal, calorific value, etc.) and for pulp and paper and panel boards.

(3) Best methods of treating wood (seasoning, preservation).

(4) Techniques of secondary processing (wooden building materials, laminated wood, reconstituted wood), with particular stress on the use of raw material which results from certain silvicutural techniques (plantation thinnings, products of natural forest refining). The economic utilization of such products often provides the key to the financial success of a given silvicultural method.

179. It is important that technological research on forest products should be planned in the closest cooperation with programmes of silvicultural research. An almost complete integration of these two essential branches of TMF research must be achieved in order to gain the knowledge which could be the basis for profitable systems of management in TMF.

## CHAPTER IV

## 4. CURRENT MANAGEMENT NEEDS IN AFRICAN TROPICAL MOIST FOREST

### 4.1 Levels of Management

180. It is possible to consider management systems at two different levels. In the context of humid tropical Africa, the classical management system, sensu stricto, would normally consist of:

(1) Control of access: The legal proclamation of forest reserves and their protection against unauthorized uses;

(2) Inventory: The ascertainment of the resources contained within the forest estate;

(3) Control of harvesting: The organization of harvesting in an orderly and efficient manner, to ensure felling in accordance with a planned system of annual coupes, with maximum use of felled trees and minimum damage to the rest of the forest;

(4) Silviculture: Action to regenerate the forest, either naturally or artificially, including sample inventories to ascertain the adequacy of natural regeneration, and intermediate fellings to improve growth or composition of adolescent crops.

181. Because the forest estate was often "reserved in perpetuity", the objective of sustained yield of produce was considered both possible and desirable. In most forests wood was overwhelmingly the most important forest product. Because of the relatively large size of trees and logs, they are easier to inventory than non-wood forest products and are also more difficult to remove unobserved. Often, however, the numbers of species commercially valuable are a tiny fraction of the total number, therefore both harvesting and silviculture have been applied to only a part of the forest.

182. Some important categories of forest are on watersheds with steep slopes. In such cases, the primary objective of the management system should consist in maintaining the conservation function of the ecosystem, for soil and water resources; conservation is the dominant objective, with sometimes control of harvesting non-wood forest products or research and recreation as complementary activities.

183. In recent years there has been increasing realization that forest management, sensu stricto, cannot operate in isolation. It is constantly affected by political, economic and social factors, by the interactions between local, national and international needs for forest products and services, between wood markets, forest industries and forest harvesting, and between the competing demands for land for forestry, agriculture and urban development. Forest management, sensu lato, must take account of all these external factors.

## 4.2 Management Systems (sensu stricto)

### 4.2.1 Control of Access

184. In most African TMF countries the concept of permanent forest reserves, fully protected against unauthorized uses and illegal felling, has been incorporated in various legal ordinances. Where countries have varied greatly is in the degree of firmness used in enforcing the laws. In some countries forest boundaries have been regularly maintained and illegal acts in the forest promptly prosecuted, in others forest clearing for agriculture has spread from outside to inside forest reserves or forêts classées, with tacit acceptance by the authorities. Where increasingly dense populations create urgent demands for scarce land for food crops, limiting access to forests will become very difficult to justify and to implement.

185. Little was done until fairly recently to win support for permanent reserves from local populations, and independent administrations still need to do much more in this respect. Not only is there a need for a vigorous and persistent campaign of education and public relations on the importance of sustainably managing forests, but more needs to be done to ensure that local communities derive their full share of the benefits generated by the forest, whether products or services. While the national forest service should retain responsibility for management, local communities should participate fully in the planning and execution of management, and should receive a share of revenue from forest products, as has been practised in Nigeria (Lowe, 1984). Local people are much more likely to help conserve a forest which they regard as "ours" than the "theirs" of a distant and impersonal national government. Scientific land use planning should maximize the land's productivity for different uses, but rural people must endorse and approve these plans for their successful implementation.

### 4.2.2 Forest Inventory

186. A great deal has already been done to standardize forest inventory techniques and there is general agreement of practice between anglophone and francophone countries in African TMF. Inventories are usually carried out to provide information on:

(1) areas;

(2) stand types;

(3) species composition;

(4) quantity and quality of the resource;

(5) volume distribution by species and diameter class.

Dynamic aspects of changes in forest resources and site qualities are especially important. Several levels of inventory are recognized, from the very low percentage national forest resource survey, using modern aids such as remote sensing, to the 100% inventory of commercial species over the minimum harvestable diameter limit on an annual coupe, which may be carried out by the harvesting concessionaire. Most past inventories have concentrated on the larger trees over or just below harvestable size, but techniques are also available for diagnostic sampling to assess the extent and silvicultural condition of young regeneration, from seedlings to pole size trees.

187. Recurrent forest inventory is also an integral part of management. It enables the forester to acquire the information on growth, mortality and recruitment that is essential if management is to be based on a clear understanding of the dynamics of the forest over time. Permanent sample plots, receiving exactly the same treatment as the rest of the forest, and containing numbered and/or mapped trees which can be identified and remeasured at each assessment, constitute a suitable method.

188. Apart from the constant striving to reduce the cost of inventory while still achieving an acceptable standard of precision of estimate, specific items which still present problems are as follows.

(1) The estimate of factors which can be used to convert species, diameter classes and numbers of trees into net commercial volume. Allowance needs to be made for defect, accessibility, topography indexes and markets. These factors differ from place to place and, in the case of markets, from one year to the next, so integrated conversion factors need to be prepared at the local level and adjusted from time to time. It is precisely these factors which give rise to disagreements between the forest service, on the one hand, and harvesting enterprises on the other. For this reason it is often desirable that, in the case of inventories in forest blocks about to be subject to concession agreements, the concessionaire or candidate concessionaires should be fully associated with the work of the inventory, to avoid subsequent argument (Catinot, 1986).

(2) The estimate of non-wood products, the so-called "minor forest products". These are usually ignored in a standard forest inventory. Fruit trees should be included in the list of species recorded, whether or not they also produce timber. Useful species among the herb and shrub layers may be difficult to quantify, but their presence should always be recorded in qualitative terms. In a few cases, if the product is of great value, quantitative inventory may be required, using a similar technique of sub-sampling as for the assessment of regeneration. But it is pointless to collect a mass of information which cannot be effectively used. Inventory of commercial timber trees is used to control harvesting yield. If non-wood forest products are harvested by numerous local individuals working freely and on a small scale, control becomes difficult; in this case qualitative information on the extent of the resource may be sufficient.

#### 4.2.3 Control of Harvesting

189. The granting of exclusive tree felling licences to concessionaires has been a common method of controlling harvesting in both anglophone and francophone countries. Standard conditions included in most licences have included:

(1) a definition of the duration of the licence;

(2) a definition of the area covered by the licence;

(3) a definition of the trees which the licencee is obliged to fell. In some cases every individual tree may be marked for felling by forest service staff. In others, trees for felling may be defined by a combination of (a) species, (b) minimum diameter, (c) quality (i.e. the concessionaire may not be required to fell obviously rotten trees of "obligatory" species);

(4) felling rules (e.g. maximum stump height, directional felling to limit felling damage);

(5) provision for orderly working of the licensed area by means of annual felling coupes;

(6) provision for forest road construction by the licensee;

(7) provision for processing e.g. minimum standards of mill construction, percentage of roundwood to be processed;

(8) annual yield, defined in terms of either area or volume. Where yield is on an area basis, the forest service should be able to provide inventory data to the licensee on average volume yield/ha to be expected;

(9) provision for payment of forest fees, by volume and/or area, including minimum annual fees, advance deposits, etc;

(10) special provisions e.g. provision by the licensee of labour to fight forest fires or to perform silvicultural operations.

190. Simple rules of this sort, if conscientiously followed, can lead to an orderly and efficient harvesting of the forests. In some areas where there was a good initial stocking of younger age classes, the observance of minimum diameter limits has been followed by the development of promising stands of juveniles or adolescents, even after several harvesting operations; this is the case in certain forests in Côte d'Ivoire investigated by SODEFOR/CTFT. Catinot (1986) has pointed out the most obvious defect of this system, the disproportion between the value of the trees felled and the amount of money put back into silvicultural operations to ensure regeneration. Most governments have not set up a National Forest Fund which could be financed by forest fees; instead the fees have been absorbed into the general revenue of the country. This is not a criticism of the system of controlling harvesting per se, it simply underlines the fact that control of harvesting is not management in its full sense. As has been pointed out in other regions (Hutchinson, 1987), some form of silvicultural treatment is an indispensable complement to diameter limit cutting. Otherwise structural and genetic degradation will occur. All of the timber plantation schemes implemented only represent a small part of the volumes removed from the natural forests.

191. Various attempts have been made to convert the conditions of concession agreements into a more effective tool of management. In the Central African Republic, one agreement made in about 1970 was for 130,000 ha of forest to be harvested over 15 years, with an average annual yield of 130,000 $m^3$ of logs, of which at least 50% were to be processed locally within the Republic. The most interesting condition in the agreement was that the concessionaire was to provide, free of charge, up to 2,800 man-days per year of labour for silvicultural operations to be supervised by the forest service. These operations were to include climber cutting and felling of understorey trees on areas already harvested commercially, as well as the marking of individual trees of fine timbers in the size classes just below harvestable, in advance of harvesting; particular care was then to be taken not to damage these marked trees during subsequent felling. Catinot (1986) has pointed out that the benefits of the silvicultural treatments could be expected to become apparent when the treated adolescent trees reached harvestable size at the end of a felling cycle of some 30 years. Provided, therefore, that the harvesting enterprise continued to fulfill its obligations to the satisfaction of the government, it would be logical to extend the agreement to a period at least equalling the felling cycle. The enterprise would itself then reap the benefits of its expenditure on silvicultural operations. If the system had worked well and for a sufficient length of time, management would have renewed the forest resource, integrating harvesting and regeneration in such a way that the harvesting enterprise could expect with confidence an adequate yield from a second cut after a known interval.

192. Unfortunately this trial of planned management was abandoned after a few years, before its results could be assessed. The govenment reverted to earlier and looser types of licence, awarded over very large areas and with no provision for regeneration operations.

193. More recently, since 1982, the People's Republic of Congo has divided the forest estate into a number of separate units, known as Unités Forestières d'Aménagement (UFAs) or Forest Management Units, to be managed in accordance with management plans prepared by the forest service. The main provisions are as follows.

(1) Each UFA to be covered by the national forest inventory before harvesting is allowed to start.

(2) A list to be drawn up of the preferred species in each UFA.

(3) Yield to be regulated in terms of the "Volume maximal annuel de coupe (VMA)" or maximum volume allowable per annual felling coupe, derived from the total estimated volume of the preferred species of harvestable size in the UFA (from previous inventory), divided by the proposed felling cycle. The felling cycle is equal to the period judged necessary for the adolescent trees which survive the felling to reach a diameter in excess of the minimum harvestable diameter.

(4) The VMA is applicable to each preferred species separately, as well as to all together.

(5) The entire UFA may be allocated to a single concessionaire or it may be divided into two or more "Unités Forestières d'Exploitation" (UFEs) or Forest Harvesting Units, each allocated to a different concessionaire. In the latter case a separate VMA is fixed for each UFE.

(6) Felling in a given year is to be confined to a well defined annual coupe, to be demarcated by the concessionaire by means of a 3 m wide cleared strip. Each coupe to be felled completely in one year (exceptionally two).

(7) After completion of felling in any coupe, no further felling is allowed in it until the expiry of the felling cycle.

(8) The concessionaire is to carry out 100% enumeration of all harvestable stems in a coupe before starting felling operations.

(9) Provision is made for grading of logs by species, length, diameter and quality; logs which fail to meet the minimum grade need not to be extracted from the forest.

(10) Concessionaires are obliged to pay forest fees on the fixed VMA of preferred species, whether or not they actually harvest that amount. Where necessary, they may complete a coupe within one year after schedule and, if there is a crisis in wood markets, the Ministre des Eaux et Forêts may reduce the VMA.

(11) Management plans are to be revised every 5 years.

194. Although the UFA management plans go to considerable lengths in providing for close control of harvesting, there is very little mention of silviculture, only a brief statement that the Secretary General of the Forest Service is to prepare a programme of improvement operations in natural stands within Forêts Classés. Without more explicit and detailed prescriptions about regeneration, the plans remain extremely useful and interesting prescriptions for harvesting control but are not management plans in the full sense. They are, however, the initiation of what might be called extensive management. In terms of institutional strength and infrastructure, it is not possible to jump from no management to fully controlled, intensive management. Also, where timber resources are in abundance, it is difficult to justify investment in intensive natural forest silviculture. The UFA system begins the institutional strengthening necessary for forest departments to control timber harvesting companies. It also builds technical capabilities for inventory and cartography that are necessary for natural forest management, whether intensive or less intensive. During ten years of cooperation between

the Government of the Congo and FAO, these plans have functioned well. It is hoped that the system can be maintained and that it will conserve the resources so that more intensive and productive management systems can gradually evolve. One idea worthy of great interest is the proposal of the government to confide the development of certain UFAs to local communities.

195. In Cameroon, various plans for the management of the proposed "model" forest of Deng-Deng have been put forward by FAO or the Forest Service over the past twenty years. None have been accepted by the Government. Harvesting by the SOFIBEL company has been going on since 1977, with apparently no attempts at regeneration and very little control of harvesting other than the allocation of a series of 2,500 ha coupes.

196. There can be no management without political commitment, but management plans must be applicable to the actual on-the-ground conditions. There is no one formula which will work in all situations. Catinot (1986) has pointed out that forest services should be realistic in the obligations which they impose on harvesting enterprises. One case in point is the list of obligatory species, which should be related to the current and local conditions of marketing; a concessionaire forced to fell and remove species which he cannot sell will soon be out of business.

197. The retention of seed-bearers from among the desirable species over the minimum harvestable diameter also presents a number of disadvantages (Catinot, 1986). There is an immediate loss of yield and hence of profit to the harvesting enterprise. If the seed-bearers are allowed to stand for a full felling cycle, they are likely to have deteriorated from overmaturity and resulting internal decay before they can be harvested. If the harvester is allowed to return in say 5-10 years time, there will be renewed felling and extraction damage to the residual crop just as it is showing its maximum response to the previous felling and refinement operations. The depressive effect of shading and competition which the seed bearers exert on the increment of established advance growth may outweigh the benefits of new (and possibly ephemeral?) regeneration.

198. There is, however, inadequate information for most TMF species on the effects of age and size on the quantity and quality of seed production. For example, will 3 adolescents of 50 cm diameter produce as much seed (and better distributed) than one mature or overmature tree of 90 cm diameter? Will the genetic quality be so good? If the smaller trees are small because they are young, they may have just as good a growth potential as the larger mature trees. But if they contain a proportion of old, slow-growing trees, then reliance on seed production from smaller trees may lead to progressive deterioration in genetic quality. The lack of reliable annual rings in most TMF species increases the difficulty of distinguishing between young fast-growers and senile slow-growers. One advantage of a monocyclic system is that it eventually produces more or less even-aged crops growing in more or less uniform conditions, so that fast-growing genotypes will tend to dominate and slow-growing genotypes can be gradually eliminated.

199. As long as the silvicultural arguments for and against retention of seed-bearers are evenly balanced, it is unrealistic to require the logger to leave, for example, one tree per hectare out of a total of only three commercially marketable. In addition to phenological studies on flowering and seed production as related to age and size; studies on the importance of the soil seed bank in the regeneration of priority species should also be intensified to support the development of sound guidelines in this respect.

200. Other conditions of an agreement in which some flexibility is needed include the following.

(1) Minimize damage to advance growth. Since every felled mature tree destroys 0.02-0.04 ha of forest, some damage to advance growth is inevitable. Marking of an excessive number of adolescents "to be preserved intact", with penalty clauses for damage, would be unrealistic.

(2) Involvement of the concessionaire in strictly silvicultural operations. For example, inventory of young trees below the minimum harvestable size should be the responsibility of the forest service, which should also be involved jointly in the inventory of commercial trees above the minimum diameter limit. In the case of regeneration or stand improvement operations, even if the concessionaire provides the labour, technical supervision must be the responsibility of the forest service.

(3) Working of annual coupes. Allowance should be made for the "carry over" of part of a coupe into the next year if conditions (excessively wet weather, depressed markets) have made it difficult to complete the coupe on schedule.

201. At the same time reasonable provisions must be strictly enforced. Harvesting enterprises are primarily concerned with short-term profitability, and it is up to the forest service to ensure that the long-term asset of the forest resource is not sacrificed.

#### 4.2.4 Silviculture

202. There is a large degree of common experience among African TMF countries. Three major strategies have been employed in the past to regenerate the forests. They are:

| | | |
|---|---|---|
| (1) | natural regeneration | following a conversion felling and aiming at a "uniform" new crop, or with polycyclic fellings aiming at uneven aged crops of the upper canopy species; |
| (2) | enrichment and/or compensatory planting | utilizing indigenous species, especially those of high timber quality; |

(3) concentrated plantations — utilizing short rotation species for utility grade sawlogs and pulpwood.

Some examples of specific methods of artificial regeneration are described in Chapter III (paragraphs 122-137).

203. The TMF is multi-storeyed with a wide range of tree heights and diameters. Mature trees of the valuable species are sparse and scattered, so selective fellings of these species disrupts the canopy only slightly, and does not radically reduce the biomass, nor the degree of inter-tree competition, nor greatly increase the illumination at ground level. In contrast, clearing operations remove the biomass which may, at least in part, be regenerated quickly by short-lived, fast growing clasmophytes, such as Trema and Macaranga species, along with a mass of herbaceous and woody climbers, all growing in full light. The results of canopy manipulations between these extremes depends upon the ecology of the forest and the autecology of the species whose regeneration is sought.

204. Both Catinot (1986) and Philip (1986a) note the failure of natural regeneration and enrichment systems when felling was restricted to only a few stems per ha, and the relative success with more concentrated patterns of planting in lines, bands and concentrated plantations - especially in the latter case when combined with "taungya farming". The best results, not surprisingly, were achieved using species characteristic of early seral stages of the forest ecosystem, for example Terminalia species, Triplochiton and Maesopsis, etc. However, Catinot notes the rising costs of such operations and their unfavourable economic returns compared to those of natural regeneration. They do, of course, produce higher yields per unit of land area. Karani (1985), reporting for Uganda, links the needs of local people and urban areas for fuel to the opportunity of achieving more complete harvesting of the existing forest. The extreme case is complete clearing for charcoal manufacture, and subsequent re-establishment of the tree cover by planting a uniform crop of Maesopsis under which a natural understorey develops.

205. African TMFs are too diverse for any one system to be suited to all. The ecological state of the forest, its specific composition, the extent of the population of woody climbers, tree and crown size, the degree of canopy disruption in past decades and the intensity of harvesting will all affect the response to treatment. The need for the forester to be seen to be working, investing in and actively managing the forest is also vital in maintaining the support of the government and the local community. The choice of an appropriate silvicultural technique, thus clearly demonstrating that the forest is a valuable production system which is being wisely utilized, is part of the strategy of conserving the forest and avoiding conversion of the land to other uses.

206. Although the ecological diversity of TMF makes it most difficult to generalize, certain guiding principles for silviculture may be set down as follows.

(1) Species that regenerate most readily are either those with a relatively balanced diameter frequency distribution in the forest before harvesting starts, or the fast growing, light demanding species characteristic of the colonizing or early seral stages of forest succession. In fact, few species in the African TMF fall in the former category.

(2) The greater the destruction of the canopy the more favourable the conditions for growth of the species characteristic of the colonizing stages, providing they were not swamped by lianes. The success of both the Uganda and Subri techniques depended upon almost complete clearing accompanied by natural re-seeding with or without planting.

(3) The more valuable species such as many of the Meliaceae flourish under a more broken or light canopy such as develops when the colonizing stage species mature.

(4) Where the forest canopy has been subject to interference over a protracted period and, as a result, the population of lianes in the upper canopy layer is both dense and vigorous, canopy destruction may be disastrous and result only in the establishment of a climber tangle that persists for more than a decade.

(5) Enrichment is unlikely to be successful except with exceptionally fast growing, light demanding species growing without overhead shade. Attention is drawn to Dawkins' conditions (paragraph 56 of Case Study No.1) that still appear to be valid.

(6) Little technical difficulty has been experienced in developing techniques for the conversion of the TMF to pure, even-aged plantations of exotics. There are instances of disease - root rot, Fomes lignosus, in teak; shoot borer in Terminalia ivorensis, etc. but, as yet, they have not had catastrophic effects on the over-all success of at least the first generation of plantations.

(7) Studies of soils under plantations have indicated rapid changes in the physical and chemical conditions but, again, none apparently catastrophic at least in the short term. There have been examples of locally severe sheet and gulley erosions under plantations of many different species, Tectona grandis, Cupressus lusitanica, for example, but none that could not be avoided by appropriate silvicultural action such as thinning to encourage an understorey.

207. The controversy between the advocates of polycyclic and monocyclic felling systems is often exaggerated. Where the eventual adoption of a monocyclic system is advocated, as in Uganda, it is preceded by first a salvage felling cycle (taking 30 to 40 years) to remove overmature trees, and then a conversion cycle which follows

30-40 years later on the first annual coupe but, by successive adjustments of the coupe areas, about 80 years later on the final annual coupe. Only in the third cycle is the monocyclic system fully operational, with felling cycle equal to rotation (assumed to be 80 years, in this case).

208. Supporters of polycyclic systems assess the possibilities of maintaining a yield at the second felling at least as high as that at the first felling, which took place in a forest not disturbed in the recent past. For example, if appropriate silvicultural treatment (harvesting + arboricide + climber cutting) can induce a mean diameter increment of at least 1 cm per year on the adolescents and if the minimum harvestable diameter is set at 60 cm, then a stocking of 15 desirable stems per ha between 30 and 60 cm in diameter which survive the first felling should, on a felling cycle of 30 years, provide an adequate yield at the second felling (Catinot, 1986). If all survive to reach a mean diameter of 75 cm, they should yield at least as high a volume as the 4-5 trees of mean diameter about 110 cm which are commonly removed in the first "salvage" felling. The produce may, however, be of less value, because of inferior log size and, for fine timbers, a higher percentage of sapwood.

209. It can be seen that, for the first 30-40 years, there is no distinction between the future monocyclic and the future polycyclic system of the above examples. During this period, it should be possible for research to shed more light on the controversy. An important need is to look further ahead to the third felling, which is when the two systems really diverge. Of the juveniles (0-30 cm diameter) present before the first felling, how many will be damaged in the first felling and arboricide treatment? How many will be damaged in the second felling and treatment? How many will survive during the intervals between felling? How many will be distorted by climbers? How many are inherently slow-growing or reach premature senility, so that they fail to achieve the predicted increment of 1 cm a year? How many will be so suppressed by their position in deep shade that they fail to respond even after subsequent removal of the canopy? The excessive degree of felling damage and the failure of long overshaded trees to respond to treatment are the two main arguments against polycyclic systems and they have still to be convincingly refuted. On the other hand, the assumption under the monocyclic system that seedling and sapling advance growth damaged by felling can be cheaply and successfully coppiced, would also benefit from more extensive research results. Although silvicultural plans should conceptualize the end of the rotation and successive rotations, history shows that the context of management, the socio-economic conditions in TMF countries, changes very quickly in relation to long rotations. Clearly then, management plans must be flexible, and it is much more important to implement what must be done this year and in the next five years than to conceptualize what may happen in the distant future.

210. The choice between natural and artificial regeneration must differ according to local circumstances. Philip (1986a) has argued that the manager is well advised to convert the TMF to plantations with a high productivity under the following conditions:

(1) intense competition for land that accompanies high population density and rates of increase;

(2) high local demand for processed forest products and for fuelwood;

(3) investment capital is available;

(4) financial and technical expertise are available.

Frequently, the highly productive species are exotics, and since the investment in intensive plantation forestry usually is higher than that for natural forest management, there is a higher level of risk. When only some of the above conditions exist, then the decision is in balance. Often a key consideration that makes the risk unacceptable is a lack of skilled personnel with adequate experience in financial control and management.

211. Establishing extensive plantations to serve complex and large scale processing plants without prior knowledge on species and provenances; or adequately trained and experienced staff to run the harvesting and transport operation, is exacerbating this risk. If the decision is in favour of plantations, then the maintenance of the conservation values of the TMF has to be performed in conservation areas whose critical size will depend on well-defined objectives.

212. In a country that:

(1) has little conflict over land allocated to forestry and agriculture;

(2) has a demand for high quality tropical cabinet woods and sawn timber of other species;

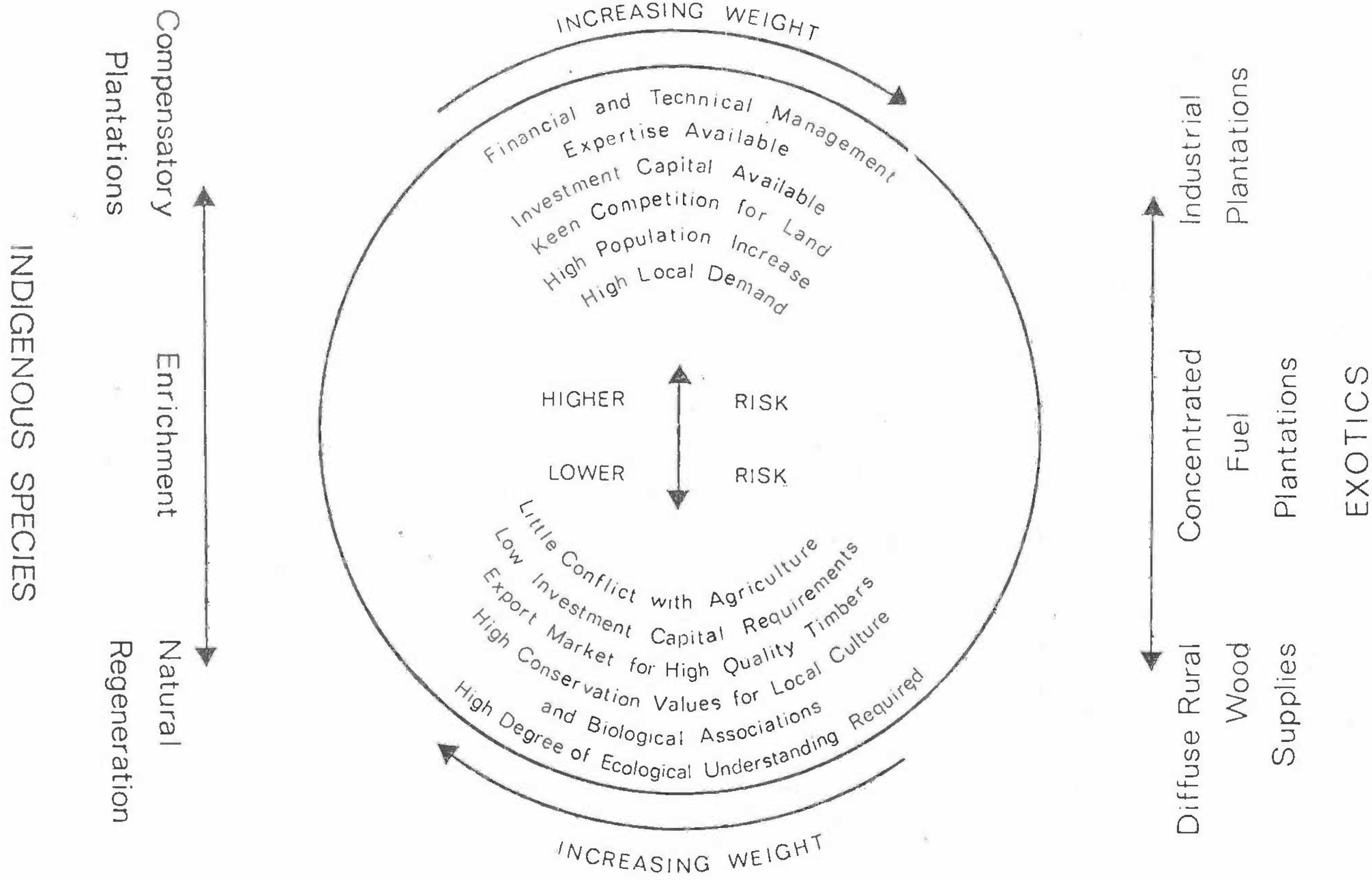
(3) has gained knowledge of the ecology of its forests;

(4) values the conservation aspects of the natural biological associations,

the forest administration can manage the natural forest with little need for intensive capital investment and less risk of disaster. Nevertheless, populations grow inexorably and the pressure on the forest land is certain to increase; consequently developing programmes in land-use planning for conservation and for implementing the most productive land use and comprehensive programmes of education to sustain the policy of retention of the natural assets, must have a very high priority. Figures 2 and 3 indicate in schematic form some of the silvicultural options, and the factors which affect their choice.

213. In some areas there may be a combination of artificial and natural regeneration. Where conditions favour natural regeneration in general, as noted in the previous paragraph, but certain coupes are found to be deficient in natural regeneration of desirable species, some form of enrichment planting may be necessary to supplement it.

Figure 2. The Options in Tropical Moist Forest Management (Source: Philip, 1986a)



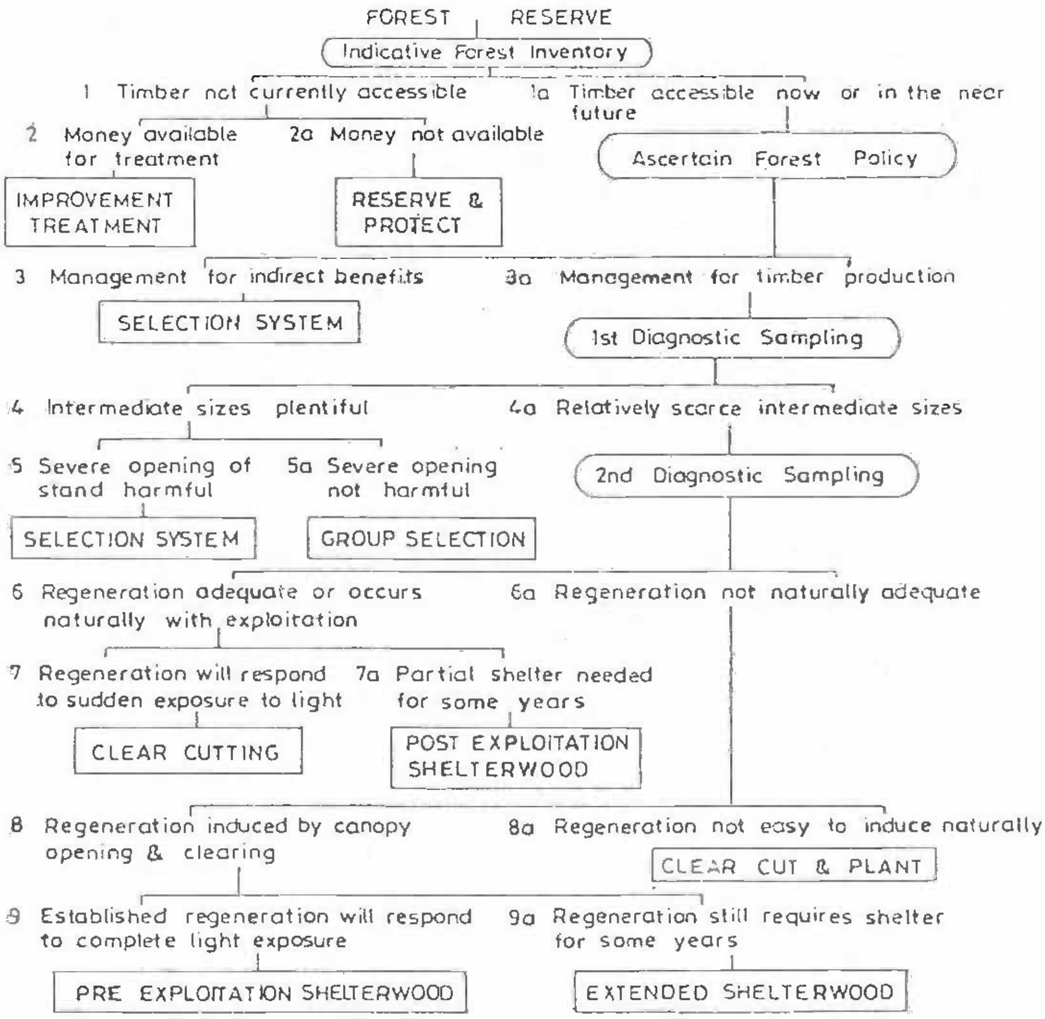



Fig. 3. Management chart for tropical moist forest.
(Source: Kio et al., 1985)

214. Catinot (1986) has quoted figures which suggest that, over a 30 year period, the ratio of yield at felling to establishment cost is not very different between natural regeneration (yield 25 $m^3$ per ha, establishment cost US$ 125 per ha, cost per $m^3$ US$ 5) and artificial (yield 250 $m^3$ per ha, establishment cost US$ 1,625 per ha, cost per $m^3$ US$ 6.5). The somewhat higher production cost of the plantation timber would be offset by the shorter time period for compounding investment costs and the lower logging costs due to harvesting an equivalent yield on one tenth of the area needed in the natural forest. The natural regeneration yield is based on the increase in yield due to silvicultural treatment, as estimated based on the SODEFOR-CTFT research in Côte d'Ivoire.

215. The large quantities of homogeneous raw material required for certain forest industries, especially pulp mills, usually call for plantations. But these do not always need to be sited on cleared TMF sites. The paradox of forestry in some African countries is that the conversion of the TMF to plantations is being put into practice while deforested or savanna zone land is relatively abundant nearby (Philip, 1986a). The forest administrations are being asked to produce more from the reserved TMF in order to withstand the pressure to convert them to agriculture. Their solution involving conversion, at least in part, to intensively managed plantations imperils the traditional values of the forests to local communities, the wider public and generations as yet unborn. The solution also applies an enormous work load to both the administrative and executive arms of the forest service. The risks are:

(1) loss of the tangible and intangible values of the natural forest;

(2) failure to meet the required level of expertise in management demanded by the capital intensive industries;

(3) failure to conserve the productivity of the site;

(4) inadequate attention to basic needs of local communities for fuel and other products.

216. Insufficient attention appears to be given to the option of using the savanna zones more intensively. A number of TMF countries, for example Congo, Nigeria and Uganda, have research programmes on savanna afforestation. However, the need to be seen to be making the reserved areas of TMF more productive has prevented large scale investment in areas where, admittedly, growth will be slower and the fire danger will be greater. The fact that such development could be done while the TMF is conserved at the same time, is seen as an ineffective counter to the demand for its conversion to agriculture. A change of attitudes by sound information and awareness campaigns based on technical and socioeconomic facts (considering also the non-wood and protective values of the TMF), is needed to allow a more balanced review of options at decision-making level.

## 4.3 Management Systems (sensu lato)

217. Whilst forest services can exercise some options in day to day management, e.g. in choice of the most appropriate local techniques in inventory or silviculture, they and the higher levels of national governments are very much affected by policies in other sectors such as industry, agriculture and economic development. The major forces and imported factors that can be seen to be operating to varying degrees are (Philip, 1986a):

(1) the extent of the natural resource and its distribution in relationship to concentrations of population;

(2) the density of the population relative to the land and forest resources, and its rate of increase;

(3) the degree of urbanization and general industrialization;

(4) the form of agriculture and land tenure;

(5) the political structure;

(6) the general level of demand for wood fuel, sawn wood and other processed wood products both in the moist forest zone and in the drier areas;

(7) the history of the trade in logs and sawn wood;

(8) ease of access to capital;

(9) availability of technical, managerial and supervisory expertise;

(10) extent of knowledge and success with natural regeneration in the natural forest;

(11) availability of land outside the high forest zone suitable for conversion to plantations;

(12) the appreciation by the people of the values of forests both natural and artificial, and its expression in political organization.

218. A sound forest management system must take account of all these forces when planning the development of the forest resource. It should attempt to estimate the direction and intensity of the influence of each factor in the local situation, not just at the present but also in the future.

### 4.3.1 Pressure for Land

219. No forest management system can function without a forest to manage. Therefore, pressure to remove land from forestry and convert it to other uses, whether agricultural, domestic or industrial, must be considered the single most critical factor in forest management in the broad sense. Massive forest clearings have taken place over the past twenty years in many TMF countries and in some areas reserved

forests have not escaped destruction. This clearing is associated with a high annual rate of population increase, generally in excess of 2.5%. Obviously, this has the greatest effect in those parts with the highest population densities, that is Nigeria and some regions of Uganda, Ghana, Côte d'Ivoire and Sierra Leone. The areas of high population densities often coincide with the remaining areas of TMF, for example towards the coast in Nigeria and Côte d'Ivoire and in the highlands of Kenya. Although increased density of population leads to increased demand for forest products, especially wood, and so to more intensive utilization and an opportunity for more efficient management, it also accentuates the pressure to convert forest land to agriculture, on the grounds that food is even more essential than wood and forest products. Land pressure can be eased by improving the productivity of both agriculture and forestry, but in the long run stabilization of populations offers the best hope of maintaining the TMF as forest.

### 4.3.2. International Trade and Local Wood Demand

220. In certain countries in West Africa the influence of overseas markets has been powerful for nearly a century. Characteristics most sought after by these markets were (a) dimensional stability, (b) decorative figure, and (c) ease of working. Often the goal was to find a substitute for West Indian mahogany, teak or oak. Only large, high quality logs could support high transportation costs. The above characteristics are still important, even though often solid wood has been replaced by veneer. Consequently, the economic climate in the importing countries governs demand and is a vital factor in the management of the TMF. The costs of processing, wherever it is done, are also important, and factors that affect this - such as interest rates, energy costs, exchange rates, etc. - affect the management of the forests. Such interactions must be studied and understood in any analysis of TMF management systems.

221. Mass production of furniture increased after the Second World War and led to increased demand in Europe for less expensive, bland white woods - such as Triplochiton - for the hidden parts; as well as for plywoods - such as Antiaris and Tetraberlinia - and surface veneers, made from the traditional, high-quality species. In colonial East Africa the establishment of tea estates after India achieved independence, promoted a demand for plywood for tea chest manufacture. One can see the complexity in the trade in wood in these examples; an action in one part of the world triggers a reaction elsewhere. Changes within a country also affect trade; rising local demands compete with exports and increasing population and urbanization raise the total drain from the forest, so that products previously exported are used locally and forest land is cleared for food crops or alienated for urban services.

222. The political scene also exerts an enormous influence on the forest. Politicians have to balance the need of the country for the external earnings of the timber trade against local demand for land and forest products. The overseas trade cannot be abandoned lightly where it dominates the economy, and the forest:

(1) is a source of raw material drawing overseas investment into the country;

(2) provides local employment;

(3) provides a base for local investment and the development of local manufacturing and entrepreneurial skills.

223. Industrialization has been advocated as the solution to the problems of the less developed countries and it has accelerated the trend towards urbanization. The concentration of the population changed the patterns of both supply and demand as the needs of urban populations are different from those of rural dwellers. Charcoal tends to displace bulky firewood; sawn timber and concrete replace roundwood; and the demand for more sophisticated processed wood products rises. Also competition for scarce resources of land, capital and particularly, trained personnel becomes acute both between government agencies and with the independent business sector. Increasing awareness that forestry is very important, even central, to environmental conservation and sustainable economic development, attracts national and international investment. This creates demand for skilled managers and there is often a delay in developing these human resources.

224. The conflict between local demand and the export markets and the competition for logs met by local processing plants on the one hand, and the need to concentrate exports on products with high added values on the other, resulted first in a ban on roundwood exports and later a ban on almost all timber exports as, for example, in Nigeria.

225. Access to outside capital went hand in hand with trade. The stronger a country was economically, then the more aid it attracted (although many aid formulas are, and have been, inversely proportional to <u>per caput</u> GNP). Capital was in demand not only to expand manufacturing but mainly for the improvement of infrastructure, communications, health services, education and facilities of all kinds. The natural forest in all countries played an important role in providing the wood for this type of development, but a price was paid first in the exploitation of the forest resource and secondly in the rise in demand, not only for traditional products and processed articles from the forest but for more technically advanced processed products. These cost foreign earnings if imported and thus raised a demand for processing facilities within the country. As fast as a country developed so its needs increased. The benefits from any development were spread over an ever increasing number of people, so the net benefit per person was small, while the costs in terms of impoverished natural resources were sometimes large. This situation is facing the forest managers in e.g. Nigeria and Kenya today.

#### 4.3.3. Forest Industries

226. Currently there are few mills of 50,000 $m^3$ intake and most work at only 50% of capacity. Yet the modern plants now being constructed or contemplated require an annual intake of 100,000, 200,000 $m^3$ of wood, or more. The lack of mills currently working with a capacity of

even 50,000 m³ per year, means that the pool of experience and expertise available to run larger plants is very limited. Lowe (1984) suggests that the reasons the existing mills rarely operate at more than 50% capacity over extended periods are because of breakdown in log supplies, power supplies or machinery.

227. Modern, large scale wood processing plants are capital intensive. A paper by Mac Neil (1981) gives the following crude data indicating the level of investment in different plants (Table 15):

Table 15. Investment Levels for Wood Processing Plants

| Type of Plant | Output ($10^3 m^3$) | Investment ($10^6$ US$) |
|---|---|---|
| sawmill with kilns | 70 (2 shifts) | 19.0 |
| plywood mill | 20 (2 shifts) | 13.5 |
| plywood mill | 40 (2 shifts) | 22.0 |
| medium density fibre board mill | 60 (3 shifts) | 23.0 |
| particle board mill | 60 (3 shifts) | 21.0 |
| hard board mill | 53 (3 shifts) | 32.0 |

This scale of investment implies heavy fixed charges that have to be spread over the minimum planned production or the costs per unit of production are inflated to levels that make the plants uneconomic. Normally, shift working is required and down-time from whatever cause should be strictly controlled. As with harvesting, only good management served by skilled and responsible staff, as well as supported by reliable supplies of wood raw materials, other materials and supporting services, including adequate financial resources for maintenance and replacement, can ensure effective cost control. Developing countries do not have control over many of these aspects of management. For example, current decreased demand has depressed prices of raw materials and reduced the foreign earning capacity of many developing countries. Often this forces governments to curb imports through a variety of control measures the result of which is delay in the arrival of essential materials, spare parts, and technical services. Such almost inevitable events mitigate against success in complex industrial enterprises. Developing countries have surmounted many of these difficulties by a variety of strategies, including contracting management to specialist organizations. Nevertheless, all such organizations, whether contractors or quasi-government corporations, must work within the general economic framework of the country and cannot be entirely insulated from such disruptions.

### 4.3.4. Research

228. The physical factors of the environment of regions with TMF can be considered generally similar, but the ecological and biological factors, especially those that interact with the human or social factors, may vary quite widely. A sound foundation of fact about the ecology of the forest and the biology of its constitutent species are essential if reasonable deductions are to be made by comparison with other areas. The more simple the ecological frame, the more likely appropriate experience can be gleaned from another apparently similar area.

229. The success of the management systems adopted in the TMF of Uganda has been deduced to be due to the relatively simple ecological succession apparent in these forests, especially in Budongo (Philip, 1986a). In turn, this simple succession has been attributed to the relative lack of human interference. In contrast, the reverse is, perhaps, true of the forests of Nigeria where the extent of disruption of the canopy and persistence of climbers has been attributed to the secondary nature of the forest after centuries of human use. The history of recurrent interference in the forest even in recent decades in Nigeria by the concessionaires has exacerbated a situation already inimicable to simple manipulation by foresters. To some extent, the same situation was apparent in some of the forests of western Uganda where climber tangles proliferated after repeated incursion into regeneration areas by elephants.

230. Many have referred to the complexity of TMF, its diversity and richness in species, all of which has meant that the response to blanket canopy treatment has been uncertain. Hence the value of knowledge on the autecology and biology of the species, especially those either sought after or to be proscribed by the forest manager, is invaluable. The types of information needed to improve on prevalent management methods, include:

(1) the composition of associations;

(2) the seral succession;

(3) the physiological characteristics and responses of individual species - not only of those with marketable timbers -, especially their rates of growth, growth patterns, breeding systems, flowering and fruiting periodicity, means of dispersal, and conditions for establishment and success.

Such knowledge must be complemented by knowledge of timber properties and uses.

231. Lessons can be learnt from the type of research that was not successful, only partly successful or extremely valuable. Ecological and biological research has passed through successive stages of:

(1) casual and systematic observation and description;

(2) permanent observation plots with recurrent assessment;

(3) unreplicated trials of comparative treatments;

(4) formal replicated trials;

(5) observations capable of multivariate analyses.

232. Replicated trials do have the enormous advantage of concentrating observation and assessment into small demarcated areas of the forest over a number of years. Analyses on a plot basis alone, however, may not always yield results of adequate precision in such complex ecosystems. They can now be supplemented by the use of multivariate analytical techniques applied to data collected, often, at subjectively chosen but replicated loci. This subjectivity in the selection of observation points can make the data cheaper to collect and more representative of the variety of conditions in the forest. Nevertheless, recurrent measurements at demarcated points are irreplaceable as a means of recording change.

233. In addition to the general research items listed above, a number of more specific items are of priority. They include:

(1) development of an inventory sampling method capable of estimating, with a sampling error of ± 10%, the commercial volume (as opposed to gross volume) of any forest to be managed;

(2) quantification of the response, in growth rate, to felling/thinning/refinement operations over a wider range of forest types than those currently under study;

(3) long-term investigation of soil changes under managed "natural" forest and plantations;

(4) studies on species and provenance selection, species for site interactions and methods of genetic improvement, with the aim of increasing the productivity of plantations of native and introduced species and so improving the ratio of yield to cost;

(5) development of technology for the profitable conversion of small roundwood derived from plantation thinnings;

(6) investigation of wood properties of managed "natural" forest and of trees grown in plantations, as affected by shorter rotations, faster growth rates, and smaller log sizes than occur in unmanaged TMF.

### 4.3.5. Partnership between Harvesting and Silviculture

234. Both harvesting and silviculture have been discussed as parts of forest management (*sensu stricto*), but the integration of the two into a smooth and efficient working partnership is one of the most essential, and most difficult, elements of management in the broad sense. Catinot (1986) advocates a real, long-term partnership with mutual confidence and understanding - especially of its long-term nature and goals -, commercial realism and minimal constraints. Its adoption and success will require increased emphasis to be placed on harvesting, processing, marketing and business enterprise management in the curricula of forestry training schools.

235. A major difficulty in the development of a genuine partnership lies in the fact that, in African, as well as in other TMF countries, the harvesting and processing lobby is so often far more powerful than the forest service lobby. Where countries lack mineral resources and offer little attraction for tourists, the forests may be one of the few sources of revenue. The harvester/miller offers immediate revenue in the form of forest fees; if wood exports are involved, he offers an opportunity for the country to earn badly needed foreign exchange. The forest service, on the other hand, would like to spend government money on silvicultural operations and can only offer return benefits in the distant future. It is not surprising that governments sometimes pay more attention to the revenue-paying harvesting enterprise than the would-be spending forest service and that they shrink from imposing the least restrictions on the freedom of action of the former. Not surprising, but still wrong and, above all, shortsighted. Governments, like forest services, are custodians of the assets of their countries and should not condone any reduction in their long-term value in exchange for quick profits. The design of a suitable, simple, administrative organization, effective in controlling both the harvesting of the forest and the tending of the next crop, is the problem that has to be solved. This is as, if not more, important than deciding on which silvicultural treatment should be applied.

236. Catinot (1986) has outlined the various steps in an integrated management programme to combine both harvesting and silvicultural operations. Initially, action needs to be taken at the national level in several fields. In some countries the necessary action has already been taken, at least in some fields, in others it may be necessary to go through all the various stages.

(1) Where necessary, completion and updating of national forest inventory. In areas where existing inventories are 15-20 years old, new inventory may be needed. Maximum possible use should be made of satellite imagery, as a complement to ground operations.

(2) Drafting of new or up-dated maps showing the different forest/vegetation types.

(3) Subdivision of the national forest estate into management zones, on the lines of the forest management units of Congo. If possible, creation of a communal forest estate, owned and managed by local communities, to complement the national forest estate.

(4) Socio-economic study of each forest management zone, with a view to drawing up a realistic list of species which can be profitably harvested, either for local markets or for export. Where appropriate, stratification within a forest management zone may be proposed to take account of local differences in accessibility. Catinot suggests a team of three specialists to carry out this study: one in inventory, one in harvesting and one in economics.

(5) Preparation of a National Forest Development Plan, to include, if possible, a breakdown of the various forest management zones according to their priority rating for development. This plan should be incorporated as an integral part of the overall National Development Plan.

(6) If necessary, creation of new institutional structures, for example units for planning, execution and control of technical operations.

(7) Creation of a National Forest Fund, to be financed from forest fees and possibly from overseas aid and to be used to carry out a well-conceived and realistic programme of national forest management. To mark its determination, the government should set an example by deciding to earmark all forest and forest products fees which it collects to the National Forest Fund.

237. This last is the most revolutionary proposal of those outlined above. Although it may be over-optimistic to suppose that hard-pressed governments should pay over all forest revenues into a National Forest Fund, it would be eminently reasonable that they should pay over a substantial proportion. This would ensure that an increase in the volumes of wood removed from the forest, which automatically increases government revenue, would also automatically increase the money available for regenerating and tending the new crop.

238. Catinot (1986) has proposed the following procedures for the management of a large concession, involving close cooperation between forest service and harvesting enterprise:

(1) selection by the government of a candidate for the concession who shows adequate evidence of technical competence and provides financial guarantees;

(2) drawing up of a concession agreement specifying the area covered by the concession, its duration (15 years renewable is suggested), the annual cut proposed, the proportion of volume to be processed locally (e.g. 50%), the minimum quantity of production to be available to local markets, the time-schedule for setting up the harvesting organization and forest industry, the amount of area tax to be paid (per hectare of the concession), penalties in case of non-compliance with the terms of the agreement, etc.

Other conditions may be specified in schedules to the agreement and should include the following:

(3) division of the area into felling blocks. Each block should be open to the concessionaire for a period of 4-5 years;

(4) list of commercial species, established as a result of the previous economic study of the management zone in which the concession is situated, and approved by the concessionaire;

(5) minimum harvestable diameters for each species;

(6) inventory procedure. The concessionaire will himself carry out, in the 2-3 years before harvesting, an inventory of each block in succession, enumerating all trees of commercial species above harvestable size, by diameter classes, and estimating the net saleable volume. The forest service unit responsible for forest management will check the concessionaire's inventory by a 10% sample. It will also carry out statistical sampling of commercial species between 20 cm diameter and the minimum harvestable diameter;

(7) the period of harvesting in each block will be 4 or 5 years. In case of emergency it may be extended by one year;

(8) in addition to the area tax, the concessionaire will pay forest fees on the volume felled, in accordance with three rates of fee which correspond to the three species groups in which all exploitable species are to be divided. The groups are:

| | | |
|---|---|---|
| Group 1 | Fine timbers (ebony and red woods) | High fee |
| Group 2 | White woods for peeling or joinery | Medium fee |
| Group 3 | Other woods | Low fee |

By fixing a steep gradient of fees between the groups, it is hoped to help the concessionaire to find markets for the Group 3 species.

(9) the amount of fees will be revised every five years in accordance with market changes, or more often in case of gross market fluctuations and at the discretion of the government;

(10) the concessionaire must respect the usual felling rules, e.g. low felling height, marking of logs, maintenance of mill register, no abandonment of logs of commercial species. Every year he should provide a statement of harvesting carried out in the previous year and a harvesting plan for the following year;

(11) the forest service unit responsible for management will make periodic checks on the observance of the conditions of the concession, by inspection of the log yards or by checking the mill register. It will verify the volume recorded as felled by the concessionaire each year;

(12) the concessionaire will provide, free of charge, a stated number of man-days of labour to be devoted to stand improvement operations under the technical direction of the management unit of the forest service;

(13) after harvesting has been completed, the concessionaire will vacate each block for a period of 30 years, during which the management unit of the forest service will carry out any necessary silvicultural operations. Where a

sufficient number of advance growth adolescents (in general 15 or more stems/ha) have survived harvesting operations undamaged, operations will consist of refining the crop. Where the number is inadequate, planting will be required, either through enrichment, by clearing and close planting in situ, or by compensatory plantations elsewhere.

239. If all goes well and if the concessionaire fulfils all his obligations satisfactorily, it can be expected that his concession could be renewed to enable him to carry out the second felling in 30 years time.

240. Similar agreements could be made for smaller concessions (10,000-20,000 ha), but clauses about industrialization would be less strict and fees would be charged on the expected annual yield based on previous inventory, rather than on the volume actually felled. The management unit of the forest service would then be able to reduce its control operations to checking that minimum diameter limits and coupe boundaries were respected; measurement of every log would not be needed.

### 4.3.6. Non-Wood Resources

241. The forest has four major functions:

(1) conservation of the soil;

(2) conservation of water catchments;

(3) conservation of genetic resources (plant and animal);

(4) production of wood and all the other material products as well as intangible values for mankind.

242. Much of the preceding sections has been concerned with management for wood production. This is certainly an important function of the forest and, because of the large size of commercial trees and logs, it is relatively easy to quantify in terms of number of stems per ha, minimum harvestable diameters and annual yields in $m^3$. But the non-wood functions of the forest, less easy to quantify, may be just as, or more, important in the long run.

243. Any or all of these functions may dictate policy and management systems. Protection of fertile but extremely fragile soils is a major function of the forests on Mount Meru in Tanzania and at similar sites. Protection of water catchments is important throughout the regions but especially in the mountains and, not least, on the mountain massifs that rise up above more arid areas - such as those of Karamoja in Uganda, in northern Kenya and elsewhere. Management of such protection forests is usually much simpler than the management and regeneration of production forests; it involves maintenance of boundaries, fire protection, regular patrolling, prompt enforcement of local rules which prohibit activities such as felling or unrestricted grazing, and a vigorous campaign of public relations to convince local populations of the vital importance of protection forest for agriculture and water supplies at lower altitudes. While the techniques of management are simple, they must be applied, and be seen to be applied, with diligence.

244. Conservation of ecosystems and genetic resources, including plants and wildlife, is another important issue. The example of chimpanzees in Budongo is mentioned in Case Study 1. Although the impressive concentrations of large wildlife occur in grassland and savanna woodland rather than in forest, the forest is host to a vast number of smaller creatures. In some areas, it plainly complements the more open ecosystems by providing an alternative habitat in the dry season; thus some of the elephants of Amboseli retire to the north Kilimanjaro forests for certain months of the year. Although the larger animals may constitute the most spectacular examples of conservation associated with tourism and national parks, no less important are the more general principles of conservation that have been expressed by some countries in the setting aside of protected areas for genetic conservation purposes and for the conservation of natural ecosystems. The ever present fear is that increasing populations will exert an irresistible pressure for the use of the natural resource for more tangible products. Therefore it is important to analyze the material and intangible products of the forest very comprehensively (Poore, 1976). In the past, this was not done effectively and, as a result, it is possible that the advantages of the manmade forests over the natural forests have been overstated.

245. Conservation of forest genetic resources has received considerable attention recently at the international level (e.g. FAO, 1975; FAO, 1981b; FAO, 1984b; FAO, 1988; IUCN, 1980; Unesco, 1973). Establishment of a series of protected areas, ranging from Strict Nature Reserves to _in situ_ conservation areas, managed so as to conserve genetic resources of priority species while being sustainably managed for the provision of goods and services for present-day use, is an effective method of conserving ecological and genetic diversity. In all protected areas (as in the case of production forests), the involvement and consent of local populations must be sought. In all but the Strict Nature Reserves, man should be considered part of the ecosystem rather than an intruder, and management plans for local utilization of forest produce drawn up in harmony with principles of genetic conservation needs.

246. "Natural" forest, managed primarily for wood production, can act as a useful supplement to protected areas _senso stricto_, in conserving the genetic resources of priority species. However, as management for wood production generally leads to a simplification of the ecosystem, strict natural reserves are needed as a complement, for ecosystem conservation. It should be realized, however, that ecosystems are dynamic, and changes will occur also without human intervention. Thus, it is of utmost importance to specify accurately the aims of conservation, with due consideration of the various levels of variation: ecosystems, species, within-species variation, and variation at the levels of genes and alleles.

247. The same observation on importance to prior specification of aims of management also applies to management for multiple-use. Multiple-use, as practised in the past, was facilitated by a low population density and extensive use of a number of different products. As populations or market demands increased, management was intensified towards the satisfaction of demand for a particular product, whether timber, cocoa or palm-oil (Moore, 1985). It is not

necessary, however, that multiple-use should be the objective of management on every hectare of forest. In some cases it may be desirable to establish several zones in a forest area, with gradations between the least and the most intensively managed, so that each successive zone also acts as a protective buffer to its neighbour. An example (on gentle topography) might be:

```
(1) Agriculture (outside the forest)
         ↓                                               Increasing
(2) Forest plantations                                        ↑
         ↓                                                    |
(3) Managed "natural" forest with
            enrichment planting
         ↓                                               Management
(4) Managed "natural" forest without                     Intensity
            enrichment planting
         ↓
(5) Managed "natural" forest with wood
            production as primary objective                   |
         ↓                                                    ↓
(6) Managed "natural" forest with non-wood                Decreasing
            production as primary objective
         ↓
(7) Strict Nature Reserve
```

248. The methodology for conserving the genetic resources of TMF is a new and still little understood subject. Some guidelines will be found in the references quoted in paragraph 245.

4.3.7. <u>Motivation</u>

249. The political motivation to conserve the forest resource of a country is an essential pre-requisite before successful long-term, sustained forest management is feasible. This is difficult to obtain: both in sparsely populated countries with seemingly inexhaustible natural forest and in countries with ever-increasing and high population densities, where growing more and more food has the highest priority.

250. AT THE NATIONAL LEVEL, the greatest need is for a commitment by all politicians and political parties to conserve and manage the TMF as an important sustainable natural resource, and as an integral component of sustainable development.

251. This need has to be succoured AT THE INTERNATIONAL LEVEL by alloting first priority to enhancing political awareness to the forestry crisis. Much has been done at the World Forestry Congresses and other fora, most recently through the elaboration and implementation of the Tropical Forestry Action Plan (FAO, 1985), but the effort must be sustained and further strengthened so that the politicians themselves, as well as their planners and technical

forestry advisers understand the role, value and fragility of the forest. Too often foresters talk to foresters and too rarely do they manage to obtain the precious time of busy politicians dealing with the day to day needs of their people, who remain unconvinced of the urgency and need to sustain and manage their forest resources.

252. AT THE PEOPLE'S LEVEL, there is a need to understand the traditional and modern social systems, and how they interact with TMF. Also education in conservation and in the management of renewable natural resources, as well as in the value of the TMF, must be part and parcel of the national education system at all levels, not least in teacher training curricula.

253. FOR FORESTRY, the needs are daunting. Foresters must participate in the education of the people and have as much to learn from local communities as the other way around. As well as needs for technical training, it is urgent to develop effective training in less familiar skills of extension work, communication and business management.

# CASE STUDY NO. 1

## AN ANALYSIS OF THE DEVELOPMENT OF MANAGEMENT SYSTEMS IN THE TROPICAL MOIST FORESTS OF UGANDA



Tables

## CASE STUDY NO. 1

## AN ANALYSIS OF THE DEVELOPMENT OF MANAGEMENT SYSTEMS IN THE TROPICAL MOIST FORESTS OF UGANDA

### 1. INTRODUCTION

1. The following Case Study reviews and analyses the forest Management Systems used in the tropical moist forests (TMF) of Uganda. It is derived, to a considerable extent verbatim, from a paper prepared for FAO by Mr. Peter Karani, lately Chief Forestry Officer of Uganda (Karani, 1985).

2. Three stages may be recognized in the development of Uganda's forest policy and forest management:

(1) Prior to 1945 (end of the Second World War);

(2) 1945 to the late 1960s or early 1970s;

(3) The early 1970s to the present.

3. In respect of forest policy, the main developments in each stage were as follows.

(1) The basis of the 1929 Forest Policy (declared 31 years after the formation of the forestry administration) recognized the importance of the direct and indirect benefits of forestry. It stated, "The policy adopted for Uganda has been based on indirect and direct utility of its forests, the former being their influence on erosion, rainfall and humidity and water supply, while the latter is their ability to supply the future requirements of a rapidly developing country with a large and progressive population. The possible indirect effects, while admittedly a matter of controversy between experts, call for the consideration of the preservation of existing forests, particularly in areas such as the North and East of Uganda where desiccation is following forest destruction, and of the creation of forests where such are likely to increase humidity in dry areas or to drain swamps in wet areas" (Karani, 1985). The objects of management were then listed as:

(a) to retain under forests or afforest all areas of land, the retention of which under forest is considered necessary on climatic or other indirect grounds;

(b) to meet, with due regard to vested rights, such of the demands of the population of Uganda as cannot be met by individual or local administration efforts;

(c) to advise individuals and local native administrations in all matters concerning to arboriculture and forestry;

(d) in so far as is consistent with the three preceding objects, to manage the state forests of Uganda so that they will give the best financial returns on the capital invested.

(2) The Colonial Administration eventually re-declared a forestry policy in 1948 and this was adopted by Independent Uganda:

(a) to reserve in perpetuity, for the benefit of the present inhabitants of Uganda and of posterity, sufficient land (either already forested or capable of being afforested), to maintain conditions suitable for agriculture, to preserve water supplies, to provide forest produce for agricultural, industrial and domestic supplies, and to maintain soil stability in areas where the land is likely to deteriorate if put to other uses;

(b) to manage this forest estate so as to obtain the best returns on its capital value and the expenses of management, in so far as such returns are consistent with the primary aims set out above.

(3) In 1967 local governments were abolished and all areas of land for forestry were transferred to the Central Government.

4. Karani (1985) observes, "The weakness of the forest policy of this country stems from the fact that Uganda does not have a land use policy nor is there a common system of land tenure. There are no less than four land tenure systems and these affect greatly the management of the natural forests, as the population increases and land for growing food becomes scarce; forest reserves, including natural forests, are looked upon as potential producers of food crops. Notwithstanding numerous requests for excision of some of the tropical forest areas, a large part of natural forests in the centre and west of the country remain intact and will continue to be managed for forestry products".

5. Also, "It is well known that species of the mixed forests are inherently producers of low volume as compared with Eucalypts and tropical conifers. There is, however, enough land to grow conifers without interfering with the remaining natural forest. The current policy is to maintain the existing forests, but increase their value by increasing the volume of high value species. Although it has been a policy of this country to leave a portion of each major forest untouched as nature reserves, it has been realized that the areas that have been left are too small to protect the diversity of animals that depend on the forest for their breeding grounds. It is hoped that by adopting these methods and silvicultural techniques, the value of the mixed forest will not only be maintained but enhanced and that its character and composition will be preserved. The demand for all the wood requirements is unlikely to be satisfied by what the natural forest can produce. The shortfall is to be met by the plantations of conifers that have been established during the last thirty years".

6. Table 1 gives the areas of natural forests in Uganda estimated at the end of 1980 (FAO/UNEP, 1981). There are no longer extensive forests covering large areas of the country. What remains are islands, sometimes very small, in a sea of cultivation and savanna grasslands. It is these islands of forest that continue to conserve the remaining indigenous forest flora and fauna, provide domestic and industrial wood products and contribute to the protection of the environment, including the water supplies and the soil. This role of protection and conservation is of the utmost importance to the well being of the country.

Table 1. Uganda's Natural Forests ($km^2$) (FAO/UNEP, 1981)

| | |
|---|---|
| Productive* undisturbed closed broadleaved forest | 1,000 |
| Productive logged over closed broadleaved forest | 5,650 |
| Unproductive closed broadleaved forest | 850 |
| Total closed broadleaved forest | 7,500 |

* Production capacity for wood for industry.

7. The following sections describe the history of forest management in Uganda in more detail.

## 2. MANAGEMENT PRIOR TO THE SECOND WORLD WAR

8. Prior to the end of the Second World War the management environment of the forest was dominated by:

(1) difficulty in communications within and without of Uganda;

(2) shortage of staff;

(3) limited industrial potential;

(4) limited markets - either export or internal;

(5) lack of know how.

9. Uganda was a Protectorate of the British Government under a colonial administration. Prior to 1890, when the Protectorate was established, some parts of what later became Uganda had well developed political systems, notable among which were the Kingdoms of Buganda, Bunyoro, Amkole Kiziba and Koki. In these lacustrine kingdoms canoes played a major role in armed conflicts, and it is recorded that the Kabaka of Buganda could assemble as many as 200 canoes for his army. These were the Sesse-type canoe, made of a keel with side planks sewn to it by means of raphia fibres passing through parallel lines of holes burnt along the edges of adjoining planks.

10. When Arabs from Zanzibar started to trade with the Kingdoms, they built dhows to carry trade goods, ivory and slaves from the north to the south side of Lake Victoria - a distance of 320 km. These dhows were described by the early missionaries who arrived in Uganda in 1877. Fishing, hunting and trade in ivory brought wealth. Fish

drying which required fuelwood cutting was commonly practised, but the population was small and the forests regenerated themselves. Cultivation of yams and plantains (matoke) did not necessitate complete clearing of the forest, and trees that were either too large to be felled or valued for their products were left.

11. The colonial era brought to Uganda new concepts of material consumption, new agricultural crops and methods of cultivation, different standards of education and health, new levels of communication and colonial administration which brought together people of different histories, languages and cultures who lived in the same area.

12. Although coffee is indigenous to Uganda and had been grown and used for ceremonial purposes, it had not previously been exported. The development of relatively large estates for coffee, rubber, sugar cane, cotton and, later, for tea necessitated forest clearing. By 1898, it was realized that forest areas must be protected by reservation; also wild rubber was being collected and this resource had to be conserved and saved from destruction from agricultural expansion.

13. In the early colonial days Baltic Fir (Scots pine) was imported into Uganda for construction works. Consequently, forest development as a means of import substitution was an early theme and one that persists today. The building of the railway from Mombasa on the coast to Kisumu on Lake Victoria took a vast amount of timber, not only for bridges and sleepers but also for support services and infrastructure. Up to 1930, the Government, either within the Forest Department or as part of the Public Works Department, ran sawmills. Even as early as 1908, it was realized that fuel plantations would have to be created near the large towns - not only in the more sparsely wooded savanna areas but also within the TMF zone.

14. The early foresters explored the natural vegetation. They found the following two major but much interrupted belts of forest.

(1) A belt 50-80 km wide, forming a crescent around the northern and north-western shores of the Lake. The forests that later became known as the Mabira, South and West Mengo, and the East Masaka forests (including the Minziro forest) occur in this belt. The remainder of the forest has been cleared to make way for coffee, rubber, cotton and cocoa crops that have been grown for export since the beginning of the 20th century.

(2) The area in the west on the uplifted eastern rim of the Rift, stretching from Masindi in the north to Rwanda in the south. Until this century the population of this area was relatively small and there were large fertile areas of grassland between the blocks of forests. Here reservation of these blocks was possible.

15. In these early days there was no attempt to regulate the yield from the forests such as Minziro, Mabira and Nambigirwa where trees were being felled and sawn for timber. At this time even the extent of the forests was unknown. The importance of the forest was as a source of wild rubber for export and a source of timber for local construction and fuel for the railway and steamers.

16. Modern management of the country's forests can be said to have started in the 1930s when the colonial administration was able to recruit more professional staff. A forest policy statement had already been accepted by the government. In 1934, the first management plan was prepared and approved. It was for Budongo forest. In 1931, aerial photographs were taken of the forest on a scale of approximately 1:12,500, covering 500 $km^2$. An uncontrolled mosaic was assembled and corrected after a crude ground triangulation survey had been done. This aerial survey was followed by a ground enumeration using systematic strips of 10 m width and an intensity of 2.5%. Budongo has played an important role in the development of forest management in Uganda. Because the two zones of the lake shore and the western forests had such differing densities of population, their management systems differed.

## 2.1 Management in the Western Forests

17. Because of staff shortages, individual foresters wielded great influence over the management of whole regions. W.J. Eggeling lived on the edge of Budongo forest from 1937 until 1946. He studied the flora of Uganda and especially the ecology of Budongo forest. His studies were written up in scientific journals (e.g. Eggeling, 1947) and government publications and were given a practical slant in the first revision of the Working Plan for the Budongo group of forests.

18. Sawmilling had started in Budongo around 1926 and records show that in 1922 planting of Khaya anthotheca, Entandrophragma spp. and Maesopsis eminii was attempted in part of the forest. No trace of this work could be found ten years later. Because of emphasis on creating fuelwood plantations near the new centres of administration, little attention was paid to the regeneration of natural forest, although utilization continued at an accelerating rate during the Second World War. Also at this time great efforts were made in tapping wild rubber and in harvesting quinine bark from a few trial plantations that had been set up around the country. Towards the end of the war H.C. Dawkins was recruited as a new staff member to supervise rubber tapping.

19. The significant features of the management environment in this early period as detailed in paragraph 8 above dominated the management system, leaving few options to the forest managers. It is interesting to consider why artificial regeneration was resorted to so early on. One can only speculate that the foresters of the day were persuaded that the sparseness of the valuable species in the upper and middle layers of the canopy reflected a lack of seedlings or, at least, established saplings. In the light of later research findings this may have been an erroneus impression.

## 2.2 Management in the Lakeshore Forests

20. Most of the records of activity in these early years refer to three forests - Minziro near the Tanzania border, Nambigirwa near Entebbe and the Mabire between Kampala and Jinja. Two were sites of government sawmills since before the First World War but Nambigirwa was exploited by pit sawyers.

21. Minziro forest lies in the flood plain of the Kagera River and originally was notable for its magnificient stands of two taxa of Podocarpus latifolius, then referred to as P. milanjianus and P. gracilior. This is a low altitude for these species and there have been doubts on their correct taxonomy. What is certain is that the forests were overmature and contained almost no Podocarpus regeneration although a dense forest dominated in parts by Baikoa plurijuge had developed below the Podocarpus relicts. The site is extremely low lying, with complex soils, and much of it has been flooded when lake levels rose during the late 1950s after the completion of the Owen Falls dam at Jinja. The abundance of this extremely useful conifer timber near the lake shore and hence accessible to lake transport attracted early attention. Harvesting of Podocarpus continued from 1908 until 1915 processed first by pit sawing and then in a mill. Sporadic attempts to plant Podocarpus had some success and in 1929 and in 1930 some 40 hectares of the Kaiso section was regenerated by line planting at 9 m intervals and at 1.9 m along the lines. Larger plants survived better than the smaller, which were browsed by various forest antelopes. This work was abandoned in 1931.

22. This forest area and the surrounding swampy grasslands became a leased concession. The lease on the forest area was for thirty years and an attempt was made to encourage the conversion of the grasslands to agriculture. Various crops were tried, including rice in the swamps and sisal on the drier parts, but without success. The grassland soils were of low base status and with little retention capacity. Throughout the lease the forest was harvested and the last Podocarpus was felled around 1950.

23. It was tempting in 1950 to criticize the length of the lease and the fees which, by that time, were only a fraction of those in other areas. On the other hand early working by government mills had removed the most accessible timber, the area was extremely remote from other centres, and the lessees were obliged to sink capital into agricultural enterprises which, with hind sight, were ill-advised. Also the terrain, though flat, was extremely wet and difficult for harvesting operations. It is now clear that artificial regeneration of a species was attempted without adequate ecological knowledge of either the site, the autecology of the species or the ecosystem.

24. Similarly in Nambigirwa forest seedlings of Entandrophragma spp., Lovoa trichilioidas, Podocarpus latifolius, Cupressus spp., probably C. macrocarpa and Toona spp. were raised and planted in a trial plot before 1920. There is little record of regeneration work in the Mabira forest.

25. Thus, as in the western zone, management was fragmentary, with most of the emphasis on meeting the requirements of the Treasury for revenue whilst encouraging the development of harvesting and establishing the forest estate. Whatever attention was given to silviculture appears to have been concentrated on trials of some form of enrichment planting wherever staff were available, using the species that had been harvested.

## 3. MANAGEMENT FROM 1945 TO THE EARLY 1970S

26. The management environment changed rapidly after the Second World War. Prior to Independence in 1962 the major factors in a continually changing picture were:

(1) the population was growing rapidly and new settlements were constantly established in previously lightly settled areas;

(2) cotton, sugar and coffee prices were high, and Government was actively encouraging increased production;

(3) urbanization was accelerating and infrastructure in towns - electricity, water supplies, government housing schemes, schools, etc. - was improving;

(4) educational standards were rising and opportunities for further education were expanding;

(5) money from the cash crops was available for investment by both Government and private enterprise.

This was a time of general growth and development, but the seeds of conflict among land users had already germinated and a bitter harvest of disruption and diseconomy was developing.

### 3.1 Management in the Western Forests

27. Budongo forest was by far the most studied and intensively managed forest in Uganda at the start of this period. The 1935-44 management plan stated the following objectives:

(1) to provide facilities for profitable exploitation whilst endangering to a minimum the preservation of the existing type of forest;

(2) to provide an elastic yet conservative regulation of the yield;

(3) to provide a free hand for the executive officer to increase the stock of valuable indigenous species in all suitable localities.

A brief outline of the ecology has already been given in paragraphs 36-44 in Part I. The first revision of the management plan rephrased the Objects of Management as:

(1) to provide for the permanent profitable exploitation of the Budongo and Siba forests by private enterprise on the basis of a sustained annual yield;

(2) to endanger to a minimum by this exploitation the perpetuation of the rain forest;

(3) to increase by artificial means the stocking of the more valuable and useful timbers by planting in the wake of exploitation; to assist the growth of natural regeneration; and to encourage the spread of the forests into the surrounding grasslands;

(4) to check the invasion of mixed forest by Ironwood, and to discover a practical method of converting the climax Ironwood forest into a more valuable rain forest type.

28. This revision placed the forest under a systematic felling plan that envisaged a preliminary 40 year salvage felling that would cover all the blocks of the forest and remove all the very large high class timber trees that were unlikely to stand until a more normal conversion cycle of operations aiming to convert the forest to sustained yield management, had been completed. At the start of this salvage operation few species were marketable other than the Meliaceae, Maesopsis and sparsely occurring species that yielded particularly durable woods, such as Mildbraediodendron excelsum and Erythrophleum suaveolens. The annual yield was controlled by the volume of sound logs, the estimate being based on an early enumeration of the trees over 60 cm dbh. The limit of felling in the Meliaceae was 80 cm dbh and 60 cm for other species.

29. The principal aim of management at this time was to produce Meliaceae. Other species, especially those such as Maesopsis eminii which were typical of the colonizing stage in the forest, were also encouraged as nurses. The cut over forest was enriched by line planting striplings as described in paragraph 50 Part I.

30. At first, group plantings were tried but, later, the common difficulty of relocation forced concentration into lines or groups along lines. Often the planted stock was set back off the access route to provide some protection from browsing. In Budongo not only was browsing by antelopes common but a lot of damage was caused by elephants whose feeding in the forest proved to be very selective. They found that the surge of herbaceous climbers that followed felling provided attractive feeding sites, and would follow the access lines cut for planting and either pluck out or browse on the Meliaceae along the way. The planted stock was tended largely by climber cutting and later some release operations were performed - partly to give more light to the crowns of the regeneration and partly to block the access paths against the elephants by means of the felled poles. Some of this early enrichment appears to have been very successful with stockings of 90 Meliaceae established per ha when tending ceased. However, in the later work the espacement was much reduced only 22 plants per hectare being put out. In general, establishment seemed to present no problems but the speed of growth of competing vegetation meant that tending had to continue. The response in height growth from the released Meliaceae was marked and it was apparent that the species in that family need their crowns free from overhead shade.

31. Planting operations ceased in the mid-fifties, partly because of decreasing labour availability and increasing cost. At the same time research started in the early 1950s, including the use of newly developed arboricides, held out promise for natural regeneration. By this time, the permissible annual cut had been increased and year by year more species were finding a market and hence the intensity of the salvage operation was increasing, leaving the canopy more broken. Regeneration of a marketable (then termed desirable) species was to be found in almost all felling gaps.

32. Thus social conditions governing labour, marketing conditions within the country and technological advances in arboricides all acted together to bring out a change in silvicultural technique. The policy of management and, indeed, the system of management changed little.

33. The second revision of the plan for 1955-64 defined the objects as:

(1) to produce the highest possible perpetual yield of forest produce, especially mahogany (Meliaceae) timbers, for the lowest possible cost (this paradox was not recognized);

(2) to nurture, with the exception of the larger game, specimens of the characteristic living communities in Budongo in their natural state.

34. The third revision amended these to read:

to provide economically the maximum sustained yield of hardwood timbers - especially the mahoganies and to maintain specimens of the characteristic plant and animal communities of Budongo.

This series of revisions of the objects shows the gradual change away from concern for profitable working towards conservation of both yield and the uniqueness of the forest.

35. The silvicultural changes involved a range of new operations. Most of these were merely modifications of existing techniques substituting arboricide for the axe. The changes were in:

(1) the timing of the operation;

(2) the area that could be treated per man-day;

(3) the nature of the canopy destruction that ensued.

Simple work study indicated that if control of such operations was to be successfully established, then the forest had to be both accessible to vehicles and sub-divided into small identifiable blocks. Only then could the arboricide and solute be delivered on site and the execution and results of the treatments be monitored and supervised effectively. Otherwise the progress of the work was impossible to check, with some parts being omitted and others treated repeatedly. Such work was only possible because of the high standard of the supervisory staff then available out of Nyabyeya Forest School.

36. At this time in Budongo, at the peak of the arboricide work when over 1,500 ha were being treated annually, the silvicultural regime was:

(1) cutting the access road into the compartment (some 300 ha in extent) 2 years before the salvage operation was planned, followed by a progression of operations in sequence over some 12 months:

(a) cutting of access paths to divide the forest into 4 hectare blocks;

(b) enumeration of the desirable stems available for salvage felling (100%);

(c) climber cutting, immediately followed by arboricide treatment of all unmarketable and defective stems;

(2) salvage felling;

(3) 10 years after felling, by which time the canopy of clasmophytes was expected to have raised the climber tangle sufficiently to permit entry:

(a) diagnostic sampling was carried out to establish the extent and condition of the regeneration;

(b) if necessary the regeneration was released from competition by climber cutting and further canopy treatment of relicts that had not died, and of understorey trees that were now suppressing the regeneration.

In fact, this post felling treatment was applied to areas that had been regenerated artificially. They were found to be very rich in the desirable species, but the origin of these stems was often in doubt.

37. In the mid 1950s Dawkins (1959) was concerned with the extent of the damage to advance growth from felling. His measurements suggested that the large trees of the salvage felling were damaging 0.04 ha on average each, and he doubted if this could be reduced below 0.02 ha, even with well planned harvesting in climber free stands. Consequently, Dawkins recommended conversion of the forest after the salvage felling to a monocyclic felling and regeneration system, rather than the polycyclic systems that had been visualized elsewhere. Dawkins described this as tropical uniform shelterwood system but envisaged that the forest would be of many species with a large variation in diameter, due to the retention of advance growth at the time of conversion, great variation in the growth rate even among individuals of the same size and species, and the regeneration of species that naturally occupied different levels in the canopy.

38. The third revision of the working plan was approved in 1965, when the management system was found to have been successful, but the rise in local demand for sawn timber made it imperative to try to attain a higher sustainable yield. Consequently, the plan authorized

conversion to the uniform system without delay and before the completion of the salvage cycle. Hence, both cycles would continue simultaneously but in different parts of the forest - the conversion felling following some forty or so years behind the salvage operation. This plan continued until the end of the period under review.

39. Mention of wildlife, including elephant, damage to forest trees, has been made. As the area of the forest that had received canopy treatments increased, the wildlife factor assumed greater significance in the management system. At the same time other factors in the management environment were also affecting the elephant and other animals of the forest. The Murchison Falls National Park was established in the early 1950s and the boundary ran alongside that of Kitigo Central Forest Reserve that adjoined the main block of Budongo. This area had been a game reserve since around the time of the First World War and the populations of many species of animal increased dramatically in response to the protection from hunting. The National Parks of East Africa assumed economic importance as air travel brought them within reach of European and American tourists. The tourist industry developed rapidly and became important in creating employment and as a source of foreign exchange earnings. However, the inexorable increase in the human population, improvement of roads and clearing of forest for agriculture progressively restricted the elephants' seasonal movements. The result of this was that more and more elephants were found in the forest and their utilization of woody vegetation increased dramatically, both in Budongo forest and in the forest outliers within the park boundary, where even the savanna trees were killed (Buechner & Dawkins, 1961).

40. To the chagrin of many foresters, international funds for research on elephant appeared more readily available than funds for forest research. Nevertheless, the efforts of Beuchner, Buss (1961), Wing & Buss (1970) and later Laws, *et al*. (1975) were invaluable in providing information and insight into the role of the elephants in Budongo at this time. During this period elephants were shot regularly within the regeneration areas in an attempt to protect the new crop trees. Access tracks were made and maintained to allow guards to patrol and chase out herds as soon as possible, but serious efforts to manage the elephant population scientifically were sadly lacking. By the late 1970s, illegal shooting had reduced their numbers from over 20,000 to less than 3,000.

41. Budongo forest also attracted researchers in zoology and primatology working along the lines of Jane Goodall's pioneering work on chimpanzees in Tanzania. Budongo was the home of chimpanzees as well and it was feared that the arboricide treatments might adversely affect their habitat, especially if none of the various species of *Ficus*, many of which provided food for many birds and animals including the chimpanzees, were protected (Reynolds, 1964).

42. During this period, the timber management system of Budongo forest was judged successful. It was a period when the conflicts amidst competing interests in the total environment were limited, and the forest manager was able to evolve a feasible means of timber management that adequately considered the ecology of the forest and the autecology of the tree species.

43. Other forests in this western group were not as easy to manage as Budongo. The Bugoma forest, lying only some 100 km to the South of Budongo and in the same topographical position with respect to the Rift, had different species associations though many were similar to those of Budongo. Bugoma lacked the richness in Meliaceae which made Budongo so notable, and the central zone was dominated by Dynometra spp. It appeared younger in parts, with riparian strips amidst the surrounding grasslands. Marketing timber from Bugoma was difficult, and consequently felling was less intensive. The climber population in the younger forest appeared much heavier than in Budongo. Arboricide treatments were more expensive, as more trees were counted as weeds; as well there was doubt whether adequate regeneration of marketable species would become established. Late in the 1950s research plots were established in some of the characteristic Cynometra blocks in order to establish the response, but of course the results were not soon available.

44. During the early part of the 1950s low percentage enumeration of the forests of the western zone was completed and management plans were written - several by Osmaston (1959, 1960).

45. The situation in the forests of Toro further to the South was not dissimilar. These forests were more montane in character, almost completely evergreen and in an area with higher rainfall and lower average temperature. Here Parinari excelsa appeared to occupy the niche of Cynometra alexandrii at Budongo and Olea welwitschii was a colonizing species similar to Maesopsis eminii, though slower grown, longer lived and with a more valuable decorative timber. Timber yields were low, felling intensities light and regeneration uncertain. Also parts of the forest had high populations of elephant, especially in the south where the forest was included in part of the Queen Elizabeth National Park. Marketing became easier when the Kilembe copper mines were opened in 1956, and the railway was extended westwards from Kampala to Kasese to transport the copper. The P. excelsa was found useful as a mining timber. Unfortunately, the mines were not as successful as was hoped, and this market weakened throughout the 1960s.

## 3.2 Management in the Lakeshore Forests

46. The environment of the forests near the lakeshore was very different from that in the west, particularly on account of:

(1) the political situation (in Buganda there was a degree of political friction between Central Government and the Kabaka and his supporters);

(2) a high rate of immigration and natural increase in the population;

(3) an accelerating rate of urbanization and industrialization around Kampala, Jinja and in the area between these two centres;

(4) a high rate of increase in incomes, especially of the coffee farmers;

(5) a high rate of increase in the demand for sawn timber, building supplies and wood products such as furniture, etc.;

(6) a low incidence of damage from wildlife.

47. Whilst these factors increased the ease of marketing, they also resulted in great pressure on forest boundaries. In the early years of this period much of the energy of staff was spent on opening boundaries in order to establish the extent of existing encroachment and minimize its extension. This created friction with neighbouring farmers and land owners. Also much effort was spent on stopping illegal felling for sawmills, for pit sawyers and for charcoal burning. This also brought the Forest Department into dispute with local inhabitants.

48. The policy for management of all these forests was that they were to be managed for production of all marketable hardwood species and not particularly for the mahoganies (Meliaceae) as was the case for Budongo. The first Management Plan was written for the South Mengo Forests by R.B. Sangster (1948) for the period 1948-57 and the objectives were:

(1) to provide for permanent profitable utilization of South Mengo forests on the basis of a sustained annual yield for the needs of the inhabitants of Uganda, at rates which they could afford to pay, exports being made only after local needs had been satisfied;

(2) to replace harvested trees by artificial regeneration, using all the species recorded as removed from government and private forests;

(3) to improve the quality of the crop by using Meliaceae and Lovoa as the chief species in the planting;

(4) to encourage natural regeneration and to assist the indigenous crop by tending;

(5) to preserve a closed forest cover in all existing forest reserves and, where for any good reason this has to be removed, to replace it with the least possible delay.

49. Although these objects applied to South Mengo forests, similar objects applied to many other forests in the zone, for which management plans were approved during this period. The policy was to improve the economic value of the forests by encouraging the most valuable locally occurring species, and to introduce such species where they were absent. Local was defined as indigenous to Uganda rather than found in Mengo, so Khaya was introduced in order that this valuable timber might be available in future.

50. Planting began in 1945, using Khaya anthotheca, Entandrophragma angolense and E. utile. Two year old striplings were used in line-group plantings. "Stripings" were tall seedlings 1.2-2.4 m in height, stripped of leaves and side roots and bare root planted with the tap root and terminal bud intact. This type of stock prevented excessive

loss of water, prior to the re-establishment of the root system, and loss of the terminal bud from browsing by forest duitter and bushbuck. 3 to 5 striplings made a group sited at 9 m centres along lines at 45 m intervals. These plantings did not take much account of site selection for these species. Survival figures quoted for the 1945 plantings assessed in 1947 were Khaya 45%. E. angolense 36%, and E. utila 13%. A major handicap was the scarcity of labour in the area. Cotton and coffee prices were high and growing such crops paid better than working for the Government. Consequently labour had to be recruited from among migrants and the cost of providing food and housing added to the expense. Finally artificial regeneration was abandoned because of this labour shortage and cost.

51. At this time Dawkins demonstrated that natural regeneration was more common in these forests than had been supposed. He perfected the technique of killing the trees in the canopy using non toxic arboricides as, previously, it had been ruled that sodium arsenite should not be used in those areas where the population density around the forests was so high. However, the list of trees that proved marketable, i.e. desirable, grew almost continuously in the face of the high demand for timber. Species after species became acceptable. Consequently arboricide treatments eliminated trees that later came to be highly prized. This was particularly true of Antiaria toxicaria, a very tall tree with a magnificent bole for which there was no market in the 1950s. However, at this time industry was investing in new technology; a plywood mill was located in Jinja, and part of the production was destined for tea chests to transport the crop increasingly being raised in the west. Antiaris was found to be an ideal timber for this purpose and trees that had been treated with arboricide up to two years previously were sought after and felled before their boles deteriorated. The same story was repeated for wild rubber, Funtumia elastica, and many other species. As in Budongo, the conversion to monocyclic felling and a uniform system of silviculture was adopted. By the early 1970s most of the species in the Lake Shore Region had become marketable with the exception of Cola qiqantea.

52. As the use of arboricide continued, its efficacy was monitored. It was found that the break up of the canopy was causing a lot of damage to advance growth, and that the regeneration needed costly release from competition by the understorey species and climbers. Also at this time, supplies of wood from the natural forests on private land were becoming short. This had been a traditional source of wood for the charcoal burners who obtained it free or at very low cost in exchange for clearing the forest to make way for agriculture. As a result of the loss of these cheap sources, the price of charcoal in the large towns like Kampala and Jinja, as well as in the many smaller trading centres in the countryside, increased. It was possible, therefore, to encourage the burners to convert branches and tops left in the forest together with otherwise unmarketable trees in the logged over forest. This reduced the later damage and the need for release operations.

53. At this time, a lot of Maesopsis planting was being done to consolidate the forest areas up to their boundaries, increase productivity, decrease the perception that the land was not being used, and reduce the temptation to encroach upon it with agricultural crops. A successful technique of raising seedlings of this species

and establishing them in openings had been developed. Height growth greater than 4 m in two years had been achieved. The charcoal burners used the traditional earth kilns, the sites of which left clear areas suited to exactly this form of restocking and, moreover, competing vegetation was slow to become re-established on the sterilized ground. There were thus many advantages to this method:

(1) the forest was enriched with fast growing Maesopsis;

(2) charcoal was made available;

(3) the utilization of the existing forest resource was greatly improved;

(4) the regeneration of the forest developed under conditions more suited to its rapid establishment and growth;

(5) the total cost was decreased.

54. This system of using charcoal burners to refine the forests of the Lake Shore Region was improved upon and earth kilns were partially replaced by the more efficient portable steel kilns (Earl, 1969). Charcoal burning replaced the use of arboricide in West Mengo and the parts of Masaka and was extended to Kalinzu and Kibale in the west. The operations followed the following sequence:

(1) felling coupes of 40-80 ha were allocated to concessionaires and felling of all well formed marketable trees was done;

(2) trained staff of the Forest Department then selected and marked the young trees of desirable species for the next crop, and directionally felled the remaining undesirable and defective trees >60 cm dbh;

(3) charcoal burners and firewood merchants were then allowed to fell and remove all other unmarked trees and all branches and tops, one coupe being cleared satisfactorily before a second coupe was opened;

(4) immediately after, fast growing trees, mainly Maesopsis eminii, Terminalia ivorensis, T. superba and Cedrela odorata, were planted in gaps either singly or in pairs. They grew at a rate of 2-3 m in height a year.

55. This technique harnessed the results of research work on enrichment planting carried out in Mpanga Research Forest in this zone. Recognition must be made of the contribution from the Research Section to silviculture and management; much of the success of the management system was due to the foundation of research on which the silviculture and management practices were based. The scope of the work that was particularly relevant spanned the development of techniques for: forest enumeration, based on sound applications of statistical principles that allowed valid deductions from low 2%

samples; diagnostic sampling; arboricide work and canopy manipulation; enrichment planting; and techniques to measure growth and monitor the development of crops. This work has been recorded by Dawkins (1958) and in Technical Notes of the Forest Department and the Silvicultural Research Plans.

56. The five conditions enumerated by Dawkins as necessary for successful establishment of trees using line planting enrichment techniques in the tropical high forest were:

(1) little or no demand for thinnings;

(2) the species planted must be fast growing (1.5 m annual height growth is a minimum requirement), naturally straight and self pruning i.e. generally of the colonizing or gap-filling, light demanding type;

(3) there must be no upper canopy, only clear felled, clear deadened, low bush or recent secondary growth is suitable;

(4) the re-growth between the planted lines must not be inflammable;

(5) browsing animals must be absent, scarce or of negligible effect on the planted trees.

Most of these conditions were met following charcoal burning.

57. The use of T. ivorensis was discontinued after attacks by a shoot borer that destroyed the apical shoot, but T. superba is so far free of such pests and is capable of reaching a dbh of 60 cm in less than 20 years. The provenance commonly used came from Ghana and Sierra Leone, but the Central African provenances from Congo, Gabon and Zaire are recommended if seed can be procured.

58. The distinction in the management system of the Lake Shore zone from the more remote forests to the west, is obvious. Population pressure on the forest, the demand for sawn timber and charcoal, and the level of investment in wood processing plants all influenced the management system, and not unfavourably. Nevertheless competition for the scarce resource of land remains a problem, and the Draconian land use allocation imposed in early colonial days has yet to prove that it can withstand the claims of agriculture - especially in those areas where the soil is suited to permanent plantation crops such a coffee and tea, which may protect the soil and water supplies as well as the forest. In fact, the soils of this area are not as fragile and liable to degradation by erosion or loss of fertility as in many parts of the tropics.

## 4. MANAGEMENT SINCE THE EARLY 1970S

59. Between 1950 and 1955 all major forests were inventoried and these surveys provided data for the yield control prescriptions. In 1971, Lockwood Consultants re-examined the data and established new inventories for two forests in the west, namely South Kibale and

Kasyoha-Kitomi (Lockwood Consultants, Ltd., 1973). The report made recommendations on most aspects of forestry development including a revision of policy, organization of the Department, management, wood processing industries, marketing and logging. At the time of the report the consultants predicted an annual harvest of:

| | |
|---|---|
| 1973-84 | 314,000 $m^3$ |
| 1985-93 | 171,000 $m^3$ |
| then | 154,000 $m^3$ |

They suggested that if the harvesting limit was dropped from 50 to 30 cm dbh, then an additional 68,000 $m^3$ would be available per year up to 1984 and 50,000 $m^3$ a year from 1985 to 2000.

60. The position is now radically different because of the country's political and economic difficulties throughout the 1970s and 1980s. The sawmilling industries have deteriorated through lack of new investment, and there has been a lack of intensive management of both the natural forests and the plantations. In 1970, there were 30 sawmills producing around 170,000 $m^3$ of sawn timber. With the expulsion of many of the owners in 1972, production levels declined drastically on account of:

(1) political instability and consequent ownership uncertainties;

(2) lack of adequate managerial experience and inadequate skilled maintenance;

(3) acute scarcity of foreign exchange and, therefore, spare parts.

New developments planned, such as veneer and chipboard plants at Budongo and a parquet flooring plant at Jinja, were never completed, and others that had started production had to close.

61. In 1980, there was again a change of policy and the sawmills, which had been nationalized and run by the State Wood Industries Corporation, were re-privatized. The new owners were mainly individuals with political connections but they lacked sufficient capital to invest in such mills and return them to full capacity.

62. In 1982, the policy on property ownership changed again and the Government asked all the 1972 owners to return and reclaim their mills. Many had done so by 1985, but the current owners - or, in some cases where the old owners have yet to return, the current users feel uncertain about their future in sawmilling. They are reluctant to make further investment or even in some cases to carry out essential maintenance. Now out of the 30 mills existing in 1970, only 17 are active and altogether they produce only 6,500 $m^3$, or some 4% of the 1970 production. Pitsawing has increased dramatically but records of this are very incomplete.

63. Potentially the country has enough timber to supply all its needs and continue to be self-sufficient in wood products at least up to the end of the century. At present, the country is unable to produce enough sawn wood for the estimated demand of between 300,000 and 500,000 $m^3$; production, mainly met by pit sawing, is expected to

be around 100,000 $m^3$ (72,000 - 125,000 $m^3$ are the low and high estimates respectively). Apart from the uncut yield of the natural forests, a recent inventory of softwood plantations in the west (at Mafuga and Bugamba) indicate that there are over 2 million $m^3$ of softwood timber that could be logged between 1986 and 2000. It is believed that in all there is 1.3 million $m^3$ of softwood timber - Cupressus lusitanica and Pinus patula - that requires harvesting within the next 5 years. This is partly because droughts in 1981-83 caused considerable die-back in some of the P. patula plantations in the drier areas, and these need salvaging and replanting with more drought resistent species without delay. An estimate of the timber available up to the end of the century is shown in Table 2.

Table 2. Available Supplies of Hardwood and Softwood Roundwood in Uganda ($m^3$) (Karani, 1985)

| Period | Annual yield available | | |
|---|---|---|---|
| | Hardwoods | Softwoods | Total |
| 1985-1990 | 287,000 | 260,000 | 547,000 |
| 1990-1995 | 262,000 | 160,000 | 422,000 |
| 1996-2000 | 244,000 | 160,000 | 404,000 |

64. Markets, both within and outside Uganda, have changed and will continue to change. They are reviewed briefly below under the headings of exports, pulp and paper, and both domestic and industrial fuel.

## 4.1 Exports

65. Uganda high class hardwoods used to command high prices on the international market and still do despite the low production. There is a buoyant demand in neighbouring countries for Chlorophora excelsa, Entandraphragma utile and Khaya ivorensis because supplies are not available from elsewhere. Pit sawn timber from the eastern Lakeshore zone is on sale in Nairobi and Mombasa and pit sawn cypress finds a ready market in Rwanda to the west. It is well-known that hardwood timber is smuggled into the Sudan, Zaire, Rwanda, Tanzania and Kenya. Even poorly sawn and unseasoned Meliaceae and C. excelsa fetch premium prices. Consequently, there is little incentive to raise the standard of the goods. Nevertheless, when conditions become more stable, it will be in the nation's best interests to achieve higher prices and larger markets by presenting a better and more uniform product.

## 4.2 Pulp and Paper

66. Uganda has one paper mill at Jinja using imported pulp and built in the mid-1960s. It produces a variety of packing papers as well as a little writing and duplicating paper. As would be expected, the consumption of these types of paper products has decreased with the fall in industrial capacity within the country. The total national consumption is estimated at less than 25,000 t and so it is unlikely to be economic at present to contemplate establishing other mills. Both Kenya and Tanzania have, or will soon have, pulp mills in production and these will provide opportunities for trade.

67. If in the future a pulp mill was to be established, then it would be advisable to afforest some 30,000 ha of fast growing tropical pines or hardwoods. This would avoid competition with the market for tropical hardwood sawn timber, and allay the fear that harvesting the natural forest for pulp might endanger its conservation as a resource which provides a large number of products and services to the nation.

### 4.3 Industrial and Domestic Fuel

68. Wood fuel and charcoal are the main sources of energy for both the industrial and domestic sectors of the country. 90% of the present estimated total population of 15 million people live in rural areas and collect and cook with wood. Usually those in the town prefer to cook on charcoal because it is easier and cheaper to transport and store per unit of energy. Unfortunately, under the present conditions in the country, the cost of both charcoal and firewood in the towns has risen beyond the reach of the lower income groups. A global figure of annual use for all domestic purposes of 1 $m^3$ per person per year implies an annual consumption of 15 million $m^3$ of wood. When this is compared to the annual consumption of sawn timber (high estimate 500,000 $m^3$), the critical importance of firewood to the nation is obvious.

69. Charcoal is an important source of energy for lime making and for the tea and tobacco industries, but in most cases they depend on Eucalyptus plantations rather than the mixed forest.

## 5. THE CURRENT MANAGEMENT SYSTEM

70. The current situation in the country is dominated by political and economic uncertainty. The policy is clear. The goals are to provide as much as is economically possible of the forest products needed by the nation, including the indirect benefits of protection of the soil and of water catchments, provision of clean water and the conservation of the genetic resources and other values of the indigenous flora and fauna. Consequently great emphasis is laid on conserving the remaining areas of mixed tropical forest whose total service is valued at far more than just its production of cellulose and lignin.

71. Somewhat ironically in a country where so much forest has been cleared for agriculture, many believe that forest destruction has caused or at least contributed to the irregularity of recent rainy seasons. For the first time there have arisen pressure groups fighting against the loss of forests and trees and urging Government to provide more funds for forestry.

72. The intention, bearing in mind the current and future requirements of the nation, is to continue conversion to the monocyclic harvesting system whilst increasing the commercial value of the forest by increasing the representation in numbers and volume of the most valuable species for local, regional and international markets. Some of the forests, where extraction of large volumes is unlikely to be economical or desirable from the environmental stand point, will be left with, possibly, no more than casual pit sawing of over-mature trees. Also adequate areas of each major forest will be left untouched as "strict nature reserves".

73. This policy calls for avoidance of any system that will tend to convert the TMF into single species plantations or even uniform blocks. There is enough land in the savanna areas to grow high yielding conifer or hardwood crops without interfering with the remaining TMF. During the period of conversion to the monocyclic management system it is recognized that a lot of changes are being made to the structure and composition of the TMF, and that a forest of fewer species is being created and exotics introduced. The concern of conservationists, as groups and individuals, that the forests should be left untouched and protected for their intrinsic values and as gene pools, is recognized as is their value as a refuge for the remaining indigenous fauna. However, it is difficult to justify the expenditure of resources on such protection unless the object of the protection also contributes to the economic well-being of the nation. The adoption of the policy and strategy outlined above will, it is hoped, achieve a high degree of conservation, as well as increasing the economic value of the resource.

74. Since 1980 the Forest Department has wished to survey and quantify the stocking of all regenerated forests, but this has been impossible. The following indications have been gleaned from field observations and the results of recurrent assessments of research plots.

75. In 1968, Nambigirwa forest near Entebbe was harvested a second time following utilization by pit sawing before the end of the First World War. The proportion of Entandrophragma angolense and of Lovoa trichilioides was unusually high and some must have originated in the early enrichment plantings between 1916 and 1926. The exotics Toona ciliata and Eucalyptus grandis had attained diametres at breast height of over 50 and 70 cm respectively, but Cupressus macrocarpa and Podocarpus latifolius had been suppressed and only attained a dbh of 30 cm.

76. About the same time stock mapping was done in some of the forests of South Kyagwe that had been enriched after harvest in 1944-48, some of the enrichment was done with Khaya anthotheca that is not indigenous to these forests. Again the proportion of the Meliaceae was higher than would otherwise have been expected and some of the Khaya had reached 50 cm dbh after less than 25 years, although a more common size was between 20 and 30 cm. Unfortunately, the majority remained at the sapling stage, stagnating but surviving in the understorey.

77. In Budongo, the number of Meliaceae in the Biiso block, where much of the earlier enrichment planting was sited, is also high and the crop appears very even aged. In the neighbouring Nyakafunjo block Research Plot No. 34 was planted in 1952 at 2 m by 2 m and 4 m by 4 m replicated in two clearing treatments after exploitation - low clearing and line clearing. The whole experimental areas was refined 6 years later. Most of the planting stock was Khaya anthotheca. By 1976 - the most recent assessment and 24 years after planting - the diametre distribution of the four leading desirables per 0.04 of a hectare is shown in Table 3A. Not all the trees recorded were planted. A second research Plot, RP 14, was sited on the edge of the forest in colonizing forest rich in Maesopsis eminii, which was felled in 1958. The crop was virtually pure Maesopsis so that it was, in

fact, clear felled, damaging 50% of the advance growth mahoganies. By 1974, 60% of the regeneration was Entandrophragma and Khaya and only 4% was Maesopsis, and by 1982 this 4% had disappeared. This seems to confirm the succession suggested by Eggeling.

Table 3A. Research Plot 34 - Budongo - Diameter Frequency

| Dbh class (cm) | 10 | 20 | 30 | 40 | 50+ | Total |
|---|---|---|---|---|---|---|
| Frequency per ha | 42 | 26 | 11 | 4 | 3 | 86 |

78. Karani (1985) quotes data comparing regeneration results and growth in Budongo and Bugoma forests (see Table 3B). Felling dated from 1955-56, and the sampling to collect the data was done in 1965-66, approximately 10 years later in both cases. These data were collected during studies of the effect of elephant in these forests (Laws et al., 1975) and the two sites were selected as being comparable. However, one must keep in mind that the method of assessment only records the four leading desirables per 0.04 ha, and it is not certain whether the trees measured date from the felling or already existed as advance growth. He suggests that "the difference between the regeneration of the two forests can only be explained by the presence of more elephant in Budongo than in Bugoma. The regeneration in the former forest is destroyed or kept back at the sapling and pole stage and is not allowed to grow into the larger diametre sizes. Another aspect of concern is that elephants tend to browse the species that are common in the regeneration, particularly Chrysophyllum albidum and Khaya anthoteca, which together account for 50% of the stocking of desirable species. If the damage continues, it may alter the composition of the future crop and the form and nature of the forest". However, now that the population of elephants has fallen so drastically, one is more concerned for their welfare than worried about the damage they might do to tree crops.

Table 3B. A Comparison of the Diameter Frequency of Regeneration in Budongo and Bugoma Forests

| Dbh class (cm) | <10 | 10 | 20 | 30 | 40 | 50+ | Total |
|---|---|---|---|---|---|---|---|
| Budongo | 96 | 9.7 | 3.4 | 1.5 | 1.3 | 3.5 | 115.4 |
| Bugoma | 52 | 16.3 | 13.8 | 7.9 | 4.7 | 5.7 | 100.3 |

79. Karani also quotes data from the Research forest at Mpanga for forest that was felled and treated early in the 1950s (Table 3C). These data are not comparable with those given above because they refer to all species rather than the limited list of valuable species recorded in Budongo and Bugoma.

Table 3C. Diameter Frequency of Regeneration 25 Years after Felling Mpanga Forest in West Mengo

| Dbh class (cm) | 10 | 20 | 30 | 40 | 50+ | Total |
|---|---|---|---|---|---|---|
| Frequency per ha | 181 | 29 | 13 | 1 | 1 | 225 |

80. Natural regeneration has now been in use in the TMF of Uganda for thirty years and it is time for a definitive assessment of the results which, unfortunately, is not possible immediately. The indications are that, provided the regeneration is not suppressed by climbers or overwood, then success is probable and an average of 0.5 cm a year diameter increment on 50 stems per ha is feasible.

81. Thus, although there is need for a great deal more research on the autecology of the different species and their relationships within associations, the current yield control and silvicultural system is acceptable as being that most likely to meet the objects of management.

82. The existing facilities for training staff at university level and at the middle or technical level are adequate; there is no shortage of personnel though most lack adequate experience. As opportunity permits, staff are sent on courses to increase their professional abilities and potential.

83. At present there is a severe shortage of equipment and resources to allow the staff to be effective; travel to and within the forests is sometimes hazardous. It is expected that investment in the sawmilling sector over the next ten years will bridge the gap between the current supply and the estimated sustainable yield from the forest. It is also recognized that the 5,600 $km^2$ of natural forest cannot meet the energy (firewood and charcoal) requirements of the 15 million people of Uganda and those of industry. Fortunately, there is experience in afforestation and by the dual policy of creating intensive plantations of exotics for industry and encouraging the rural people to establish individual woodlots and agroforestry practices, this demand could be met. In the years to come, the extension arm of the Department will be deeply involved in helping to increase the area and volume of the wood resources in the rural areas.

84. Therefore, given the re-establishment of stability in the country, the Uganda Forest Department is confident of the adaptability of the current management system to meet the demands of the future.

## CASE STUDY NO. 2

## AN ANALYSIS OF THE DEVELOPMENT OF MANAGEMENT SYSTEMS IN THE TROPICAL MOIST FORESTS OF NIGERIA

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# AN ANALYSIS OF THE DEVELOPMENT OF MANAGEMENT SYSTEMS IN THE TROPICAL MOIST FORESTS OF NIGERIA

## 1. INTRODUCTION

1. This Case Study is derived from a paper prepared by Professor P.R. Kio, Director of the Federal Research Institute of Nigeria, and his colleagues A.B. Oguntala, D.O. Ladipo and F.O.C. Nwonwu. The text largely follows theirs but some re-arrangement and condensation has been made to fit the structure of the present publication.

2. Their report emphasizes policy and land use planning in relation to forest production, and discusses the silvicultural methods of high forest treatment and plantation establishment, harvesting and industrial developments and the institutional arrangements affecting policy and forest management. Over the years, the need for the establishment of plantations to augment the productivity of the TMF has been recognized in many countries in West Africa. Despite the inherent dangers of monoculture, the productivity of plantations is more attractive to most countries than reliance on the management of the TMF for wood production, and this has resulted in the development of large areas of forest plantations over recent years. This trend is continuing, especially in countries where pulp and paper industries are being established. An example of this is Nigeria where over 70% of the plantations established are for the supply of raw material for pulp and paper manufacture.

3. Nigeria's forest policy in 1975 had much in common with that of Uganda and other anglophone countries in Africa. Kio _et al._ (1985) quote parts:

(1) an adequate area shall be dedicated to permanent forest to meet the requirements of protection and production; land outside the forest estate shall be regarded as potentially agricultural;

(2) that the management of the forest estate shall be always by methods aimed at attaining maximum sustained yield to derive in perpetuity the maximum benefits for the greatest number of people;

(3) that greater government participation in the exploitation of the forest and establishment of wood-based industries shall be fostered in order to increase sectoral revenue and ensure that a state of full employment would occur;

(4) that the savanna areas be managed for the dual purposes of wood production and grazing;

(5) that where the need exists, plantations shall be established to provide fuel and poles; and

(6) that it shall be the aim of the government to maintain efficient forest services and to provide adequate funds to achieve this objective.

4. Adeyoju (1975) and Kio et al. (1985) have observed that great difficulties were experienced in reconciling the multiplicity, ambiguity and hierarchy of aims. Kio et al. (1985) conclude that, "With a federal government system with states spread in different ecological zones, official declarations are so conflicting that it must be extremely difficult if not impossible for forest officers to pursue the aims simultaneously".

## 2. THE PHYSICAL, BIOLOGICAL AND ECOLOGICAL FACTORS

5. Most of the TMF in Nigeria occurs in the high rainfall belt towards the coast in the states of Oyo, Ogun, Ondo, Bendel, Anambra, Imo, Cross River, Rivers and Lagos with riparian forest in Kwara. Table 1 gives a breakdown of forest cover and land use. A description of the vegetation is summarized efficiently in White's (1983) "The Vegetation of Africa", from which the following notes have been gleaned. Here Nigeria is included in the Guineo-Congolian regional centre of endemism that includes the coastal high forest areas of parts of Sierra Leone, Liberia, Côte d'Ivoire, Ghana, Nigeria, Cameroon and Gabon as well as the Zaire basin. The rainfall is lower than in rain forest areas on other continents - mainly between 1,600 and 2,000 mm - and with dry periods when less than 100 mm a month falls. White states, "The classification of Guineo-Congolian rain forest is difficult. This is partly because variation in floristic composition, physiognomy and phenology is largely gradual and continuous, and partly because the distribution of many species is very imperfectly correlated with obvious environmental factors. Most of the forests of Nigeria have been classified as mixed moist semi-evergreen. Mixed moist semi-evergreen rain forest is relatively rich floristically. In Okumu Forest reserve, near Benin in Nigeria, Jones recorded 170 species more than 30 cm in girth in a plot of 18.4 ha, of which 52 belonged to the upper, emergent, storey. Most species in this type of forest are widely distributed. The following large trees, among many others, occur West of the Dahomey gap, and also in southern Nigeria and throughout the greater part of the Zaire basin:

> Entandrophragma angolense, E. candollei, E. cylindricum, E. utile, Guarea cedrata, G. thompsonii, Lovoa trichilioides, Maranthes (Parinari) glabra, Nauclea diderrichii, Parkia bicolor, Pericopsis (Afrormosia) elata, Petersianthus macrocarpus (Combretodendron africanum, C. macrocarpum).

Some of the more abundant emergent species of mixed moist semi-evergreen lowland rain forest e.g.:

> Canarium schweinfurthii, Piptadeniastrum africanum, Ricinodendron heudelotii, Sterculia oblonga (Eriobroma oblongum) and Terminalia superba

are also found in dry peripheral semi-evergreen rain forest. In the former, they usually occur in secondary forest. Lophira alata, another secondary forest species in mixed moist semi-evergreen rain forest, is also an abundant component of secondary forest in the hygrophilous coastal evergreen rain forest regions, of which it is more characteristic".

Table 1. Land Use and Land Cover in Nigeria (1976/77)

| Total Land Area (ha) | 89,206,279 |
|---|---|
| Land Use | Percentage |
| Tropical High Forest | 5.5 |
| Swamp and Riparian Forest | 4.2 |
| Plantations | 0.2 |
| Water | 0.8 |
| Other Uses | 89.3 |

6. White also recognizes three related forest types in this zone:

1) drier peripheral semi-evergreen Guineo-Congolian rain forest;

2) single dominant moist evergreen and semi-evergreen rain forest;

3) hygrophilous coastal evergreen rain forest,

and suggests that much of the remaining rain forest both inside and outside forest reserves on well-drained soils occurs on land that has been formerly cultivated; it is therefore secondary forest which, if old, is very difficult to distinguish from primary forest. He recognizes and infers three stages of succession:

1) pioneer secondary forest up to 12 m in height. Dominants include Anthocleista spp., Caloncoba welwitschii, Chaetocarpus africanus, Harungana madagascarensis, Rauvolfia vomitoria, Tetrochidium didymostemon, Trema orientalis, Vernonia conferta;

2) young secondary forest characteristically dominated by Musanga cecropioides. Other species include Buchnerodendron speciosum, Caloncoba glauca, Croton mubango, Lindackeria dentata, Macaranga monandra, M. spinosa, Maesopsis eminii, Myrianthus arboreus;

3) old secondary forest with Alstonia boonei, Antrocaryon micraster, Trilepisium madagascariense, Canarium schweinfurthii, Ceiba pentandra, Clorophora excelsa, Discoglypremna caloneura, Zanthoxyllum gilletii (Fagara macrophylla), Funtumia africana, Holoptelea grandis, Khaya anthotheca, Morus mesozygia, Pterygota macrocarpa, Pycnanthus angolensis, Ricinodendron heudelotii, Terminalia superba, Triplochiton scleroxylon, Xylopia aethiopica.

White also states "Some of these e.g. Canarium, Chlorophora, Morus, Ricinodendron, Triplochiton, and Terminalia are also characteristic species of dry semi-evergreen Guineo-Congolian forest, and it is not always easy to determine the status of the forests in which they occur. Chlorophora, Terminalia and Triplochiton can regenerate abundantly on abandoned farmland without the necessity of an intervening Musanga stage". From the foregoing the similarity with White's lake Victoria regional mosaic and the links with the Afromontane rain forest are obvious.

3. SOCIAL FACTORS

7. Kio et al. (1985) state "In Nigeria forest exploitation is on the increase and experts have warned that given the present rate of exploitation, the forest resources may be depleted by the turn of the century. Figures estimating supply and demand are given in Table 2. To combat the imminent shortage, plantations of high quality woods and other timber species are now being established. Plantation establishment is one way of meeting wood demand and also ensuring the supply of high quality timber species which may be lost from the natural forest. Forest policy is geared towards supporting research on indigenous and exotic species that are amenable to plantation management. Among the species that are now planted for this purpose is *Gmelina arborea* which serves as a utility saw timber, pulpwood and utility veneer. *Terminalia ivorensis* is also included in the policy of plantation extension. Osafu (1981) has indicated that Nigeria is now engaged, as a matter of priority, in the creation of forest resources, that is plantations, to feed forest industries that it plans to establish".

Table 2. Balance of supply and demand for major wood products in Nigeria - millions of $m^3$, roundwood equivalent
Source: Agricultural development in Nigeria, 1983-2000 Forestry Sector Review

| Product | 1975 | | | 1985 | | | 1995 | | |
|---|---|---|---|---|---|---|---|---|---|
| | D | S | SEF | D | S | DEF | D | S | DEF |
| Sawnwood | 2.0 | 2.0 | - | 4.8 | 2.2 | 2.6 | 11.6 | 2.4 | 9.1 |
| Plywood | 0.1 | 0.1 | - | 0.4 | 0.1 | 0.3 | 1.1 | 0.1 | 1.0 |
| Paper products | 0.6 | - | 0.6 | 1.9 | 0.5 | 1.3 | 5.2 | 1.0 | 4.2 |
| Poles | 1.6 | 0.8 | 0.8 | 2.0 | 0.8 | 1.2 | 2.3 | 1.0 | 1.3 |
| Firewood | 42.0 | 42.0 | - | 48.0 | 49.0 | (+1.0) | 54.0 | 54.0 | - |
| Total | 46.3 | 44.9 | 1.4 | 57.0 | 52.6 | 4.4 | 74.1 | 58.5 | 15.6 |

D = demand S = supply DEF = deficit between demand and supply

8. Speaking of the demand and supply of energy, Kio et al. (1985) have pointed out that even in a petroleum producing country like Nigeria, wood for fuel constitutes over 80% of total wood consumption in the country.

9. The traditional sources of wood are gradually diminishing through massive forest clearance (shifting cultivation). Both the TMF and the woodland savanna have been put under severe pressure. In Nigeria, there now remain only some 16,000 $km^2$ of reserved TMF. The potential for managing forest for firewood (rather than complete clearance) is still great, since almost all the fuelwood currently being utilized comes from the natural forest and woodlands. It is now common to find fuelwood markets in all urban centres. Fuelwood has definitely joined the cash economy. Wood is cut and stacked along the roadside for sale to drivers of vehicles bound for the urban centres. Certainly the overwhelming importance of fuelwood is indicated in the data presented in Table 2.

10. Against this enormous demand the plans for establishing fuelwood plantations are relatively modest. The proposed development is for 500 ha of fuelwood plantations in each of ten states annually for five years, i.e. a total of 25,000 ha. Even assuming an optimistic yield of 10 $m^3$ $ha^{-1}$ $yr^{-1}$, this total area will only produce 250,000 $m^3$ or about 0.5% of the predicted current demand. However, this programme will be supported by a vigorous rural community forestry effort to persuade individual house holders to establish trees to provide them with their own wood.

## 3.1 Population and Land

11. With the increase in population, the area of forest has been diminishing because of the demand for land for farming, industry and urban settlements.

12. The rate of growth of the population in Nigeria is high. Official figures since just prior to independence in 1960 are not easy to interpret, but the current population is estimated at over 90 million people with a current rate of growth of nearly 2.5%. However, national averages mask the effects of regional differences which themselves are exacerbated by the fast rate of growth in the size of towns and the density of population in their peripheral fringes. Many of these towns are situated in the southern half of the country where the rainfall is higher and conditions for agricultural production are often more favourable than in the more northerly parts. Consequently the pressure on land is that much higher in the TMF zone than elsewhere. Where shifting agriculture is the traditional practice, increasing population pressure has shortened the fallow period between successive cultivations to such an extent that it is incapable of restoring the fertility of the site (Kio, 1980).

13. Also forest lands are being increasingly acquired for large scale agricultural developments of various kinds which, it is claimed, will prove more productive in terms of both economic output and employment than under forest management. There have been cases where prime forest reserves rich in timber have been cleared and converted to oil palm, rubber, citrus, cocoa or other plantation crops - even when suitable non-forested land existed close-by. The appraisals are rarely comprehensive and often exclude not only the present worth of the standing timber and regeneration but also the indirect benefits of the forest. In one study undertaken by the Forestry Research Institute of Nigeria (FRIN) on behalf of the International Institute of Tropical Agriculture (IITA), a 30 ha agricultural research plot excised from the Okumu Forest Reserve in Bendel State contained a merchantable wood volume of 165 $m^3$ per ha with a market value of Naira (N) 30,000 per ha. This did not include any food, medicinal or other values of the forest plants and animals, nor the indirect benefits of the ecosystem (FRIN, 1984).

14. Other major elements in the degradation of the forest have been industrial and urban developments. The period 1978-88 has been declared as the "Transportation and Communication Decade" in Africa. In this period, important new road networks connecting major parts and capitals of the continent are to be completed. The first Trans African Highway linking Mombasa on the coast of Kenya with Lagos on

the coast in Nigeria has already been completed. Such highways open up hitherto inaccessible areas and provide new foci for deforestation. Increasing urban development has also led to the enlargement of existing centres at the expense of the surrounding farm land and forest. Similarly forested land has been used for airfields, man-made lakes, military installations, schools and industrial estates. This forest destruction not only has immediate effects on wood supplies, but may have long term effects that are a major concern to ecologists, foresters, agriculturists and conservationists alike.

3.2 Staff

15. The professional staff in Nigeria consist of graduates from local and overseas university departments of forestry. Because of shortages of suitably qualified graduates, some are recruited with degrees in the natural and applied sciences such as agriculture, botany, zoology, chemistry, engineering, sociology or economics. They gain knowledge about forestry, both "on the job" and by attending intensive courses at local or overseas forestry schools in universities and institutes of higher learning. Professional staff also take post-graduate degrees to enhance their training and expertise. There is a need for continuous in-service training to maintain their efficiency in a fast changing world, and resources have been allocated for this purpose in the Development Plans. Nevertheless, shortage of experienced trained professional staff still remains a bottleneck to the effective execution of development programmes and even to current activities. Forestry has to compete for trained manpower with many other disciplines; it may not be considered one of the most attractive, as it is associated with remote areas and harsh working conditions.

16. A pre-requisite for admission to Nigerian technical training schools of forestry is the West African School Certificate. There the trainees take a two year course followed by one year field attachment. Other trainees spend only one year in forestry school and take up supervisory duties at a lower level. Students with only primary school certificates are trained for some 6 months, partly in training schools and partly "on the job". Forest workers have little formal training but, as the tools they use become more sophisticated, training in correct operational techniques, safety and maintenance will be required.

17. In special circumstances experienced and well qualified technical staff can be promoted to the professional grade. Also, even though there is a substantial difference between the role of a professional officer in charge of a geographical area and that of an experienced technician supervising operations and programmes of work, some interchange of staff is both feasible and practised. Where the Forest Law empowers professional forest officers but not senior technical officers, then special Gazette notices have to be published empowering the latter to undertake all the legal duties of the professional officer during his tenure of a professional post. In this way, the grading of the staff has a degree of flexibility built in to suit the manpower situations, needs of the country and the capability of individual staff members.

## 4. ECONOMIC FACTORS

18. Nigeria experiences many of the common difficulties in funding which have already been described in paragraph 84, Chapter 2. Kio et al. (1985) suggest that the pattern of budget provision by Government and of other investment has changed since the boom in exports of wood products of the 1950s. This trend started with a drive for import substitution through, primarily, sawmilling during the 1960s and 1970s and now is concentrated on integrated and sophisticated industries.

19. During the early colonial days investments were mainly in logging and transporting equipment, at first for small scale and then for an increasing size of operation. The early 1970s saw the substitution by locally manufactured goods of imported wood products such as construction timber, doors, veneer products, furniture, etc. and many sawmills sprang up. Harvesting intensified and the natural forest - especially that outside the forest reserves in what was known as the "free areas" - was brought to the brink of destruction. This initiated projects to establish compensatory plantations, that is plantations that would supply an equal volume of sustained production from a smaller forested area. Both Federal and State funds were allocated for plantation projects, even though the costs per hectare were high (US$ 2,200 per ha). Meanwhile private investors, many of them expatriate companies, established sawmills and embryonic integrated industries. By 1980, there were over 1,000 sawmills in Nigeria, many of them simple horizontal band mills costing some US$ 70,000 each.

20. This period and type of investment in the 1970s has been followed by fewer but more capital intensive investments in more sophisticated processing plants in the 1980s. Nigeria now has two particle board mills, and three pulp and paper mills are either already in existence or due to open in the near future. Investments in forestry projects in Nigeria and the amounts contributed by the implementing agencies for the years 1980-82 and the financial allocations to Federal Department of Forestry projects for the years 1981 and 1982 are shown in Tables 3-6. In the three major afforestation projects, 60% of the investment is being subscribed locally, compared to 40% from the World Bank.

Table 3. Financial allocation to Federal Department of Forestry, Nigeria - Naira. Projects for 1981 & 1982

| Project | Allocation 1981 | Allocation 1982 |
|---|---|---|
| Forest management capability and data bank | 400,000 | 164,150 |
| Forestry cartography and photo-interpretation | 250,000 | 171,120 |
| Watershed management and flood control | 1,250,000 | 152,750 |
| Sawmilling & forest utilization centre | 850,000 | 248,750 |
| Arid zone afforestation | 4,000,000 | 4,242,500 |
| Rural forestry development & seed services | 2,000,000 | 1,459,248 |
| Timber & poles plantations in the TMF | 1,500,000 | 259,164 |
| IBRD/FGN forest plantation development | 4,920,000 | 1,907,488 |
| Establishment of field offices in the state capitals | 850,000 | 156,375 |
| Kainji Lake National Park | --- | 46,655 |
| Pulpwood plantation development | --- | 2,100,000 |
| Total | 16,020,000 | 10,908,200 |

Table 4. Contributions by implementing agencies for the Anambra World Bank Pine Project, 1980-82 - Naira

| Year | Federal Government | State Government | World Bank |
|---|---|---|---|
| 1980 | 461,000 | 498,261 | 89,216 |
| 1981 | 289,645 | 342,973 | 369,135 |
| 1982 | 750,609 | -- | 211,263 |
| Total | 1,501,254 | 841,234 | 669,614 |

Table 5. Contributions by implementing agencias for the Ondo State World Bank afforestation project 1980-82 - Naira

| Year | Federal Government | State Government | World Bank |
|---|---|---|---|
| 1980 | 600,000 | -- | 70,001 |
| 1981 | 1,200,000 | 1,400,000 | 737,393 |
| 1982 | 1,833,949 | 650,000 | 2,845,443 |
| Total | 3,633,949 | 2,050,000 | 3,652,837 |

Table 6. Contributions by implementing agencies for the Ogun State World Bank Afforestation Project 1980-82 - Naira

| Year | Federal Government | State Government | World Bank |
|---|---|---|---|
| 1980 | 1,200,000 | 600,000 | 183,913 |
| 1981 | 1,600,000 | 1,940,000 | 2,258,132 |
| 1982 | 799,358 | 350,000 | 2,293,525 |
| Total | 3,599,358 | 2,890,000 | 4,735,570 |

21. Although Kio *et al.* (1985) described the 3% share that forestry was allocated in the 4th National Development Plan as paltry, it amounted to almost three times the allocation of the previous plan and totalled N 291,877 million. Details of major items are:

(1) N 115 million or 40% of the total forestry capital budget to establish:

- 6,250 ha per yr of utility and peeler grade log and pulpwood plantations;

- 400 ha per yr timber and transmission pole plantations in the 10 southern states;

- 400 ha per yr pine plantations in Anambra state (Table 4);

- 3,200 ha per yr Gmelina pulp plantations in Ogun & Ondo states (Tables 5 & 6);

- 500 ha per yr bamboo plantations.

(2) N 56.84 million capital expenditure on plantation development in all 19 states;

(3) N 9 million for inventory studies of which 6.5 million is allocated to the Federal Department of Forestry to establish a data bank and provide various management services to State governments;

(4) N 8.7 million for infrastructure development, including the setting up of Federal Forestry field offices in the State capitals.

This budget clearly shows the emphasis on plantation establishment.

## 5. PROCESSING AND HARVESTING

22. Kio et al. (1985) quote some disturbing statistics about the capacities of Nigerian industries which are reproduced in Table 7. The total of over 11 million $m^3$ input capacity seems to be very much more than is required to produce either the demand or supply figures quoted in Table 2. Part of this discrepancy may be due to underestimates of the supply from private lands and areas outside the forest reserves. Also illegal felling is common. Ikumoguniyi (1980) has estimated the total loss to Government through illegal felling at N 26 million a year from within the forest reserves harvested by 6 of the major wood based industries in Nigeria. The total loss to the nation must be far in excess of this figure, as log thieves operate throughout the forest areas, and are now well organized and invade the forest reserves armed with sophisticated automatic weapons.

Table 7. Log input capacities of wood industries by States in Nigeria, 1980 - $m^3$ per year

| State | Log input capacity |
|---|---|
| Bendel | 1,400,000 |
| Benue | 257,000 |
| Cross River | 182,000 |
| Gongola | 94,000 |
| Kano | 49,000 |
| Kwara | 367,000 |
| Lagos | 1,427,000 |
| Niger | 73,000 |
| Ogun | 1,837,000 |
| Ondo | 2,561,000 |
| Oyo | 3,058,000 |
| Rivers | 82,000 |
| Total | 11,387,000 |

After Alviar G.O. (1983) Report on forest industries in Nigeria.

23. Logging has developed from a predominantly log export oriented operation controlled by foreigners to one dominated by indigenous contractors working for domestic sawmill owners or the larger integrated industries. As yet there has been little delivery to the pulp mills, as they are not yet in full production. However, the developments needed in the future are little short of revolutionary. A great deal of effort will be needed to organize the harvesting of the pulpwood plantations, and an extensive training programme for machine operators and supervisors will be necessary.

## 6. INVENTORY

24. Of Nigeria's 924,000 km² of land, a belt of some 200,000 km², in the south, forms the TMF zone. The forest has been so depleted that Persson (1975, 1977) reported that only some 45,000 km² was left. The Federal Department of Forestry (NAS Report on the Tropical Moist Forest, 1980) recorded an area of only 25,500 km² worth classifying as forest reserve. FAO (1981) reported about 20,000 km² in forest reserve (of which 4,000 km² was forest fallow) and about 117,000 km² outside forest reserve (of which 74,000 km² was forest fallow).

25. The history of forest inventory in Nigeria dates back to the 1930s when complete enumerations of merchantable sized trees of a few economic species, were carried out by timber contractors in their concessions to determine the timber available for the export market. Large scale inventories were later carried out by the Forestry Departments, based on samples, to provide the information necessary for the control of harvesting, the planning of management and for feasibility studies for industry and its expansion. In the former Western State stratified random sampling using 20 m wide strips at an intensity of between 2.5 and 5.0% was adopted (Akinsami, 1976). All trees exceeding a specified girth were enumerated, as well as regeneration counts of economic species in sub-samples.

26. In late 1948 the Nigerian Survey Department carried out an aerial survey using a light aircraft. This was mainly used for large scale photography of limited areas - mainly of towns. Some more extensive surveys were of interest to geologists, soil surveyors, foresters, agriculturalists and soil conservationists (Phillips, 1950). Two important forest inventories involving the successful application of aerial photography in Nigeria were reported by Kio (1971). The most recent, extensive and sophisticated forest inventory was the Indicative High Forest Inventory (I.H.F.I.) of the reserved high forest in Southern Nigeria which took place from 1973 to 1977 and covered 13,300 km² of forest reserve. It was carried out by the Federal Department of Forestry with the assistance of FAO under the United Nations Development Programme. The two main objects of this were:

(1) to determine the amount and quality of timber of saleable size of the species now being utilized and of those with potential;

(2) to assess the degree of exploitation and the quality and type of regrowth that could be expected in the near future.

The data generated from the I.H.F.I. were intended to serve as a guide for forest management studies and for the selection of areas to be converted into plantations.

27. Aerial photography was used to only a limited extent in this inventory, as those available were out of date and no new ones could be obtained quickly. Consequently, the I.H.F.I. used a systematic layout of clusters, and the inventory was designed to provide a precision where standard error would not exceed 20% of the average, at a probability level of 95%, over sub-divisions of the total area of roughly 400 $km^2$ each. The net harvestable volume of all tree species above a minimum dbh of 60 cm was determined, with separate estimates for currently utilized and unutilized species. Stand basal areas and stock tables were compiled for the different forest types within individual forest reserves as well as for groups of reserves.

## 6.1 Radar Imagery

28. The extent of cloud and dust haze over the TMF zone of Nigeria limited the use of aerial photography in the I.H.F.I. During 1976-77, a Side-Looking Airborne Radar survey of Nigeria was carried out. It was named the NIRAD Project (Federal Dept. of Forestry, 1979). The objects of the survey were:

(1) to calculate the area of different vegetation types (see Table 1);

(2) to define the primary strata for forest inventories;

(3) to determine the land use potential for plantation development;

(4) to provide a benchmark or base from which to measure change in the vegetation and land use in future.

29. Table 8 shows an example derived from the inventory of Oyo State forest reserves in which Ainslie (1933) reported that *Triplochiton scleroxylon* was plentiful. The I.H.F.I., using the stratification derived from the Nirad project, indicated that six reserves in the State contained only some 400,000 $m^3$ of this species in 1976. By now, with the current rate of exploitation, only half this amount probably remains.

## 6.2 The Role of the Forestry Research Institute of Nigeria in Inventory

30. FRIN does not execute large scale inventories, but is engaged in monitoring forest development in research plots in order to support the design of treatments to encourage natural regeneration. Permanent sample plots have been established in the natural forest in order to study ecology, assess yields and monitor the rate of growth of the individual trees and the development of the crop. Recent studies include estimates of total biomass.

Table 8. Volume of trees of Triplochiton scleroxylon in six forest reserves in Oyo State

| Reserve & forest type | area-ha | volume total | $m^3$ per ha |
|---|---|---|---|
| Gambari - all types | 6,578 | 42,575 | 6.3 |
| Ife & Shasa - moist, disturbed | 17,539 | 158,201 | 9.0 |
| undisturbed | 23,231 | 135,901 | 5.8 |
| Osho River - all types | 33,950 | 13,153 | 3.3 |
| Ago-Owu - moist secondary | 5,944 | 2,615 | 0.4 |
| moist, disturbed | 9,873 | 32,383 | 3.3 |
| moist, undisturbed | 806 | 2,498 | 2.1 |
| Ijaiye - dry, disturbed | 3,523 | 1,409 | 0.4 |
| dry, undisturbed | 12,801 | 28,930 | 2.3 |
| Ikeju-Ipetu & Oni River | | | |
| moist, disturbed | 5,729 | 14,952 | 2.6 |
| moist, undisturbed | 1,351 | 567 | 0.4 |
| Total | 121,505 | 433,184 | 3.5 |

31. FRIN also has a corps of trained taxonomists and field forest botanists skilled in tree and plant identification. The importance of correct identification of trees during inventories cannot be over-stressed, especially as year by year more and more species become marketable. Authenticated herbaria are now maintained at both Ibadan and, more recently, at Enugu.

## 6.3 Sampling Designs and Assessments

32. Both systematic and stratified random sampling designs have been commonly employed. Some systematic designs have employed multiple random starts in order to provide valid estimates of the sampling error. Precision and sampling intensity have been constrained in most inventories by the level of funds and manpower available. Between 1933 and 1969, some thirty different inventories were executed, using sampling intensities between 1 and 5% (Esan, 1971). A more recent inventory of 145 $km^2$ of the Ago-Owu Forest Reserve in Oyo State done by the Federal Department of Forestry used an intensity of 0.1%. The I.H.F.I. (paragraph 26) based its layout on the results from a pilot study of the Ife-Shasha Forest Reserve. Enumeration in research plots has used very much higher intensities, for example 5% in a 2.6 $km^2$ plot in Akure Forest Reserve (Bamgala & Oguntala, 1973) and 16.7% in a 0.3 $km^2$ block in Okumu Forest Reserve (FRIN, 1984).

33. In most inventories poles and saplings are recorded in a sub-sample only. In some cases the sub-plots have been sited in the centre of the sampling units and sometimes they have been discontinuous parts of transects. In the I.H.F.I., trees above 40 cm dbh were sampled with probability proportional to basal area at breast height using a relascope, but trees in the range of 20 to 39 cm dbh were measured in circular plots of 0.03 ha centred on the sampling point used for the relascope sweeps.

34. Formerly, very many inventories in Nigeria used narrow transects or strips. However, now that base topographical maps are generally available and there is less need to map topography and drainage patterns during the inventory, this design is less common. Now, relatively small circular plots are more common as they represent the variation well and problems with borderline trees are fewer. Square plots are also used in both inventory and research in the TMF. Plots of 50 m by 50 m or 0.25 ha have been used frequently in the past; larger plots up to 2 ha may be preferable to reduce between plot variance in variable forest associations. Sub-divisions may be demarcated in order to aid the identification, charting and relocation of individual trees.

35. Volume estimates are usually based on the measurement of diametres along the bole from stump height to either the base of the crown or to a specified minimum diameter over bark. Volume reductions for defect and waste may be calculated. In the I.H.F.I. volume estimates were analyzed into 6 species groups based on timber characteristics and quality and 5 grades of log quality. Table 9 gives the analysis of the volume of timber available (all species) from this inventory for the six states comprising the bulk of the TMF.

Table 9. Results of Indicative Forest Inventory, Nigeria

| State | Area of surveyed forest reserves ha | Net standing volume ($m^3$/ha) > 60 cm dbh | > 40 cm dbh |
|---|---|---|---|
| Ogun | 151,200 | 44.38 | 66.46 |
| Ondo | 320,000 | 83.85 | 110.07 |
| Oyo | 118,200 | 59.05 | 80.55 |
| Bendel | 510,900 | 52.83 | 80.08 |
| Anambra & Imo | 37,100 | 15.01 | 22.05 |
| Cross River | 192,700 | 114.36 | 159.91 |
| Total | 1,330,100 | 67.74 | 95.74 |

36. Kio (1981) has carried out a more detailed analysis of these inventory results and established that great variation exists in the standing volume even between forests in similar ecological zones. He also calculated (Kio, 1979) that the total volume of wood could reach as high as 240 $m^3$ per ha if all species above 10 cm dbh were enumerated. He calculated these volumes using a pan-tropical form factor and height classes. Though at present the smaller trees of the lower and middle storeys are rarely harvested, they do represent a potential source for wood-based industries that are less selective of their raw material - fuelwood, pulp, fibre and particle board mills, for example.

37. The tree increment plots so far established in the Nigerian high forest are few and mainly subjectively sited for ecological studies at particular sites. The I.H.F.I. provides a description of the forest in 1976 and is a base against which to monitor change. However, it must be complemented by a study of the dynamics of the forest and, therefore, at least 50 permanent sample plots will be

established at the rate of one per cluster used in the I.H.F.I. Demarcation will be by trenches. The intention is that these plots will truly represent the whole forest area and, therefore, it is imperative that they are not given any special treatment. Soil samples will be taken at each plot, analyzed and used to monitor change in soil characteristics after treatments, such as conversion to plantations, for example.

## 7. SILVICULTURE

38. Accounts of the history of natural regeneration practices in Nigeria have been given by Lancaster (1961), Oseni and Abayomi (1970), Lawton (1978) and Lowe (1978). Until 1944, although the need to maintain productivity of the natural forest was realized, there was no one regeneration method systematically applied in Nigeria. There was, however, a great deal of observational work recorded on the ability of various species to regenerate naturally.

39. In 1906, new rules gave lessees of concessions the option of either planting trees to replace those felled or tending the natural regeneration by weeding, releasing and thinning. These measures were ineffective. At that time, the main economic species were:

(1) *Nauclea diderrichii*
(2) *Afzelia africana*
(3) *Chlorophora excelsa*

In 1910, attempts were made at Olokumeji to stimulate group regeneration under mother trees of *Chlorophora excelsa* by removing all other growth.

40. During the 1920s the main forest estate was demarcated and gazetted and, progressively, harvesting became regulated and the forests were put under working plans. Yield was initially regulated by volume and a minimum girth limit, but regulation by area based on a felling cycle of 100 years was introduced in the 1940s (Collier, 1946). Group planting at stumps after some site preparation was done by the felling agency, but these were difficult to maintain and were abandoned as unsuccessful (Oseni, 1971). By this time, *Triplochiton scleroxylon* (Obeche) and a few other species were marketable as secondary timbers.

### 7.1 The Tropical Shelterwood System (TSS)

41. In the 1930s attempts to induce natural regeneration by climber cutting and light thinnings were made along with progressive arboricide treatments using sodium arsenite. Post regeneration climber cutting and arboricide treatment to stimulate the development of advance growth were also done. Notable among these efforts were the experiments laid down by Kennedy at Sapoba between 1927 and 1936 (Lancaster, 1961; Lowe and Ugbechie, 1975). Four regeneration methods were tried: Transition system, the Uniform system, Walsh's system and Groups. The Transition system consisted of obtaining regeneration in groups and enlarging them until they joined up. The Uniform system resembled the later Tropical Shelterwood System (TSS), it comprised climber cutting in the first year, girdling of uneconomic species in

years two and three, and felling of economic species in years four and five. Seed was dibbled into the ground in year two in places where regeneration had not occurred. Walsh's system consisted of clear felling and burning over a whole compartment, stacking and re-burning debris and felling the few remaining mother trees three years later. The Group system consisted of clearing, stacking and burning debris from around selected mother trees and around stumps of exploited trees, the number of such groups being augmented annually until they had joined together. Although the Group system appeared to be the best, they were all less than satisfactory and were abandoned. Line planting on an experimental scale also started in the 1930s.

42. The presence in Nigeria during the Second World War of a number of experienced forest officers from Malaysia, helped to formulate the prescriptions of the Tropical Shelterwood System introduced in Nigeria, because it was a variation of the Malayan Uniform System adapted to Nigerian conditions. The system was used by the former Western and Mid-western regions - now Oyo, Ogun, Ondo and Bendel States. It entailed the gradual opening of the canopy, by felling or arboricide treatments, to induce regeneration and promote the development of the resulting seedlings or advance growth. This gradual opening aimed at limiting the vigour of the climbers and involved succession of pre- and post-harvesting operations that necessitated a high standard of organization and supervision. Two regeneration counts were usually done before harvesting and it was considered satisfactory if there were about 100 or more well grown seedlings per ha (Oseni and Abayomi, 1970). A summary of the operations as described and modified in successive Forestry Department Instructions (Anon., 1950, 1953 & 1961) is presented in Table 10. A total of around 2,000 km² were treated under TSS operations - mainly in accordance with the 1953 Instruction (Lowe, 1978).

Table 10. Summary of operations in the Tropical Shelterwood System, Nigeria Instruction 1/1961

| Year | Operation |
|---|---|
| -5 | milliacre sampling, climber cutting, cutting back saplings of weed species if advance growth inadequate |
| -4 | milliacre linear sampling, arboricide treatment of lower & middle storeys |
| -1 | climber cutting |
| 0 | harvesting |
| 2 | climber cutting, removal of shelterwood |
| 9 | 0.025 acre linear sampling |

Abbreviated from Kio *et al.* (1985) after Lowe (1978).

43. Until the introduction of TSS, artificial regeneration using taungya appeared to have been the preferred method but could not be supervised over the extensive areas of the concessions. Therefore, more extensive natural regeneration areas were used to complement the intensive plantation work of that time. Only some 7,000 ha of plantations had been established by 1960 (Ball & Daniyan, 1977).

44. Application of Nigerian TSS encountered a number of problems. As originally conceived, it was to involve complete felling/ arboricide, with regeneration under a shelterwood to create a more or less uniform new forest. The removal of the older wood was to be done by a combination of intensive harvesting of the overstorey trees and poisoning of the shadebearing uneconomic species of the middle and lower storeys. The system was then described as a clear felling system with a shelterwood period lasting approximately five years. In practice, however, it was found impossible to apply the system in all respects as conceived. Whereas in Malaysia, whence the Nigerian system was derived, the Malayan Uniform System was applied to high forest with a fairly continuous canopy and numerous seed bearers of the desirable species, in Nigeria the situation was quite different, particularly in the broken nature of the canopy. The effective stocking of the commercial species in the Nigerian forest rarely exceeded 10 per ha compared to very much higher levels in the Dipterocarp forests of Malaysia (Oseni & Abayomi, 1970). Also the irregular seeding of species such as Triplochiton scleroxylon did not facilitate regeneration.

45. There was also the problem of climbers that were common and stimulated by the opening of the canopy whether by harvesting or, apparently, by windfalls. Jones (1950) studied this problem in Okumu Forest Reserve and noted "we saw no evidence of their (high climber tangles') reversion to useful forest without intervention".

46. The selection of a few economic species, each with different silvicultural characteristics, rather than a range of species that would respond to the growing conditions resulting from a particular canopy treatment, also contributed to the problems of TSS. Arboricide treatment that was designed to remove the shade-casting uneconomic species of the middle and lower canopy layers, particularly those with wide spreading crowns, was not always successful. Species such as Diospyros spp., Funtumia elastica and Strombosia postulata were particularly resistent. At the inception of TSS almost every species not recognized as economic was treated with arboricide, including Celtis zenkeri, Combretodendron macrocarpum, Cordia platythyra, Pycnanthus angolense, Sterculia spp., etc. all of which are now marketable (this is an exact parallel with the story from Uganda).

47. Although these problems in TSS were unquestionable, opinion remains divided as to how successful it was and to what extent the problems could have been overcome by improved techniques. For example, the earliest prescriptions concentrated on the destruction of the middle and lower storeys and made no provision for removal of the upper storey, apart from the very light commercial felling. Because the market, and hence the harvesting, at that time was highly selective, only 3 or 4 trees were felled per ha. Fellings of so few trees made little appreciable difference to the upper canopy, except for the occasional gap. The residual crop in the upper storey consisted largely of the less desirable secondary species and the amount of shade left prevented any significant increase in growth rates among the desirable saplings and seedlings.

48. Theoretically, once the regeneration treatments had been completed, the forest was to be left relatively undisturbed until the end of the rotation. In practice, a dense residual stand was left and higher volumes have been known to have been removed in subsequent felling operations by concessionaires than under the first TSS harvest (Kio et al., 1985). Thus, the first cycle of the TSS as practised under the early prescriptions was more a modified form of a selection system than a true uniform shelterwood system. Later instructions did provide for removal of the entire shelterwood within eight years after harvest, but there was insufficient time to assess the long-term effects of the treatments on the rate of growth of the new crop and on the climber towers that resulted from the combined effect of felling and poisoning. Early management instructions envisaged a felling cycle of 100 years, presumably equal to the rotation, but in the mid 1960s the felling cycle was reduced to 50 years (Lowe, 1984).

49. At least in some areas TSS operations were successful in increasing the stocking of established regeneration. Lawton (1978) quotes one example where there was a fivefold increase in the number of saplings of marketable species over 3 m high (or 30 cm girth) in a treated sample as compared with the untreated control. It was, however, difficult to achieve good results consistently over wide areas, because of the variability of the forest, and effective stocking was often much reduced by climber damage.

50. There is also evidence that the TSS is capable of increasing diameter increment in the residual stand. If the forest is opened up by either heavy harvesting or arboricide treatment, then many of the advance growth of saplings, poles and trees in the 10-50 cm dbh classes respond vigorously to take advantage of the gaps created (Kio, 1976, 1980). Table 11 summarizes the average annual increments - cm dbh per tree - for different diameter classes over an eight year period under different TSS canopy treatments. Comparison of treatments is incomplete but the differences are not great. Nevertheless, the data demonstrate a positive correlation between diameter increment and diameter, and indicate that this type of crop tree is capable of accelerated diameter increment even in the larger sizes.

Table 11. Investigation No. 273: Sapoba Forest Reserve, Nigeria
Individual tree annual increments, cm dbh 1967-75

| | ten cm dbh classes | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| T | 15 | 25 | 35 | 45 | 55 | 65 | 75 | 85 | 95 | 100+ |
| 1 | 0.25 | 0.32 | 0.94 | 0.99 | 1.73 | 2.02 | 1.36 | 2.23 | 2.83 | 2.90 |
| 6 | 0.12 | 0.37 | 0.94 | 0.98 | 1.65 | 2.23 | 2.59 | 2.31 | 2.37 | 5.26 |
| 12 | 0.18 | 0.39 | 0.88 | 0.98 | 1.48 | 1.80 | 1.36 | 3.20 | 2.33 | 2.84 |
| 13 | 0.19 | 0.40 | 0.62 | 0.52 | 1.34 | 1.63 | 1.90 | 3.51 | 2.13 | 3.81 |
| Av. | 0.22 | 0.36 | 0.86 | 0.84 | 1.50 | 1.91 | 1.81 | 2.89 | 2.34 | 3.80 |
| n | 39 | 86 | 68 | 73 | 70 | 45 | 31 | 21 | 20 | 23 |

Note: average increments per class weighted by numbers of trees

T 1: heavy arboricide treatment and climber cutting for 4 years
T 6: selective arboricide treatment and climber cutting for 5 years
T 12: climber cutting only for 11 years
T 13: no treatment

total number of trees = 476

51. The main reason for the abandonment of the TSS in 1966 was political. There was pressure to release forest reserves for shifting cultivation, for urban and industrial development, or for permanent crops such as oil palm. At the same time projections of wood demand and supply indicated that the area of reserved forests within the TMF zone would be unable to provide for the needs of the population if managed as mixed, multispecific, naturally regenerated forest. The programme of conversion of a great part of the TMF in Nigeria to forest plantations would, it was hoped, lead to higher yields per unit area and at the same time provide clear evidence that the area was being managed in a dynamic manner; this would counter the pressures to direct the land from forestry to other uses.

### 7.1.1. Case Studies of Research Projects in TSS in Nigeria

52. Two research investigations, Nos. 273 & 278 of the FRIN attempted to test the effect of TSS treatments. They were both established in the mid-1950s, 273 in the moister forest at Sapoba and 278 in the drier type at Shasha where Triplochiton scleroxylon was abundant. The former was designed to study the effect of various treatments combining climber cutting and canopy opening on:

(1) the regeneration and growth of economic species;

(2) the incidence of climber tangles - the principal obstacle to the development of good form of young trees.

Treatments began in 1956 and continued beyond 1961-62 when timber harvest took place. The harvesting altered the site and complicated the layout because it let in light to plots originally only selectively treated with arboricide or not treated at all, and was followed by an increase in climber tangles. Multivariate analyses indicated that the distribution of the regeneration was closely associated with:

(1) distance to trees of the same species;
(2) frequency of trees of that species;
(3) basal area of trees of that species.

The strongest link was between regeneration and the sum of the reciprocals of distances to the trees of the same species within the assessment plots. Univariate analyses indicated that diameter increment was greatest in plots treated with annual climber cutting only and logging. The control showed the smallest diameter increments. Severe canopy opening was not associated with rapid diameter growth.

53. Similar results were obtained at Shasha where soils are shallower but with a higher base exchange capacity, and the climate exhibits a marked two peaked rainfall pattern with dry months of less than 100 mm of rain. Similar analyses to those performed on the Sapoba data (Kio, 1978) indicated the advantage of climber cutting and selective arboricide treatment to promote the establishment of saplings and accelerate the increment of poles. Heavy arboricide treatment depressed the development of poles and young trees though it promoted sapling recruitment. Response to the duration and periodicity of the treatments indicates the complexity of the system and the difficulty in designing rigorous experiments.

54. Kio et al. (1985) conclude: "It is difficult to be certain, but the indications from these experiments are that climber cutting and limited canopy treatment is beneficial both in augmenting the recruitment to the sapling size class and in stimulating the diameter increment of the poles and young trees. Generally, the fast growing pioneer species tend to predominate at first, but there are indications that the slower growing species of the upper canopy - that is the species with valuable timbers - later become more evident. This will, in time, enhance the value of the upper storey which will become substantially richer in these species than the original crop".

55. Redhead (1960) investigated felling damage in Cmpt. 142 of Sapoba forest reserve. He found that felling and extraction of 5.7 trees per ha affected about 0.5 ha of the residual stand. Of this, felling damage affected about 0.3 ha, within which 32% of stems were destroyed, while crawler tractor damage affected about 0.2 ha, within which 59% of stems were destroyed. This agrees fairly closely with Dawkins' estimate of 0.04 ha destroyed per tree felled (Case Study 1, Uganda, para. 37) Ola-Adams (1983).

## 7.2 Other Systems Used in Nigeria

56. In its original conception, with a proposed felling cycle of 100 years, the Nigerian TSS approximated a monocyclic shelterwood system. Later, when the proposed felling cycle was reduced to 50 years, it may be considered as a bicyclic system, with felling cycle approximately equal to half the rotation. Other systems used in Nigeria have mostly involved some degree of artificial regeneration.

### 7.2.1. Polycyclic Systems

57. Kio et al. (1985) have pointed out that conditions in Nigerian TMF are quite unsuitable for application of the classic selection system of temperate forests, in which cleanings, thinnings and final fellings are carried out simultaneously and frequently in all parts of the forest, and yield is derived from trees of all sizes, not just from the largest trees in the forest.

58. Some attempts at polycyclic management have been made. The Southern Ishan Group of Forest Reserves and Ife Forest Reserve were to be managed on a 25 year felling cycle (Allison, 1955), although information on diameter distributions below harvestable size was insufficient to demonstrate the potential of future crops. Also, most forests in Benin and Ondo have been re-entered for felling over the past forty or fifty years, under the influence of the wood markets rather than of silvicultural desirability.

### 7.2.2. Enrichment

59. Where natural regeneration has been found slow and uncertain, planting has been carried out in order to increase the stocking of the valuable species. In Nigeria, line planting dates from the 1930s in what are now Oyo, Ogun, Ondo, Bendel, Anambra and Imo States especially. Lines were often 20 m apart, with plants up to as much as 20 m apart in the line. Commonly striplings of various Meliaceae - Entandrophragma angolense, Khaya ivorensis, Lovoa trichilioides,

*Cedrela odorata* and *Guarea cedrata* - were used. In Gambari Forest Reserve *Nauclea diderrichii* and *Mansonia altissima* were also used. Later in the 1960s large scale plantings of these species and *Terminalia ivorensis*, *Triplochiton scleroxylon* and *Tectona grandis* were established in Omo Forest Reserve.

60. Success was not good. Failure was due to:

(1) poor survival;

(2) intense weed growth and hence slow growth;

(3) poor maintenance;

(4) too much overwood left from the previous crop;

(5) browsing by antelope and attack by shoot borers.

This analysis of the reasons for failure reinforces the validity of Dawkins' "desiderata" for line planting listed in Case Study 1, Uganda, paragraph 56.

61. The complexities of evidence on natural regeneration and lack of success with enrichment, coupled with the need to raise the productivity of the forests to meet the growing needs of the population for sawn timber and other wood-based products, forced the decision to consider conversion of the forests to even-aged plantations.

### 7.2.3. Conversion of Tropical Moist Forest to Plantations

62. In the early days, the emphasis in plantation forestry was on trials of fast growing exotic species including: *Tectona grandis*, *Cassia* spp., *Cedrela mexicana* and *Chickrassia tabularis*.

However, small trials of indigenous species such as *Nauclea diderrichii*, *Triplochiton scleroxylon* and *Terminalia superba* were also established. At this time, the supplies of the indigenous species were thought to be secure through the natural regeneration in the forest reserves (Ainslie, 1933), so this work was not given a high priority.

63. Later, in 1948 and again occasionally up to 1963, plantations up to 15 ha in extent were established using, mainly, *Triplochiton* and *Terminalia* spp. The Meliaceae and *Chlorophora excelsa* were also tried (Oseni & Abayomi, 1970). *Triplochiton scleroxylon* trials were established at five different sites in Nigeria by the West African Hardwoods Improvement Project (Howland & Bowen, 1977; Leakey *et al.*, 1983). These trials were established to evaluate the extent of the variation, establish gene banks and evaluate families which would provide, possibly, clones for large scale plantation establishment. Unfortunately, these trials were badly damaged by fire during the 1980-81 drought (FRIN, 1981).

64. Analyses of the total area of plantations up to 1983 are tabulated in Table 12A and 12B and illustrated in Figure 1. The most recent data, later than 1981 in some cases, are not available in great detail, but do show clearly the enormous emphasis given in recent years to *Gmelina arborea* which now accounts for some 40% of the plantation area in the TMF zone in Nigeria. The annual programme of

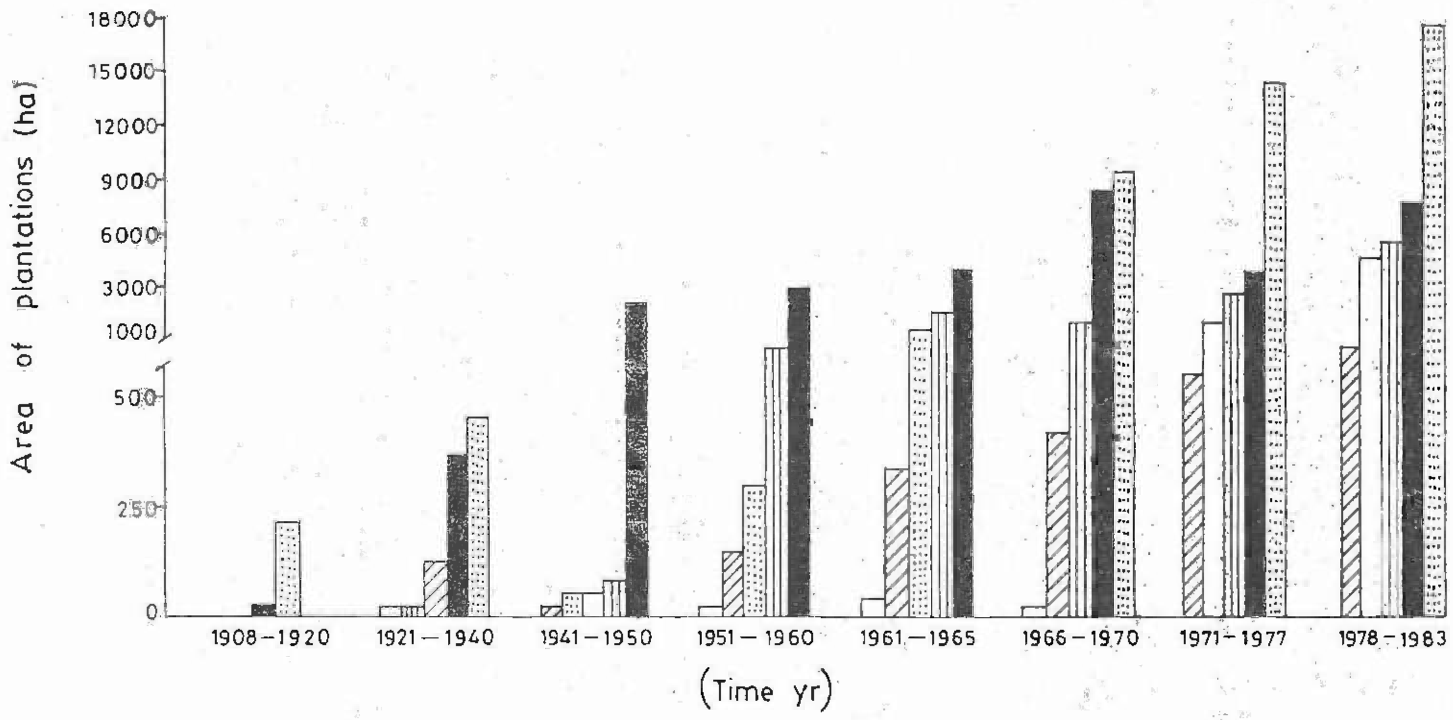



Fig. 1. Total area plantations established by individual states in the southern forest area of Nigeria (1908–1983) by years. (▦ – Oyo, Ondo, Ogun; ▨ – Cross River; ☐ – Kwara; ■ – Bendel and ▥ – Anambra states) source FDF Lagos.

planting with this species is increasing in order to provide pulpwood as well as utility grade saw logs. In parts of Oyo, Ogun and Ondo States alone, the annual rate is over 10 $km^2$ a year, and this is scheduled to double in the near future.

Table 12A. Area of plantations of indigenous hardwoods in the southern states of Nigeria (after Ball & Daniyan, 1977)

| Species | Area - ha up to 1960 | 1961-65 | 1966-70 | 1971-75 | 1976 | Total |
|---|---|---|---|---|---|---|
| *Naucela diderichii* | 585 | 337 | 1,451 | 5,952 | 839 | 9,164 |
| *Nauclea* mixtures | 5,813 | 1,883 | 4,867 | 2,311 | 643 | 15,517 |
| *Terminalia* spp. | 86 | 635 | 1,384 | 1,761 | 865 | 4,731 |
| Other indigenous hardwoods | 839 | 341 | 225 | 1,323 | 566 | 3,294 |
| Other mixtures | 99 | 308 | 280 | 271 | 75 | 1,033 |
| Total | 7,422 | 3,504 | 8,207 | 11,618 | 2,988 | 33,739 |

Table 12B. Area of plantations of Gmelina, teak & other species in some southern states of Nigeria (after Kio et al., 1985)

| Year | Niger | | | Oyo | | | Ogun | | |
|---|---|---|---|---|---|---|---|---|---|
| | Gm | teak | o.s. | Gm | teak | o.s. | Gm | teak | o.s. |
| 1970-1974 | 252 | 621 | 368 | 814 | 4,342 | 362 | - | - | - |
| 1975 | 110 | 203 | 48 | 256 | 682 | 116 | - | - | - |
| 1976 | 206 | 217 | 250 | 438 | 563 | 288 | 6,463 | 4,525 | 827 |
| 1977 | 299 | 176 | 77 | 956 | 564 | 478 | - | - | - |
| 1978 | 465 | 202 | 184 | 330 | 390 | 508 | - | - | - |
| 1979 | 400 | 90 | 159 | * | * | * | - | - | - |
| 1980 | 100 | 40 | * | 270 | 320 | 325 | - | - | - |
| 1981 | 128 | * | * | 80 | 88 | 87 | 9,168 | 740 | 1,223 |
| Totals | 1,960 | 1,549 | 1,086 | 3,144 | 6,949 | 2,164 | 15,631 | 5,265 | 2,050 |

Gm = *Gmelina arborea*, o.s. = other species

65. In recent years the practice of raising plantations with taungya farming has been abandoned in favour of what has become known as "Departmental taungya". The forest service now employs farmers to grow the agricultural crops, sells the produce and retains the revenues to help to offset the cost of plantation establishment. Elsewhere clearing and planting is done with departmental labour without any agricultural crop. Both systems are labour intensive in all phases of establishment, i.e. nursery work; site preparation; planting; and tending.

66. In the *Gmelina* plantations temporary or flying forest nurseries are common. Fruits are sown in beds and the seedlings are cut back to "stumps" after lifting, in preparation for planting. Stumps are normally 20-25 cm in length and about 1-2 cm in diameter at the root collar. The stem is cut off cleanly about 2-3 cm above the root collar and the tap root is pruned of side roots.

67. Initial clearing after harvesting is done by hand - either by taungya farm contractors or departmental labour. Debris is piled and burnt, sometimes around the base of large relicts of the original crop, the cost of felling of which is considered too high to be worthwhile. Occasionally such trees may be treated with arboricide.

68. Planting of the stumps is simple and quick as no pit is dug, but the stump is slipped into a small hole or slot made by machete, hoe or planting stick.

69. Weeding and, especially, climber control is done by hand - cutting with machetes. As yet little or no thinning is practised, especially in the pulpwood plantations. One of the main dangers to the plantations, especially towards the north where dry periods are common, is fire. So far little protection, other than care during periods when the danger is high, has been given. In fact, plantation silviculture is, as yet, little developed, as relatively extensive methods have, so far, succeeded.

## 8. FUTURE DEVELOPMENTS

70. Large gaps exist in our knowledge of the ecology and dynamics of the TMF, and more research is required. Meanwhile, conservation is required in its management to meet the objects stated in the forest policy. It is certainly easy to destroy and difficult to regenerate, so studies of its dynamics and regeneration mechanisms are vital for its future well-being. This type of forest is particularly vulnerable to destruction by human intervention, and restoration is certainly a lengthy, if possible, option.

71. Prediction of the demands of the future in Nigeria are extremely uncertain. This uncertainty places a premium on flexibility to accommodate the changing demands of the nation and consequential changing objects of management in the forest. Policy makers must be aware that the more exact and specialized the market, the more likely it is that the management strategies have to be specially designed, resulting in fewer options and greater costs if they are to be changed. For example, the advocates of wholesale conversion of the productive TMF to plantations of Gmelina in Nigeria assume that wood fibre will always be the basis of the pulp and paper industry and, further, that the demand for paper and the industry will remain substantially unchanged in the future. The impact of either change in the source of the raw material for paper, or a paper substitute, or changes in information technology that will reduce the demand for paper, are discounted.

72. Both extensive methods of regeneration of the natural forest and intensive plantation work call for a great deal of technical expertise and managerial skills. The costs of the extensive methods are, to a high degree, dependent on the number of successive operations done in the same part of the forest. The series of up to seven treatments applied before and after felling in TSS both raised costs and placed a heavy demand on staff. Similarly, the more intensive systems demand heavy initial capital expenditure and continuous servicing of that capital, through research and the annual maintenance operations necessary to protect both the plantations and the capital that they represent. Heavy investment in plantations is

certainly not without risk, in the short term from accident such as fire or wind damage, in the medium term from a change in demand and, possibly, in the long term through as yet unperceived ecological catastrophe. In contrast, the TMF is a stable ecological type which both protects the environment and produces wood while, at the same time, being capable of recovery from abuse through technical mis-management, providing the biomass is not entirely destroyed.

73. The natural forest is the source of many non-wood products and services although, in many cases, it is difficult to ascribe a value to them in economic terms. It is equally difficult to estimate the cost of replacement should the forest be destroyed. Nevertheless, as far as can be determined, it is and will be the value of the forest for the production of wood that determines its future management. If the aim is to produce for a certain cost the maximum volume of wood from the area of the forest reserves, then natural regeneration is inefficient and it is necessary to use enrichment techniques or conversion to plantations. However, if the aim is to ensure both the supply of high quality furniture and veneer grade timber and the conservation values of the forest, then improved methods of natural regeneration are likely to be an effective tool of management.

74. The current rate of harvest in the Nigerian moist forests is so high that almost all the valuable timber will have been harvested by the end of the century. In many areas efforts to increase or even maintain the stocking of commercial species in the cut-over forest have failed and, if demand continues, they are likely to increase in value as supplies diminish. In spite of the apparent ease with which some tropical hardwoods, such as teak, can be raised in plantations, attempts to emulate this success with many other species - especially those of the Meliaceae - have failed. Damage to the leading shoot from insect, attack by root rots, difficulties with the supply of seed and limited period of viability, etc., have contributed to the difficulties. Consequently, wherever the stocking of young trees of the valuable timber species promises success in regenerating the forest naturally, it is prudent to take steps to protect it, even though, according to current thought, only low yields are likely.

75. The solution to the problem of increasing the productivity of this type of forest may be found in the utilization of a greater part of the total biomass, either by using more species or decreasing the amount of wood from harvested trees left in the forest. The extension of harvesting to the swamp forest would increase the supply by 40%. A substantial rise in the price of standing timber of the currently preferred species would, probably, be the most effective way of encouraging the use of as yet unmarketed species. It may also be possible to manage the forest for the production of very much smaller trees: this may well be feasible for some species, but perhaps less feasible for those species whose value primarily lies in the greater durability and aesthetic appeal of heartwood.

# CASE STUDY NO. 3

## MANAGEMENT IMPLICATIONS OF DEVELOPMENT OF TROPICAL MOIST FOREST IN CÔTE D'IVOIRE AFTER SILVICULTURAL TREATMENT



Tables

Figures

CASE STUDY NO. 3

# MANAGEMENT IMPLICATIONS OF DEVELOPMENT OF TROPICAL MOIST FOREST IN CÔTE D'IVOIRE AFTER SILVICULTURAL TREATMENT

## 1. INTRODUCTION

1. Unlike the previous two Case Studies, the present chapter describes a specific research project and its results. This project has been in progress in the Côte d'Ivoire since 1976 and merits close study because of the possible applicability of its results to operational forest management in a number of African countries (Catinot, 1986).

2. The Government of Côte d'Ivoire considers that agricultural development should be the mainstay of its national economic development. This has encouraged the clearing of forests on a large scale and it has been estimated that 300,000 ha of forest was cleared every year between 1973 and 1982 (Catinot, 1986). Clearing has occurred even within the permanent forest estate of the forêts classées, the area of which is estimated to have decreased from 3.3 to 2.4 million ha between 1956 and 1978 (FAO, 1981). Of the remaining productive moist forests in Côte d'Ivoire, the vast majority have already been cut over at least once, either selectively for a few prime species or more heavily.

3. In order to halt this continuing forest destruction, the Ordinance of 15 March 1978 made provision for a permanent forest estate, to consist of existing forêts classées and of those other forests "which still preserve the characteristics of blocks of closed forest and which will later be incorporated into the permanent forest estate by ministerial decree". It is on this permanent forest estate that all efforts at management and regeneration should be concentrated, through the application of relatively simple management regulations.

## 2. RESEARCH OBJECTIVES

4. In order to develop management regulations, a most important research project was set up in 1976 by the Société pour le Développement des Plantations Forestières, SODEFOR, with the technical support of Centre Technique Forestier Tropical, CTFT, and has been maintained and regularly assessed since then. It occupies a total area of 1200 ha, located at three different sites characteristic of the three ecological zones of the TMF of Côte d'Ivoire: La Téné (400 ha) in the semi-deciduous forest, Irobo (400 ha) in the evergreen forest and Mopri (400 ha) in the intermediate forest. The stocking of the principal species in each forest type is shown in Table 1. The project was modeled on research conducted in Peninsular Malaysia from 1974 onwards (Cailliez, 1974). The objectives were:

(1) to develop techniques for silvicultural treatment (harvesting and arboricide) and of mensuration;

(2) to study the increment of each species in response to the different silvicultural treatments;

Table 1. Stocking (average stems/ha) of Principal Species in the Three Forest Types

| 42 most common species | | Forests | | |
|---|---|---|---|---|
| | | semi-deciduous (La Téné) | transition (Mopri) | ever-green (Irobo) |
| Guibourtia ehie | Amazakoue | 3,1 | | |
| Mansonia altissima | Bété | 4,6 | + | |
| Morus mesozygia | Difou | 4,0 | + | |
| Terminalia superba | Fraké | 2,3 | + | |
| Alstonia boonei | Emien | 1,1 | + | |
| Triplochiton scleroxylon | Samba | 16,6 | 2,4 | |
| Nesogordonia papaverifera | Kotibé | 21,2 | 7,3 | |
| Celtis zenkeri | Asan | 7,2 | 1,9 | |
| Sterculia rhinopetala | Lotofa | 24,6 | 13,9 | |
| Celtis adolphi friderici | Lohonfe | 12,0 | 6,6 | |
| Entandrophragma cylindricum | Aboudikro | 2,8 | 1,1 | |
| Gambeya delevoyi | Akatio | 12,0 | 11,1 | |
| Celtis mildbraedii | Ba | 60,8 | 68,4 | |
| Ceiba pentandra | Fromager | 1,9 | 1,1 | |
| Khaya anthotheca | Acajou | 2,1 | 5,0 | |
| Aningueria robusta | Aniegre blanc | 2,7 | 7,6 | |
| Ricinodendron africanum | Eho | 5,5 | + | + |
| Eribroma oblonga | Bi | 9,1 | 2,4 | + |
| Guarea cedrata | Bosse | 2,0 | 9,6 | + |
| Funtumia latifolia | Pouo | 8,4 | 2,4 | + |
| Lannea welwitschii | Loloti | 2,0 | 1,6 | + |
| Piptadeniastrum africanum | Dabema | + | 3,8 | + |
| Scottelia spp. | Akossika | 7,8 | 8,5 | 6,9 |
| Entandrophragma angolense | Tiama | + | 2,7 | + |
| Pycnantus angolensis | Ilomba | + | 2,2 | + |
| Trichilia tessmanii | Aribanda | + | 1,2 | + |
| Sterculia tragacantha | Pore-Pore | + | 1,4 | + |
| Dacryodes klaineana | Adjouaba | + | 3,7 | 31,9 |
| Amphimas pterocarpoides | Lati | + | + | 2,3 |
| Daniellia thurifera | Faro | + | + | 1,4 |
| Berlinia spp. | Melegba | | 2,8 | + |
| Petersianthus macrocarpus | Abale | | 2,7 | |
| Parinari spp. | Sougue | | + | 1,8 |
| Thieghemella heckelii | Makoré | | + | 1,4 |
| Gilbertiodendron preussii | Vaa | | | 1,0 |
| Hallea ciliata | Bahia | | | 1,0 |
| Anthonotha fragans | Adomonteu | | | 1,1 |
| Anopyxis klaineana | Bodioa | | | 1,1 |
| Rodognaphalon brevicuspe | Kondroti | | | 1,4 |
| Parkia bicolor | Lo | | | 3,5 |
| Uapaca spp. | Rikio | | | 15,9 |
| Tarrietia utilis | Niangon | | | 33,2 |

- Species occurring $\geq$ 1 stem/ha are listed.
- (+) indicates species occurring 1>. 1 stem/ha
- 73 total species, no listing of occurrences <. 1 stem/ha

(3) to study stand development in response to the treatments (induced mortality, recruitment into immature size classes, effects on climbers and vegetative reproduction);

(4) to evaluate silvicultural requirements and characteristics of the principle species;

(5) to study the effects of different treatment intensities on yield and to estimate costs and benefits in comparison with untreated controls;

(6) to assess possibilities for the application of results (organisation and practical implementation).

## 3. EXPERIMENTAL DESIGN

### 3.1 Layout

5. Since Malaysian experience had demonstrated the importance of having large plot sizes, each experimental area occupied 900 ha. Within this area the central square of 400 ha was subdivided into 25 plots each of 16 ha. Prescribed treatments were applied to each 16 ha plot and the effects of the treatments were measured on the central 4 ha within each plot. Measurements were made on all trees $\geq$ 10 cm dbh. The layout is shown in Figure 1.

### 3.2 Treatments applied

6. It was considered that only two types of treatment were suitable for widespread practical application: controlled harvesting of commercial species, as carried out in current practice, and the elimination of secondary species by inexpensive methods (i.e. arboricides). Treatments aimed at inducement of regeneration were not included as they were considered unreliable.

7. The treatments therefore involved alternatives or combinations of:

(1) Harvesting, which to some extent can be regulated in the interests of silviculture and which is therefore likely to be for many years the most essential silvicultural tool available to forest services;

(2) Thinning or refinement. This can now be achieved at little cost through arboricide application after frill-girdling and makes possible the elimination of trees of currently unmarketable species which are competing severely with trees of commercial species which will form part of the future crop;

(3) Non-intervention. This treatment will be "applied" in control plots or plots with treatment postponed. Comparison of growth measurements in control plots with those in the harvested and/or thinned plots will help to answer one fundamental question: is it necessary or not to apply any treatments to the residual stands after harvesting?

Figure 1a. Diagrammatic plot lay-out.
(Identical system in all three experimental areas).
400 ha in treatment area; 900 ha including buffer zone.

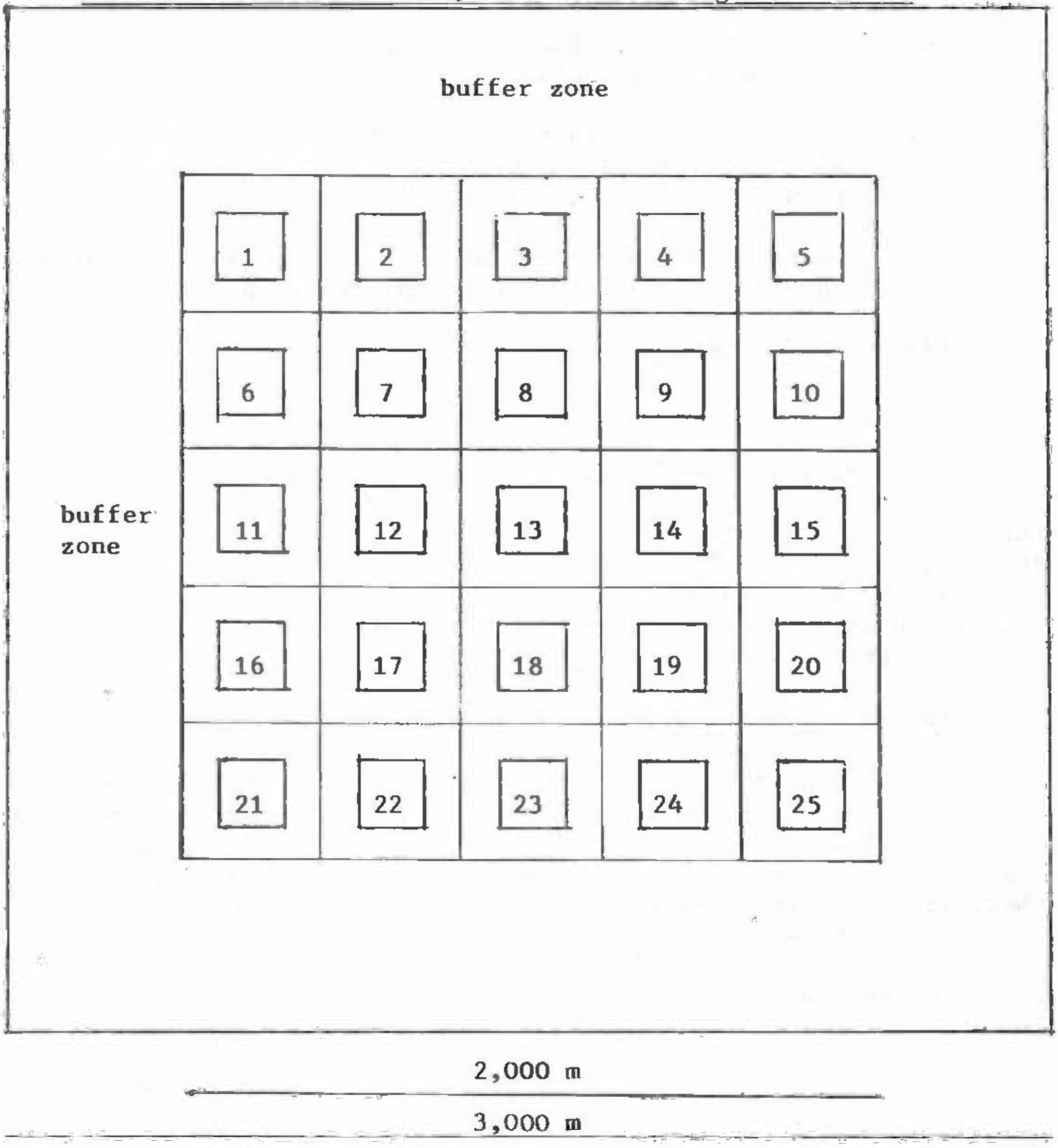
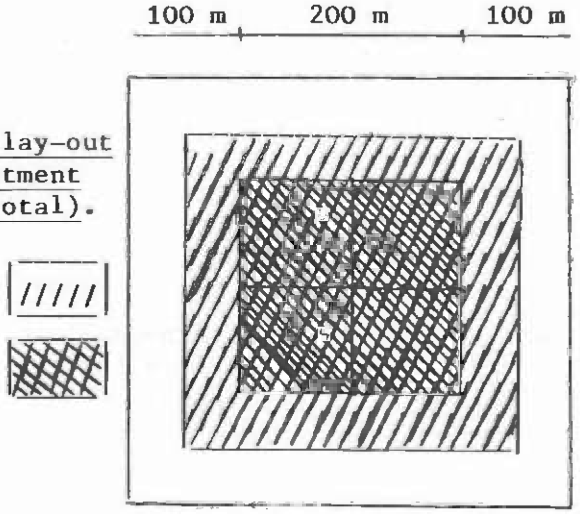



Figure 1b.
Diagrammatic lay-out for each treatment plot (16 ha total).



3.3 Treatment intensity

8. Treatment intensities were based on the proportion of basal area or volume remaining after treatment. Thus:

(1) A "heavy" thinning intensity reduced the basal area to 11-14 $m^2$/ha at Mopri and to 15-17 $m^2$/ha at Irobo;

(2) A "moderate" thinning intensity reduced the basal area to 16-18 $m^2$/ha at Mopri, 17-22 $m^2$/ha at Irobo and 15-21 $m^2$/ha at La Téné;

(3) At La Téné an additional treatment consisted of a commercial harvesting on ten plots never previously harvested. This removed 53 $m^2$/ha and was equivalent to the moderate intensity thinning treatment, except that the canopy opening was more irregular. This treatment was in conformity with current commercial logging practice.

9. The felling/arboricide treatment was carried out systematically, starting with the unmarketable species in the overstorey (and if necessary the less valuable of the marketable species) until the desired residual basal area was reached.

4. RESULTS FOR THE STANDS AS A WHOLE

10. Qualitatively, according to the responsible researchers, "some months after treatment, the appearance of the stands was striking because of the windfalls, dead standing trees and gaps in the canopy. This was the case whether the treatment was the heavy thinning in terms of basal area removal or the commercial harvesting by removal of 53 $m^3$/ha". But four years after treatment the appearance of the forest had reverted to "normal".

11. Quantitatively, on the basis of measurements after four years, the conclusions are that:

(1) The principal species respond to treatment immediately (from the first year) by a general increase in diameter increment;

(2) The increase in diameter increment in the measured sub-plots has accelerated with the time elapsed since treatment;

(3) The response of the stands in increased increment is not invariably proportional to the intensity of the thinning;

(4) Trees of smaller diameters (less than 30 cm) compete most strongly with others of similar size. The same appears to be true of larger sizes, the fiercest competition is between trees in the same size classes;

(5) For the 73 principal species assessed, the increased growth which resulted from thinning is expressed by the following figures:

(a) in the control plots, growth has been 2 $m^3$ $ha^{-1}$ $yr^{-1}$

(b) in the thinned plots, growth has been 3-3.5 $m^3$ $ha^{-1}$ $yr^{-1}$.

12. This gain in growth rate is considerable, and it refers to all trees of the principal species ≥ 10 cm dbh. The comparative study of diameter increment, by species, confirms this important gain.

5. RESULTS FOR SOME INDIVIDUAL SPECIES

13. The striking report "Study project on the development of the closed forest of Côte d'Ivoire after different types of silvicultural treatment" (Maitre and Hermeline, 1985), which provides the source of all the data reproduced here, selected eight sample species from among the dozens measured. For brevity, only two of these are described here, together with a tabulated summary of data for 20 species.

5.1 Tarrietia utilis

14. This has been a successful species for plantations, in which it maintains an average diameter increment of 1 cm/year throughout its life. It has responded very well to the thinnings in the experiment sited at Irobo, as shown by the following summary Table 2, Figures 2 and 3, and the detailed data by diameter classes shown by Table 3.

Table 2. Summary of periodic annual diameter increment of Tarrietia utilis at Irobo

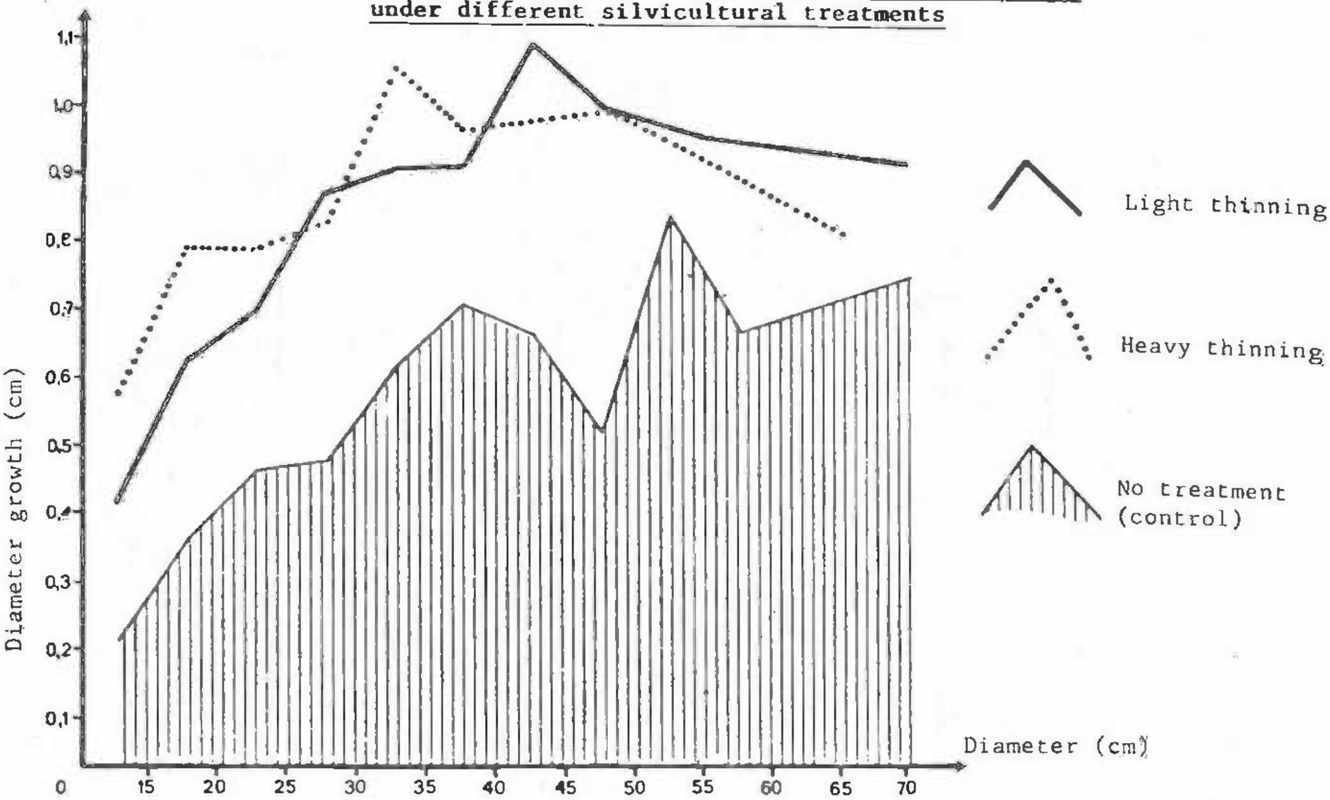
| Treatments | Diameter classes | |
|---|---|---|
| | 10 - 25 cm | > 25 cm |
| Untreated control | 0.3 cm | 0.6 cm |
| Silvicultural treatment | 0.6 cm | 0.9 cm |

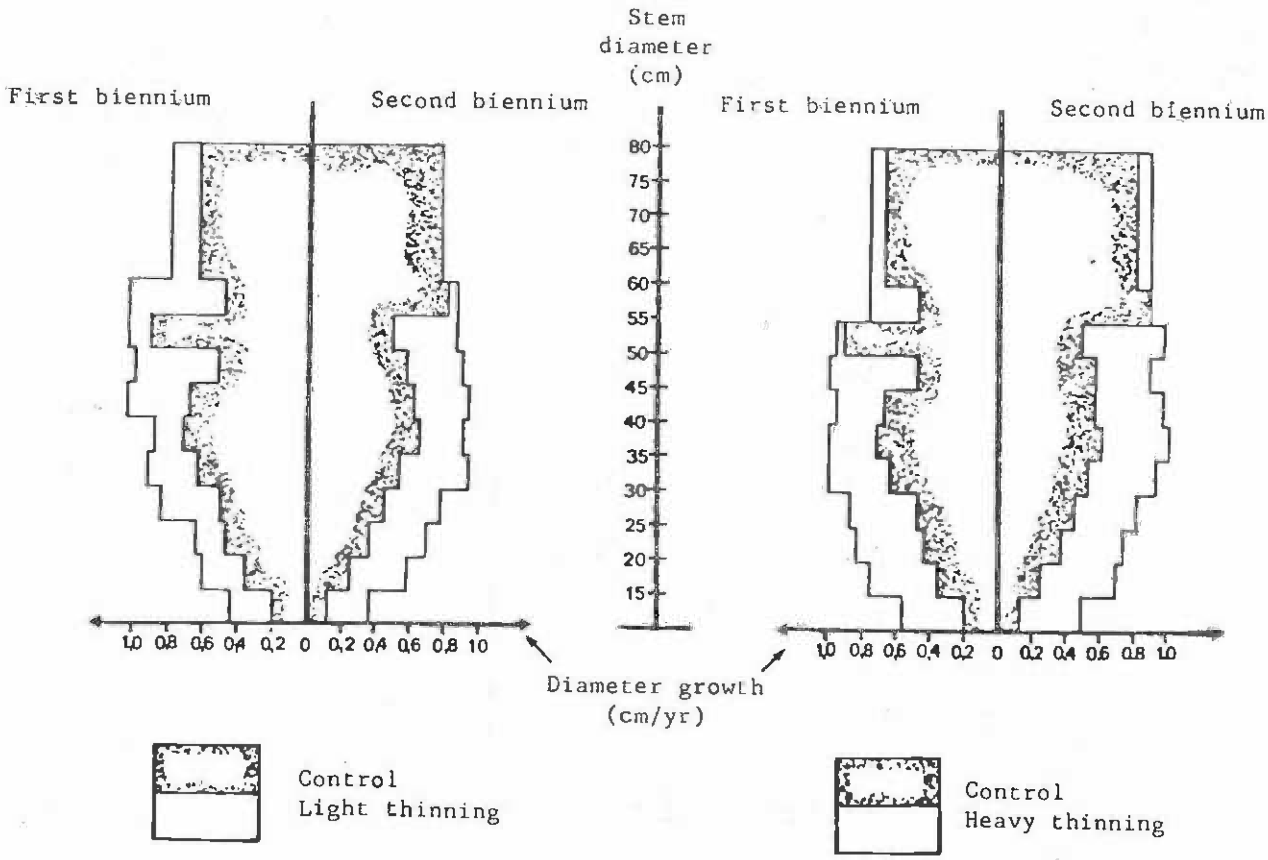
15. This improvement in increment of 100% for the smaller stems and of 50% for stems of over 25 cm diameter is rendered still more important because it is maintained or even increased with time. This is shown in the lower graph in Figure 2, which shows the diameter increment separately by diameter classes and by biennia since treatment. Figure 2 also shows the effect on volume increment of the two thinning intensities, as compared with the control.

5.2 Celtis mildbraedii

16. This is a secondary species with light-coloured wood, and it is the most numerous species of all on two of the three sites (Mopri and La Téné), which makes the increment data particularly reliable. Figures 4 and 5 demonstrate the satisfactory response of this species to treatments:

**Figure 2. Diameter growth of Tarrieta utilis by size class under different silvicultural treatments**



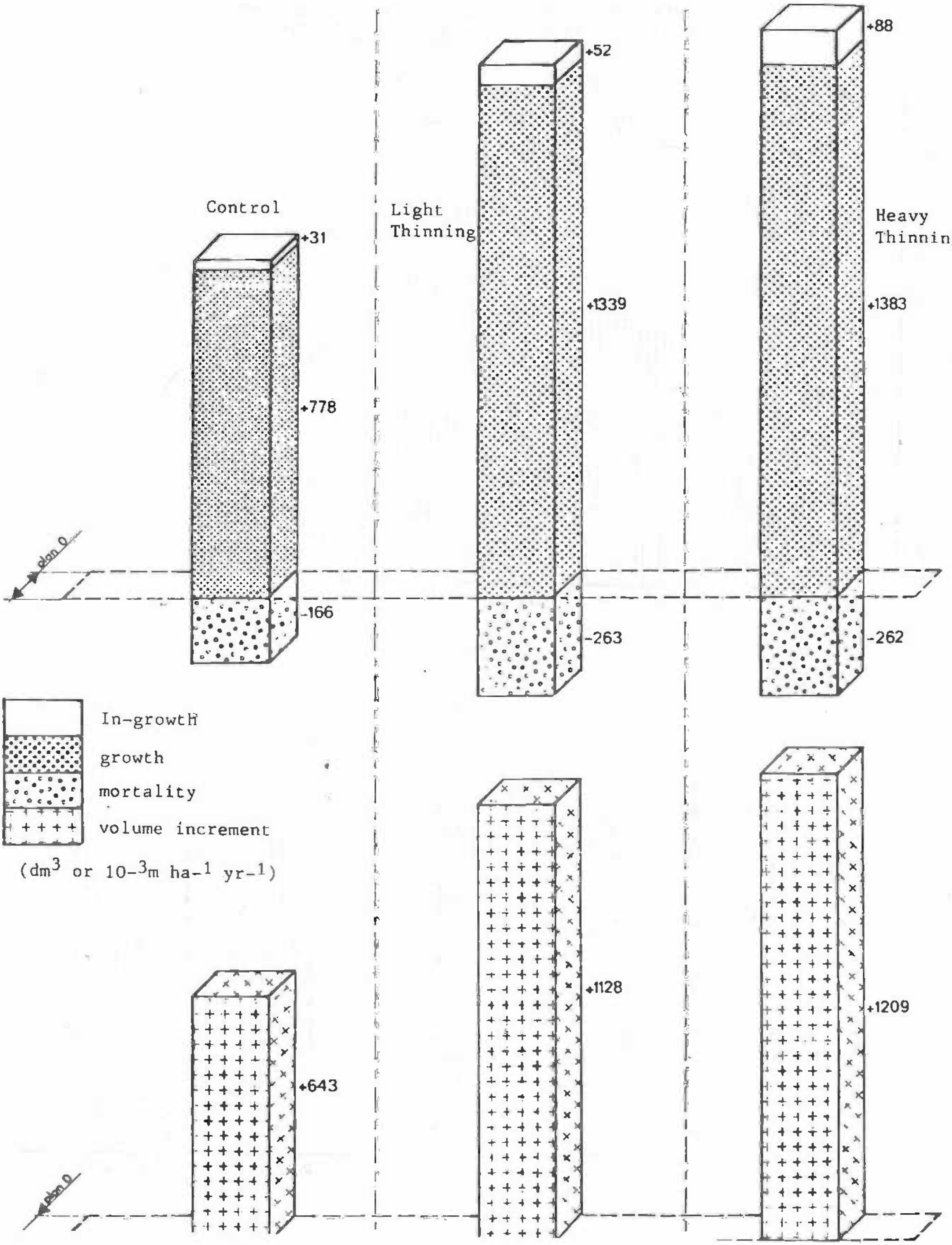



**Figure 3. Volume dynamics of Tarrieta utilis at Irobo Forest**

Table 3. Girth increment of Tarrietia utilis at Irobo after light thinning treatment

| Classe | Diameter class | N | Mean C (cm) yr 1 | Mean C (cm) yr 3 | Increment cm Mean | Increment cm CV | Basal Area (dm²) yr 1 | Basal Area (dm²) yr 3 | Basal Area (dm²) Diff. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 10 - 15 cm | 295 | 38.6 | 43.4 | 4.9 | 88.3 | 353.9 | 453.3 | 99.4 |
| 2 | 15 - 20 cm | 208 | 54.5 | 61.9 | 7.4 | 74.1 | 495.4 | 643.9 | 148.5 |
| 3 | 20 - 25 cm | 179 | 70.4 | 78.9 | 8.4 | 67.1 | 710.1 | 894.8 | 184.7 |
| 4 | 25 - 30 cm | 142 | 86.2 | 96.9 | 10.6 | 65.6 | 842.5 | 1,068.3 | 225.8 |
| 5 | 30 - 35 cm | 89 | 101.5 | 112.5 | 11.0 | 52.8 | 730.3 | 899.5 | 169.2 |
| 6 | 35 - 40 cm | 77 | 116.6 | 127.7 | 11.1 | 61.4 | 834.6 | 1,002.4 | 167.9 |
| 7 | 40 - 45 cm | 55 | 132.3 | 145.6 | 13.3 | 54.6 | 767.1 | 931.5 | 164.4 |
| 8 | 45 - 50 cm | 41 | 147.9 | 160.1 | 12.2 | 50.9 | 714.2 | 837.9 | 123.7 |
| 9 | 50 - 55 cm | 27 | 164.9 | 176.9 | 12.1 | 58.6 | 584.4 | 674.6 | 90.2 |
| 10 | 55 - 60 cm | 20 | 180.8 | 191.9 | 11.1 | 57.8 | 520.5 | 586.9 | 66.4 |
| 11 | 60 - 65 cm | 9 | 193.8 | 204.8 | 11.1 | 62.3 | 269.0 | 300.9 | 31.9 |
| 12 | 65 - 70 cm | 6 | 207.5 | 218.1 | 10.6 | 38.5 | 205.6 | 227.2 | 21.6 |
| 13 | 70 - 75 cm | 5 | 226.4 | 237.6 | 11.2 | 66.1 | 204.1 | 224.9 | 20.8 |
| 14 | 75 - 80 cm | 0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 15 | 80 - 85 cm | 2 | 258.5 | 271.5 | 13.0 | 42.3 | 106.4 | 117.4 | 11.1 |
| 16 | 85 - 90 cm | 0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 17 | 90 - 95 cm | 1 | 284.5 | 298.0 | 13.5 | 0.0 | 64.4 | 70.7 | 6.3 |
| 18 | 95 - 100 cm | 0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 19 | 100 - 105 cm | 0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 20 | 105 and + | 0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Total | 1,156 | | | | | | | |

N = Number of trees in class
C = Circumference
DIFF = Difference in basal area between measurement years
CV = Coefficient of variation of increments

Only trees present at measurement 1 and measurement 3 included (4 years between measurements).

(1) at Mopri the annual diameter increments vary from 0.2 to 0.45 cm in the control plots and from 0.45 to 0.75 cm in the two thinning treatments;

(2) at La Téné the annual diameter increments vary from 0.15 to 0.40 cm in the control plots, from 0.40 to 0.75 cm in the moderate thinning treatment and from 0.25 to 0.60 cm in the commercial harvesting project.

17. It can be seen that at Mopri the heavy thinning has increased diameter increment more than the moderate thinning, while at La Téné the commercial harvesting of 53 $m^3$/ha has been less effective than the moderate thinning. Volume increments are not represented in the figures for this species.

5.3 Tabulated data for 20 species

18. These are shown in Table 4 from which it is possible to conclude that:

(1) with very few exceptions, all the species show greatly increased increment after thinning;

(2) the highest diameter increments are achieved by species in common use in plantations (Triplochiton scleroxylon, Terminalia superba, Tarrietia utilis and Khaya anthotheca) and are around 1 cm/year;

(3) Thinning increases recruitment of young stems into the 10 cm diameter class, while commercial harvesting appears to be no better than the control. This could be due to the fact that the canopy opening which results from thinning is much better distributed on the ground than that which results from harvesting, which often creates large gaps some distance apart, with undisturbed forest between. The improvement in recruitment into the 10 cm diameter class should not be interpreted as inducement of natural regeneration from seed, since it is clear that the saplings which in four years pass the diameter limit of 10 cm must have been pre-existing advance growth. A study on regeneration inducement is currently in progress;

(4) The improvements in growth rate following harvesting are consistently less than those resulting from thinning. This can be easily understood, since harvesting fells the marketable species but does nothing to eliminate the currently unmarketable species which compete with the former.

## 6. PROSPECTS FOR APPLICATION TO FOREST MANAGEMENT

19. Although sometimes referred to as "experimental management", this research project in fact falls into the category of "experimental silviculture", but with the ultimate aim of improving operational forest management. It has the great merit of quantifying the responses of all the important species in a forest to the classic operations of release from competition and thinning, effected after harvesting. The silvicultural value of these operations has been

Figure 4. Diameter growth of Celtis mildraedii by size class under different silvicultural treatments in La Téné Forest

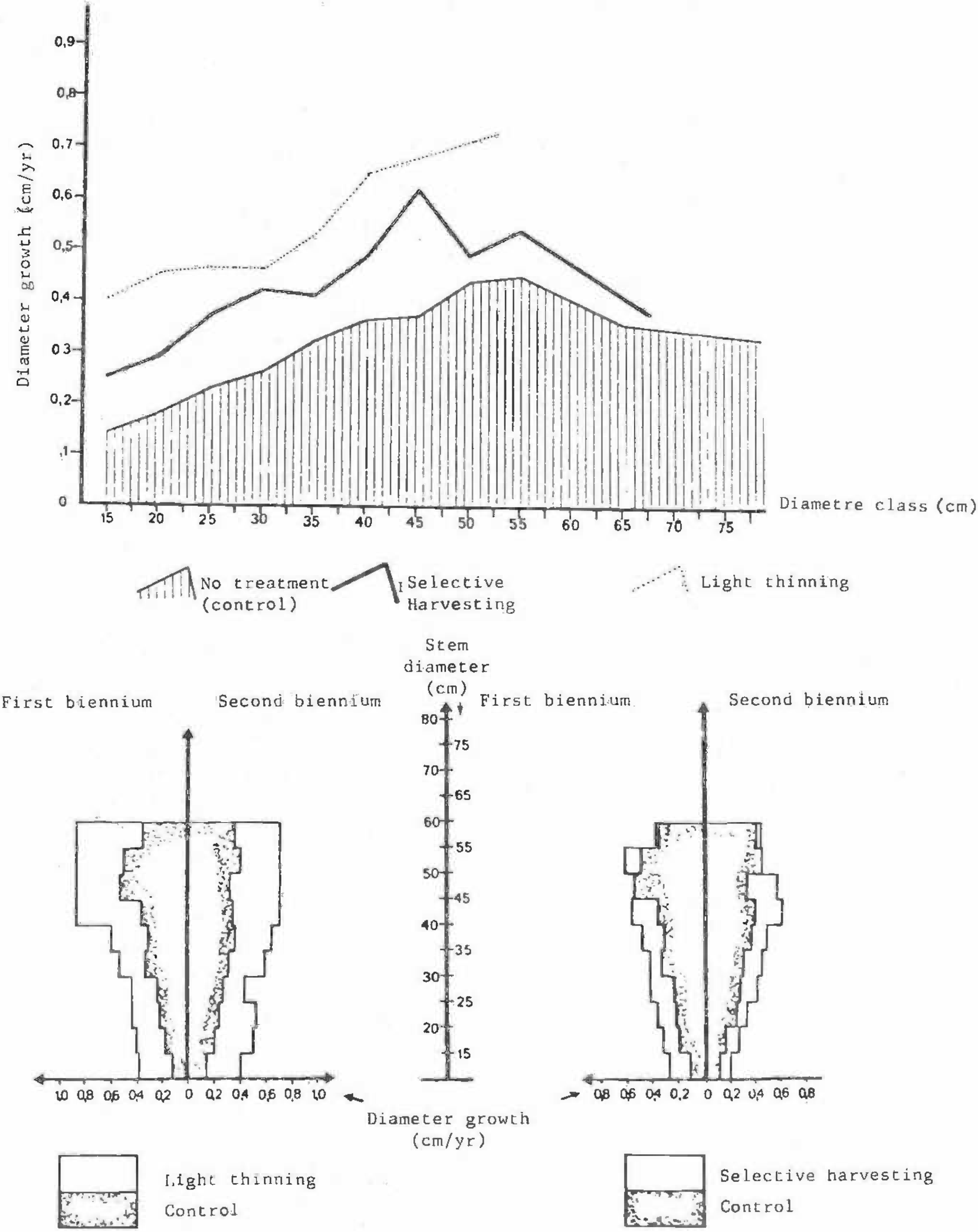
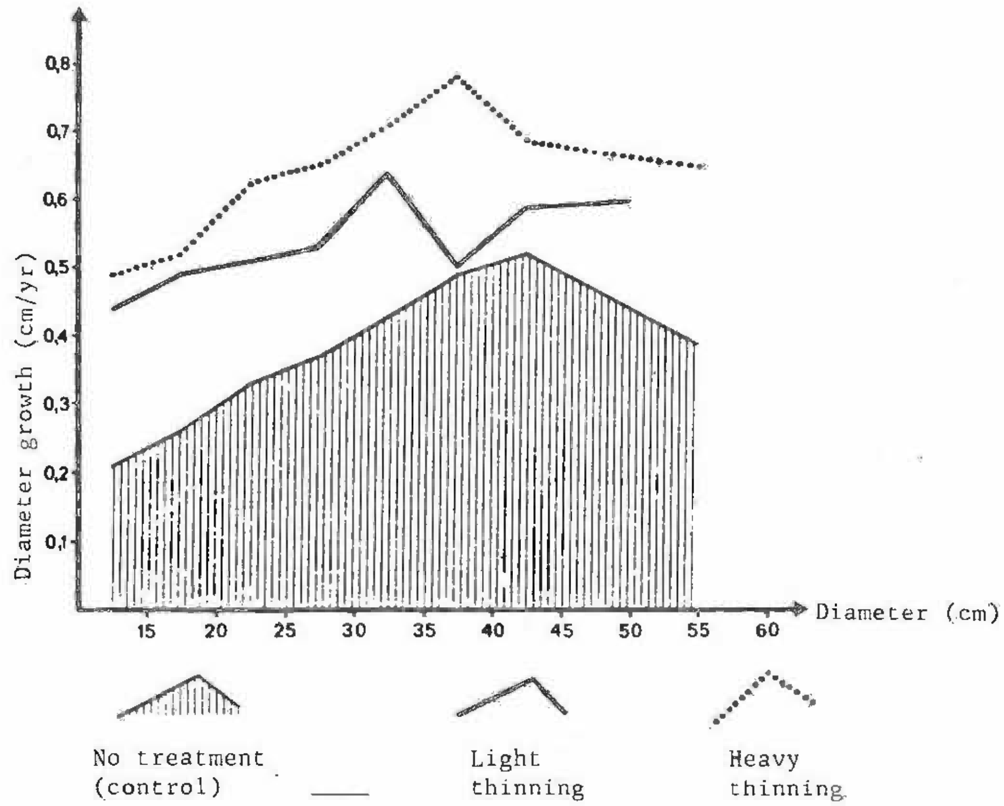


Figure 5. Diameter growth of Celtis mildraedii by size class under different silvicultural treatments in Mopri Forest



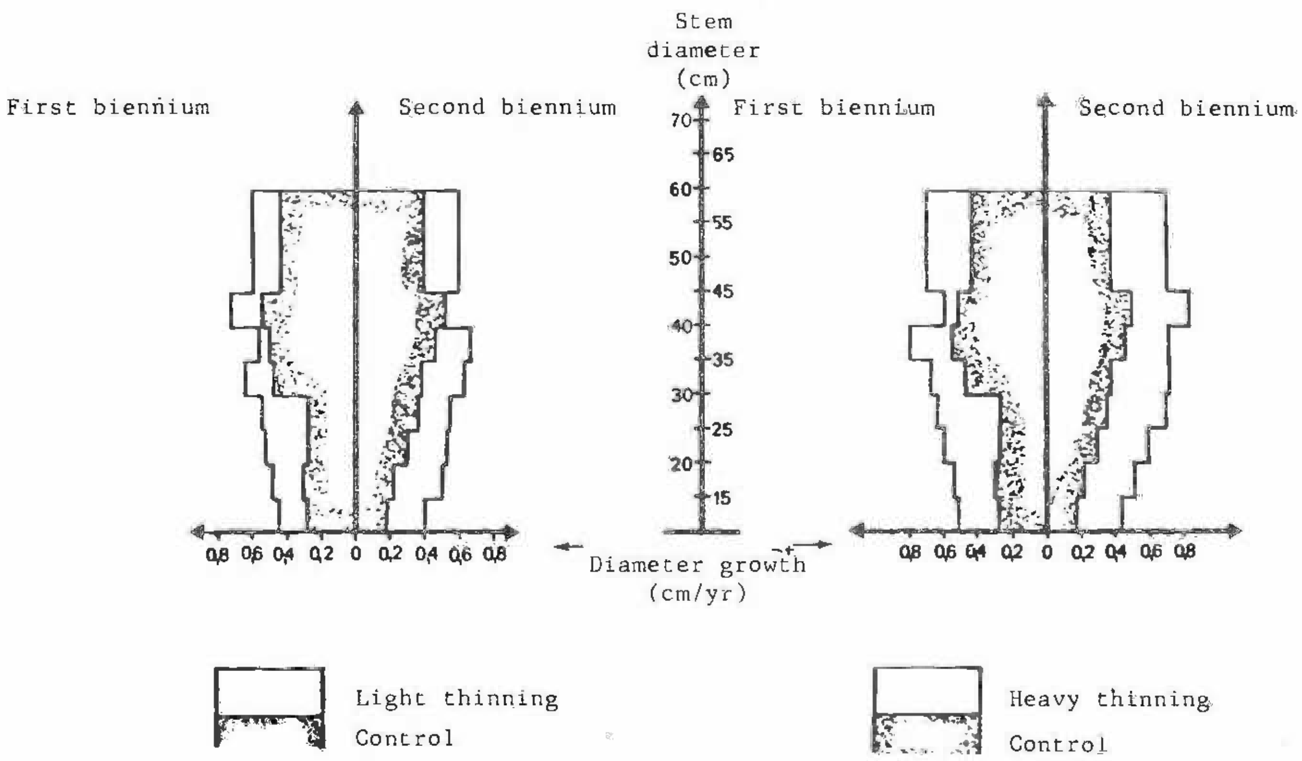



Table 4. Summary of Periodic Annual Increment, Ingrowth and Mortality according to Species, Treatment and Size Class

| Principal species | Treatment | Number of trees measured | Periodic annual increment in size classes | | Percent Ingrowth (new stems > 10 cm dbh) | Percent mortality | |
|---|---|---|---|---|---|---|---|
| Category 1 | | | 10 < 25 cm | 25 < 65 cm | | 10 < 25 cm | > 25 cm |
| Entandrophragma cylindricum | Control | 151 | 0,13 | 0,46 | + 1,2 % | - 1,7 % | - 4,7 % |
| Mopri and La Téné Forests | Thinning | 132 | 0,33 | 0,75 | + 8,9 | - 4,1 | 0,0 |
| | Harvest | 84 | 0,17 | 0,61 | + 2,4 | - 3,3 | 0,0 |
| Khaya anthotheca | Control | 198 | 0,20 | 0,61 | + 6,0 % | - 4,1 % | - 2,3 % |
| Mopri and La Téné Forests | Thinning | 308 | 0,37 | 0,97 | +10,4 | - 5,4 | - 1,4 |
| | Harvest | 104 | 0,22 | — | + 2,3 | - 2,8 | — |
| Gambeya delevoyi | Control | 741 | 0,29 | 0,32 | + 3,5 % | - 4,4 % | -12,2 % |
| Mopri and La Téné Forests | Thinning | 637 | 0,59 | 0,64 | +10,4 | - 5,1 % | - 8,3 |
| | Harvest | 253 | 0,21 | 0,38 | + 2,4 | - 4,8 | -11,2 |
| Scottelia chevalieri | Control | 812 | 0,12 | 0,28 | + 3,1 % | - 4,1 % | - 4,4 % |
| Irobo, Mopri and La Téné | Thinning | 910 | 0,29 | 0,42 | + 3,2 | - 4,1 | - 6,0 |
| Forests | Harvest | 240 | 0,16 | 0,42 | + 3,5 | - 4,5 | - 3,7 |
| Guibourtia ehie | Control | 107 | 0,14 | 0,39 | + 3,5 % | -10,4 % | -11,1 % |
| La Téné Forest | Thinning | 51 | 0,31 | 0,55 | +12,3 | - 9,3 | -15,4 |
| | Harvest | 75 | 0,25 | 0,32 | + 1,3 | - 8,1 | -13,6 |
| Aninguerla robusta | Control | 341 | 0,20 | 0,41 | + 4,5 % | - 3,9 % | - 3,1 % |
| Mopri and La Téné Forests | Thinning | 371 | 0,39 | 0,58 | + 9,9 | - 4,2 | - 5,3 |
| Mansonia altissima | Control | 175 | 0,38 | 0,22 | + 2,8 % | - 2,9 % | - 4,7 % |
| La Téné Forest | Thinning | 95 | 0,47 | 0,34 | + 2,0 | - 8,0 | - 8,6 |
| | Harvest | 149 | 0,37 | 0,20 | + 2,0 | - 6,7 | - 7,9 |
| Guarea cedrata | Control | 325 | 0,25 | 0,31 | + 7,0 % | - 5,5 % | - 3,1 % |
| Mopri and La Téné Forests | Thinning | 566 | 0,47 | 0,53 | +16,5 | - 8,3 | - 6,7 |
| Morus mesozygia | Control | 155 | 0,10 | 0,19 | + 1,3 % | - 1,4 % | 0,0 % |
| La Téné Forest | Thinning | 95 | 0,27 | 0,46 | + 7,8 | -10,0 | - 6,7 |
| | Harvest | 137 | 0,18 | 0,34 | + 3,5 | - 3,2 | - 5,9 |
| Terminalia superba | Control | 55 | 0,82 | 0,32 | +19,0 % | — | — |
| La Téné Forest | Harvest | 66 | 0,94 | 0,75 | +34,0 | — | — |
| Rodognaphalon brevicuspe | Control | 56 | 0,13 | 0,42 | + 3,4 % | — | — |
| Irobo Forest | Thinning | 85 | 0,37 | 0,58 | + 3,2 | — | — |
| Nesogordonia papaverifera | Control | 1,082 | 0,27 | 0,23 | + 5,5 % | - 2,0 % | - 1,8 % |
| Mopri and La Téné Forests | Thinning | 790 | 0,51 | 0,32 | +12,5 | - 3,2 | - 2,2 |
| | Harvest | 644 | 0,25 | 0,19 | + 2,6 | - 3,7 | - 1,9 |
| Thieghemella heckelii | Control | 53 | 0,19 | — | + 8,3 % | — | — |
| Irobo Forest | Thinning | 62 | 0,30 | — | +16,5 | — | — |
| Tarrietia utilis | Control | 1,280 | 0,28 | 0,57 | + 2,9 % | - 2,8 % | - 2,6 % |
| Irobo Forest | Thinning | 1,942 | 0,58 | 0,91 | + 6,0 | - 3,9 | - 3,3 |
| Triplochiton scleroxylon | Control | 640 | 0,60 | 0,79 | + 5,7 % | - 2,8 % | - 1,4 % |
| Mopri and La Téné Forests | Thinning | 359 | 1,53 | 1,48 | +15,6 | - 2,5 | - 1,4 |
| | Harvest | 511 | 0,87 | 1,13 | + 7,2 | - 5,7 | - 2,8 |
| Entandrophragma angolense | Control | 61 | 0,22 | — | + 1,4 % | — | — |
| Mopri Forest | Thinning | 124 | 0,30 | — | +11,0 | — | — |
| Category 2 | | | | | | | |
| Celtis mildbraedii | Control | 4,822 | 0,22 | 0,35 | + 3,6 % | - 1,3 % | - 1,9 % |
| Mopri and La Téné Forests | Thinning | 5,289 | 0,48 | 0,60 | + 8,9 | - 2,8 | - 3,4 |
| | Harvest | 1,918 | 0,29 | 0,46 | + 1,9 | - 2,2 | - 2,7 |
| Sterculia rhinopetala | Control | 1,252 | 0,23 | 0,29 | + 3,1 % | - 4,0 % | - 2,3 % |
| Mopri and La Téné Forests | Thinning | 973 | 0,57 | 0,50 | +16,7 | - 5,4 | - 5,5 |
| | Harvest | 769 | 0,26 | 0,41 | + 5,0 | - 5,9 | - 4,1 |
| Funtumia latifolia | Control | 246 | 0,13 | 0,11 | + 4,3 % | -24,5 % | -38,7 % |
| La Téné Forest | Thinning | 160 | 0,33 | 0,22 | + 5,9 | - 8,9 | -11,9 |
| | Harvest | 177 | 0,21 | 0,15 | + 6,8 | -18,6 | -29,8 |
| Category 3 | | | | | | | |
| Dacryodes klaineana | Control | 1,380 | 0,13 | 0,19 | + 1,9 % | - 1,0 % | - 0,8 % |
| Mopri and Irobo Forest | Thinning | 1,758 | 0,30 | 0,40 | + 4,4 | - 1,6 | - 0,3 |

disputed in the past, but henceforth there can be no further doubt on the subject. The two most notable conclusions to be drawn are, first, that heavy thinnings, removing 40% of the basal area, are not only no cause for apprehension but often prove to be the most effective treatment; and, secondly, that even the larger trees among the advance growth (dbh > 40 cm) can benefit substantially. This contradicts the traditional theory that, at over 40 cm dbh, trees are already mature and therefore incapable of further response to a sudden increase in available light or other elements enhancing growth. The silvicultural knowledge gained from this research is extremely important and confirms further the interest of polycyclic systems of management which are based on the hope that "improvement" operations (clearings and thinnings) will stimulate the increment of the advance growth trees sufficiently for them to be harvested after a reasonable delay (20-30 years) and still yield a large enough volume of saleable products to be profitable.

20. In this respect the Côte d'Ivoire research, which is too recent to produce firm quantitative data for management, does permit some reply to the basic question, "Is management of TMF technically possible through natural regeneration alone?".

21. This type of management is based on the principle that the forest can support an unlimited number of fellings, provided that the felling cycle is sensibly calculated so that the volume available for harvesting each time is derived from the regular passage into the harvestable size classes of the advance growth of commercial species derived from natural seeding. It follows that its success must be based on two imperative conditions:

(1) that previous inventory has shown that the forest contains a sufficient number of young stems to provide the future harvestable volumes. A reasonable estimate is that, if the minimum harvestable diameter is 60 cm, at least 15 stems/ha of young trees of marketable species between 20 and 60 cm diameter are required.

(2) that the growth rate of these young trees should be sufficient for the felling cycle not to exceed 40 years, since beyond this period management problems such as larger areas to be administered, long periods of apparent disuse and capital tied up for too long a period become very difficult.

22. In the present situation of TMF in Côte d'Ivoire, where almost the whole forest has been harvested and considerable areas have been depleted of commercially valuable species, it is necessary to examine whether these two conditions have been met.

6.1 <u>The adequacy of stocking of advance growth</u>

23. Although the SODEFOR/CTFT research is not directed specifically at this question, analysis of some of the data already available suggests a very positive response and confirms the earlier results from a pilot project at Yapo Forest. The three blocks of forest in

the SODEFOR/CTFT project and the block in the Yapo project constitute an excellent sample of the TMF in Côte d'Ivoire. Analysis of the inventories in these blocks and comparison of them with the inventory in the Botanic Reserve of Divo (in theory untouched) is shown in Tables 5 and 6. The main conclusions follow.

(1) The curves representing the variation in number of stems/ha by diameter classes in the exploited forests of Mopri, Irobo and, especially, La Téné appear very similar to that of the unexploited forest at Divo. This signifies that, if allowance is made for the trees removed in harvesting, the size-class distribution which represents the stand structure - that is its future value - has remained practically unchanged.

(2) In terms of stocking, the number of young advance growth stems is ample, since the minimum of 15 stems/ha is greatly exceeded in all cases.

(3) In practical management terms, if the stems are regrouped in the three classical size-classes which ideally correspond to a felling cycle (20-40 cm, 40-60 cm and over 60 cm diameter), it appears that here also the future of the forest should be assured for three felling cycles. In this respect it must be remembered that any tree over 40 cm diameter may be considered "safe", because there is practically no chance that it will be eliminated by natural competition, even though it can still benefit substantially in growth rate from the removal of competitors. This explains why a stocking of 40-60 cm diameter trees approximately equal to that of the over 60 cm trees is acceptable as the basis for maintaining the yield in the next cycle in a forest relying on natural recruitment into the harvestable size classes (cf. Tables 5B and 6B);

(4) As a result of this sampling of forests to be managed as natural forest, it appears that, in spite of previous harvesting which was often excessive in frequency and intensity, the stocking of trees which will become available for harvesting in the future confirms the possibility of sustaining the commercial harvest of TMF in Côte d'Ivoire through natural management.

## 6.2 Expected growth rates

24. Analysis of the data gathered over the first four years of research in the SODEFOR/CTFT project has demonstrated that the elimination of currently unmarketable species by removal of 30-40% of the basal area has increased the diameter growth of the young trees of the marketable species by 50-100%. This should make it possible to reduce significantly the length of future felling cycles. Measurements from the latest two years (years 5 and 6) which are now being analysed, appear to confirm the responses - if anything they are greater still. These results, which may be supported by other data (notably the analysis of growth rings), give grounds for confidence that in 40 years the majority of stems in each class of advance growth (20-40 cm and 40-60 cm) will pass into the next higher size class and so ensure a sustained yield at harvest.

## Table 5A. Number of Stems per Ha by Diameter Class in Four Forest Types

| Class | Forest Reserve | Diameter 10-20 cm | Diameter 20-30 cm | Diameter 30-40 cm | Diameter 40-50 cm | Diameter 50-60 cm | Diameter 60-70 cm | Diameter 70-80 cm | Diameter 80-90 cm | Diameter 90-100 cm | Diameter > 100 cm | Diameter > 60 cm harvestable |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P1 | Divo | 50 | 18.75 | 11 | 7 | 5.75 | 3.75 | 1.50 | 1.50 | 1.50 | 5 | 13.25 |
| | La Téné | 27 | 17.50 | 11.25 | 8 | 5.50 | 3.50 | 2.75 | 1.50 | 1.75 | 2.50 | 12.00 |
| | Mopri | 24.50 | 8.25 | 6 | 3.50 | 3.50 | 2.25 | 2.25 | 0.75 | 0.50 | 0.75 | 6.50 |
| | Irobo | 21.25 | 11.15 | 6.97 | 3.10 | 2.07 | 0.87 | 0.47 | 0.25 | 0.20 | 0.27 | 2.06 |
| P2 | Divo | 113 | 41 | 16 | 8.50 | 4.75 | 2.00 | 1.00 | 0.25 | 0.50 | 0.25 | 4.00 |
| | La Téné | 59.25 | 29.75 | 10.50 | 5.75 | 3.00 | 1.50 | 0.75 | 0.25 | 0.25 | — | 2.75 |
| | Mopri | 50 | 10.25 | 6.50 | 3.50 | 2.00 | 1.50 | 0.75 | 0.50 | 0.25 | 0.50 | 3.50 |
| | Irobo | 1.59 | 0.72 | 0.55 | 0.40 | 0.35 | 0.35 | 0.27 | 0.20 | 0.12 | 0.17 | 1.10 |

## Table 5B. Perspectives of Natural Regeneration

| Class | Forest Reserve | Number of stems per ha harvestable diameter > 60 cm | Number of stems of 2nd generation 40 cm < 60 cm | Number of stems of 3rd generation 20 cm < 40 cm |
|---|---|---|---|---|
| P1 | Divo | 13.25 | 12.75 | 29.75 |
| | La Téne | 12.00 | 13.50 | 28.75 |
| | Mopri | 6.50 | 7.00 | 14.75 |
| | Irobo | 2.06 | 3.17 | 18.12 |
| P2 | Divo | 4.00 | 13.25 | 57.00 |
| | La Téné | 2.75 | 8.75 | 40.25 |
| | Mopri | 3.50 | 5.50 | 26.75 |
| | Irobo | 1.10 | 0.75 | 1.25 |

Table 6A. Number of Stems by Diameter Class. Yapo Forest.

| Utilization Class | Diameter 10-20 cm | Diameter 20-30 cm | Diameter 30-40 cm | Diameter 40-50 cm | Diameter 50-60 cm | Diameter 60-70 cm | Diameter > 60 cm harvestable | Gross commercial volume > 60 cm | Net commercial volume > 60 cm |
|---|---|---|---|---|---|---|---|---|---|
| P1 | 24.38 | 6.97 | 2.21 | 1.15 | 0.90 | 0.58 | 1.43 | 9.16 $m^3$ | 3.6 $m^3$ |
| P2 | 45.32 | 44.14 | 27.24 | 10.98 | 4.11 | 1.28 | 3.29 | 24.45 $m^3$ | 8.0 $m^3$ |
| P3 | 1.83 | 1.73 | 1.10 | 1.05 | 0.98 | 0.55 | 1.76 | 12.63 $m^3$ | 2.4 $m^3$ |
| Total P | 71.53 | 52.84 | 30.55 | 13.19 | 5.99 | 2.41 | 6.48 | 46.24 $m^3$ | 14 $m^3$ |

Table 6B. Perspectives of natural regeneration

| Utilization Class | Number of stems/ha harvestable diameter > 60 cm | Number of stems of 2nd generation 60 cm > 40 cm | Number of stems of 3rd generation 40 cm > 20 cm |
|---|---|---|---|
| P1 | 1.43 | 2.05 | 9.18 |
| P2 | 3.29 | 15.09 | 71.38 |
| P3 | 1.76 | 2.03 | 2.83 |
| Total P | 6.48 | 19.17 | 83.39 |

25. This research project has also demonstrated that the thinning operations increased the diameter growth of small stems less than 20 cm dbh by the same proportion.

### 6.3 Effects on natural seeding

26. One important question remains which will be decisive for the future: what influence do these operations have on the natural seeding of the valued hardwood species? The whole system is based on the improved performance of stems occurring among the advance growth, so it is essential to know what happens at the level of natural seeding; is it also improved, or not, by the intensive thinning treatments? SODEFOR and CTFT scientists are at present carrying out a carefully designed programme of research to attempt to clarify this extremely complex problem. The preliminary conclusions are encouraging, for it seems that seedling establishment is maintained, in spite of the removal of a large number of seed bearers in harvesting.

### 6.4 Application to other forests

27. Unfortunately the intensity of forest harvesting in Côte d'Ivoire has increased as the areas available for this activity have diminished. It is arguable how representative a sample was constituted by the forests of La Téné, Mopri, Irobo and Yapo as they were in 1975-1977, since they have automatically received some protection since research started there. The potential of those forests in 1975-1977, to which the silvicultural treatments were applied, is likely to be very different from that of the average of Côte d'Ivoire forests to which future management must be applied.

28. In addition, whereas the figures presented in the tables for La Téné, Mopri and Irobo apply to the species commonly harvested in Côte d'Ivoire at the present time (preferred species P1 + P2), for Yapo all species are included which are officially classed as harvestable (P1 + P2 + P3), of which some can only be harvested commercially because of proximity to Abidjan.

29. Therefore, it seems absolutely essential, before any management of TMF in Côte d'Ivoire, to carry out the following.

(1) Inventory of all stems ≥ 20 cm dbh and appearing in the list of species classed officially as harvestable by the Direction des Eaux et Forêts (Forest and Water Department). If the number of stems in the advance growth is shown to be inadequate, it will be necessary to consider plantations.

(2) An economic study of all stages in the conversion and marketing of wood on a regional basis, in order to determine the list of species which can be harvested profitably, either as logs or for local conversion, with due regard for the conditions of accessibility and of marketing of each species. It is obvious that a species such as *Celtis mildbraedii*, which is saleable with difficulty even in the region of Abidjan, cannot appear on the list of harvestable species in the management of forests in the regions of Daloa or Abêgaurou. Such a

study would also assist in identifying the obligations for local conversion of timber (sawing, peeling, etc.) to be required of the concessionaire in a forest under management, which would be dependent on local economic conditions.

30. For a general answer to the question posed above, the management of the previously logged TMF forests of Côte d'Ivoire, by means of natural regeneration alone, seems technically very possible on condition that an inventory is carried out in advance and that an economic study is done which would lead to the determination of a realistic list of marketable species, with due regard for local conditions.

31. It is considered, therefore, (Catinot, 1986) that the results obtained after four years from this extremely well designed research project give grounds for an optimistic view of the possibilities of a polycyclic system of TMF management, even in forests repeatedly harvested in the past (not the least of its advantages). It is, however, of the highest importance from the African viewpoint that this research should be continued, developed and extended to other forest types, i.e. to other countries. In Côte d'Ivoire itself, another five years are needed for the results to be conclusive.

# APPENDIX 1

## Management Inventories

## Recommended Method

Applicable to Forest Blocks from 2,500 to 5,000 Ha

I. Basic Assumptions:

One wishes to enumerate future crop trees of 12-15 marketable species grouped in two diameter size classes:

20 cm < 45 cm;  45 cm < 65 cm

One expects to find 3 to 5 stems per ha with a coefficient of variation predicted at about 70% for 1 ha parcels.

II. Statistical Estimates

With sampling plots of 0.1 ha and a block of 2,500 ha, a coefficient of variation of 70% gives an error of 20% on the variables of interest at 95% probability with a sampling proportion of 2%.

Given the same assumption the sampling proportion must be raised to 4% to have an error of 15%.

III. Implementation:

(Sampling proportion of 2%):

Establish rectangular plots 50 m x 20 cm with the long axis east-west along parallel lines 500 m apart. Within these 20 m wide strips each 50 m long plot is separated 50 m from the next plot.

Within plot enumerate all trees of selected species $\geq$ 20 cm dbh, if they are at least 5 m apart and without major defects.

(Sampling proportion of 4%):

Continuously sample the 20 m wide strips without eliminating alternating 50 m lengths as above.

IV. Cost:

Approximately .125 man days per ha for 2% sampling and .166 man days per ha for 4% sampling.

V. Composition of Sampling Team:

- 1 tree identifier and leader
- 1 compass man
- 2 enumerators
- 10 workers

APPENDIX 2

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