The quest for natural forest management in Ghana, Côte d'Ivoire and Liberia

M.P.E. Parren & N.R. de Graaf

Tropenbos Series 13

The Quest for natural forest management in Ghana, Côte d'Ivoire and Liberia

Abstract

The history, biological background, present day exploitation and management of the moist forest of Ghana, the Côte d'Ivoire and Liberia are discussed, and examples given which have been drawn from pilot projects in these three countries. Silvicultural experiences on a broadfront is dealt with, and lastly a number of very positive developments in and ideas about forest management in the region are discussed.

Key words: Ghana, Côte d'Ivoire, Liberia; tropical moist forests; timber exploitation; forest management; silviculture; non-timber forest products.

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The quest for natural forest management in Ghana, Côte d'Ivoire and Liberia

Marc P.E. Parren & N. Reitze de Graaf

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Tropenbos Series

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FOREWORD

The great tropical forests of West Africa were described and sung by many, many travelers and scientists during this, our Century which is nearing its end. In the next Millennium, the tales and descriptions will remain in the libraries, but the 'forêts denses' will have disappeared as such. What will remain are such bits and pieces of original forest, and such surfaces of converted forest as will have been sustained by the owners.

A tiny part only of the owners are poets, travelers and scientists, just like in other normal societies. Mainly they are farmers, builders, or merchants in the local framework, and politicians, economists or civil servants in a national context. Most persons concerned are not at all conscious that these forests exist, except on television. These are the growing numbers of urban and rurban (urbanized rural) people, who depend on forests in very indirect ways only. For them, forests are somewhere in the subreal and incomprehensible realm from where the stocks in supermarkets are replenished. The internationalization of markets makes this attitude all but universal in the whole world. These problems far exceed Africa and include the North.

In this social context the book by Parren & de Graaf emerges. They have earned their right to speak up in this matter. As long as I have known Reitze de Graaf, he has been a tropical silviculturist, 'in his heart and kidneys' as the Dutch proverb has it. And since Marc Parren started his postgraduate studies with me, he increasingly became an aficionado of West Africa's forests. The man who made the CELOS system of silviculture work in Suriname and the man who thoroughly observed and documented the state of the forests in three West African countries deserve to be heard. And what they say deserves thinking over.

In the title of their book, the first five words clearly announce what is at stake. It is a quest. It asks the question of the natural, implicitly excluding the unnatural, the anti-natural or the anatural, if the latter exists at all! Finally the degree of difficulty is increased by addressing the issue of natural forest. As a matter of fact, this is not an issue at all, but rather a philosophical labyrinth, out of which one desperately seeks an issue. For instance, according to Brünig (pers. comm.) in forests there are degrees of virginity.

Throughout, the text shows some of the main characteristics of the way of thinking in forestry. It heavily leans on the past and on historical evidence, as it should if one is to obtain some understanding of these huge vegetations, the lifespans of which exceed ours by so much. Moreover, the approach is very prudent. Foresters are conservatives, who know that one fool can kill in an hour what it takes a century to grow. In this, a forestry officer is the very antithesis of a military officer. It makes foresters as suspicious as security people at airports. Even the most respectable looking person may carry a forest-destroying bomb in the form of some innovative plan or technique.

Foresters want to play it safe. It is a comfortable idea to know that there are such people. In the present text, this is expressed by its economic backbone, i.e. hardwood production. An innovation allows us to see the other bones of the skeleton too. The authors have included an up-to-date treatment of forest ecology and of the restoration of ruined forests, like in Bossematié. This substantiates their claim that they do not just equate a forest surface with a woody mass. And moreover, completely at the end, there is a timid treatment of some forest products other than wood, produced by non-arborescent forest organisms. A herbaceous plant produces a biochemical sweetener and animals produce bushmeat.

The necessary choice between extractivismo and crop or animal production outside the forest is mentioned. The fact that it is not thought through to its far consequences by these authors is a pointer to the book not being a handbook for experiments, but a survey of the state of the art as it is today.

Reading the book, one is struck by the rich history of the people of this part of the world, and therefore of their forests also. What has happened in West Africa in this century alone could easily have led to complete deforestation. It is a miracle that so many hectares did survive and that so many men and women of so many origins were available to work at that survival, by designing and applying silvicultural systems and in other ways. One should think of these people with deep respect because they solved forest problems during their time without the means we have now to do so - if we wish.

The present book can be instrumental in the survival of West African forests. It is a solid block of serious information, containing little or no speculation. Every West-African decisionmaker in the field of land use in general, and every forest officer in particular should be encouraged to study it. They will not learn how to solve their problems directly. This is good. Too long, foresters from a few schools in the Northern world have tried to dictate to tropical people what they should or should not do with their forest.

But nobody has ever become worse for an exchange of ideas, something which may seem self-evident in the homelands of the palaver. Please, African as well as non African readers, start a long and fruitful palaver with this book. I can testify to you that both Dr. de Graaf and Mr. Parren are great in palavers and do not wish to impose but to convince. And after the palaver, please build your African forest history knowing that there are friends who wish you well and who are ready to help if you feel you need a hand.

Roelof A.A. Oldeman
Professor of Silviculture & Forest Ecology
Brunoy, 24 March 1994

JUSTIFICATION

This book has been written in response to the confused information presented in the popular press about the forestry situation in West Africa. It is the negative aspects which attracted attention rather than some of the positive which are also present albeit on a modest scale, and it seems unfair to the authors not to redress the balance.

The first author, Marc Parren, has travelled in West Africa many times from 1982 on, and has gathered a host of information about forestry from the three countries under review here. The second author, Reitze de Graaf, has spent most of his working life on silvicultural research in the Neotropics (Latin America), but has also visited the Côte d'Ivoire several times when supervising field research undertaken in Taï National Park.

The authors hope that this book will help to eradicate some of the confusion mentioned above. The book has been written for those people already informed to some degree about forestry in general and is not to be seen as a textbook on tropical silviculture. Further information about specific forestry concepts and expressions should be sought in regular textbooks about silviculture (Matthews 1989), books on forestry in general (Westoby 1989), and on tropical silviculture (Lamprecht 1989). Botanical names have been taken from Voorhoeve (1965), Hall & Swaine (1981) and Hawthorne (1990). All figures and values presented are according to the metric system.

In describing and analyzing the, mostly experimental, silvicultural systems in this book, we have avoided presenting a single silvicultural or forest management approach as being the best for the region as such an approach has to be adapted to each specific situation and forest area. So this is not a book in which to find the 'ultimate solution'. Rather it was written in order to contribute to the search for the right strategies and paths for reaching the desirable future state of the forest based on a considered appraisal of what has happened in the past.

An overview of all site locations mentioned in this book is presented in Figure A, opposite the first page of chapter 1.

SUMMARY

Deforestation in West Africa has been strongly influenced by western Europe. Most of the timber felled was destined for Europe, just as had been most of the agricultural export crops such as coffee, rubber and cocoa. This book concentrates on the three most important timber producing countries in the Upper Guinea region: Ghana, the Côte d'Ivoire and Liberia.

The earliest colonial interest in forest products had been in non-timber products but later on attention was focused on large and valuable timber logs. Scant attention was paid to the sustained production of this commodity in those early times although forest areas had been reserved on a local basis in the early colonial periods.

Biologically the West African moist forest can be characterized as being a biome that has been subjected to large fluctuations in size over geological time. This could explain the relatively low numbers of species found in this ecosystem when compared with other tropical moist forest ecosystems. The various kinds of forest found along the decreasing rainfall gradient are briefly discussed and this is followed by a treatise on regeneration processes in the forest. The role of an important animal, the forest elephant, is outlined and a plan is suggested for helping to save this animal in its habitat, the closed forest of West Africa.

When large scale forest exploitation began in the last decades of colonial rule, the legal status of the forests had not been satisfactorily settled in any of the three states discussed. Land use planning proved necessary in order to save at least some of the forest. Most of the unreserved forests have been converted to other land uses except for Liberia which is still able to make choices but is now experiencing hard times in an ongoing civil war. Total moist forest area left over in official reserves varies from 1.6 to 1.8 million ha per country. The condition of forests of the permanent forest estate varies widely, from poor to excellent, in both the Côte d'Ivoire and Ghana.

Forest exploitation in the Ghanaian Forest Reserves has long been better controlled as regards the yield and the maintenance of the remaining forest stand as compared with Cote d'Ivoire Forêts Classées. The situation in Ghana could serve as an example of the conservative use of timber resources originally induced by British colonial providence but also by the tenacity of the indigenous Ghanaian landownership itself. It will be a considerable challenge to Liberia to excercise controls when the civil war is over.

Silviculture in forest management in West Africa is treated in detail, by referring to a number of pilot projects in the various countries. The emphasis which was formerly laid on timber growing (production) is gradually changing for the better towards a more all-comprising view of the forest ecosystem and its management needs. Nevertheless the large, commercial, timber producing trees can be regarded as being the mainstay of the whole without which the forest would not have the

quality needed. The question of planting or natural regeneration was especially important in the Côte d'Ivoire.

Silvicultural interference to assist valuable timber species to maintain their share in the exploited forest stands has proved to be an interesting option. Experience in this was gathered in Ghana initially but, more recently, the experiments have been more extensive in the Côte d'Ivoire and Liberia. Intervention in the early silvicultural systems focussed on assisting the regeneration of commercial species to assure their establishment. These silvicultural systems resulted in a virtually even-aged forest at high cost and risk. More recent silvicultural systems tried in Liberia and the Côte d'Ivoire concentrated on the assistance of ‘Potential Crop Trees’, which are pre-mature trees, to ensure an adequate number of harvestable trees in the next felling series. The structure of the forest is more uneven in age and, at all stages, shows many of the aspects of a natural forest. At the moment we are at the point at which the knowledge acquired from the experiments will have to be translated into implementation on a larger scale.

The future possibilities and desirable developments show up in various projects described in the last chapter. Ghana, re-assessing its Forest Reserves, is exerting more control on its timber industry and timber exploitation with the reorganisation of the forest sector. In the Côte d'Ivoire, German forest research workers are now indicating new directions for forest management to take in the region by showing how to nurse a plundered forest back into a complete forest again which would include the important fauna from snails to elephants. The large trees, so important for the African forest, might need a new harvesting approach, since their huge biomass has much potential. Such ideas, more in line with natural forest dynamics, have been developed in the Taï National Park, by Dutch forest research workers.

The possibility of incorporating lesser-used timber species and non-timber forest products are discussed at the end. The importance of non-timber forest products can be easily demonstrated and two examples from these multiple products are given. The most important one might be 'bushmeat' and the other one is a sweetener, of interest to the food industry.

RÉSUMÉ

La déforestation en Afrique de l'Ouest a été fortement influencée par l'Europe occidentale. La plupart du bois abattu était destiné à l'Europe, comme l'avaient été la majeure partie des produits agricoles exportés, tels le café, le caoutchouc et le cacao. Ce livre se concentre sur les trois plus importants pays producteurs de bois dans la région de la Haute-Guinée: le Ghana, la Côte d'Ivoire et le Liberia.

L'intérêt colonial premier pour des produits forestiers s'était porté sur des produits non ligneux, mais par la suite l'attention s'est focalisée sur des grands rondins de bois de haute valeur. A cette époque, très peu d'attention fut portée au maintien de la source de production de cette marchandise, bien que localement, des zones de forêt aient été mises en réserve pendant cette période initiale de la colonisation.

Biologiquement, la forêt humide d'Afrique de l'Ouest peut être caractérisée comme étant un **biome** qui a été sujet à de grandes variations de superficie, dues à des changements d'ordre géologiques. Ceci pourrait expliquer le nombre relativement restreint d'espèces trouvées dans cet écosystème en comparaison avec d'autres écosystèmes de forêt tropicale humide. Les différentes variétés de forêts que l'on trouve le long du gradient des précipitations sont brièvement présentées; suivi d'un traité sur les processus de régénération de la forêt. Le rôle d'un animal important, l'éléphant de forêt, est souligné et un plan d'action est suggéré pour aider à sauvegarder cet animal dans son habitat, la forêt dense d'Afrique de l'Ouest.

Quand l'exploitation de la forêt a commencé à grande échelle durant les dernières décennies de la tutelle coloniale, dans aucun des trois Etats mentionnés le statut légal des forêts n'avait été établi de façon satisfaisante. Il s'est révélé indispensable d'aménager le territoire afin de pouvoir sauvegarder au moins une partie de la forêt. La majeure partie des forêts non classées a été utilisée à d'autres fins, à l'exception de celles du Liberia. Ce pays est encore en mesure de faire des choix, mais vit actuellement des moments difficiles en raison de la guerre civile qui y sévit. La superficie totale des forêts tropicales restantes dans les réserves officielles oscille entre 1.6 et 1.8 millions d'hectares par pays. Aussi bien en Côte d'Ivoire qu'au Ghana, l'état dans lequel se trouvent les forêts permanentes varie énormément, allant de faible à excellent.

En comparaison avec les forêts classées ivoiriennes, l'exploitation forestière des réserves ghanéennes a longtemps été mieux contrôlée en ce qui concerne le rendement et l'entretien des peuplements forestiers restants. La situation au Ghana pourrait servir d'exemple pour l'utilisation conservatrice des ressources en bois. Cette utilisation a originellement été induite par la présence coloniale anglaise, mais aussi par la ténacité des propriétaires terriens ghanéens. Ce sera un défi considérable pour le Liberia d'exercer un contrôle quand la guerre civile aura pris fin.

La sylviculture dans la gestion des forêts en Afrique de l'Ouest est traitée en détail, en se référant notamment à divers projets pilotes de différents pays. L'accent initialement mis sur la production de bois s'est graduellement converti en une vue plus globale, incluant l'écosystème de la forêt et ses besoins de gestion. Néanmoins, les grands arbres destinés au commerce peuvent être considérés comme piliers de l'ensemble, sans lesquels la forêt n'aurait pas la qualité requise. La question de plantation ou de régénération naturelle était spécialement importante en Côte d'Ivoire.

Le recours à la sylviculture pour aider des espèces de bois de haute valeur à maintenir leur position appréciable dans les forêts exploitées s'est avéré une option intéressante. Initialement, les expériences dans ce domaine ont été effectuées au Ghana, mais plus récemment, les expérimentations ont été plus étendues en Côte d'Ivoire et au Liberia. Dans les premiers systèmes sylvicoles, l'intervention a porté sur l'assistance de la régénération d'espèces commerciales afin d'assurer leur implantation. Ces systèmes sylvicoles ont résulté en une forêt d'âge égal à coûts et risques élevés. Des systèmes plus récents expérimentés au Liberia et en Côte d'Ivoire se sont concentrés sur le support "d'arbres potentiels de récolte". Il s'agit là d'arbres prématurés qui assurent un nombre adéquat d'arbres propres à l'abattage lors des prochaines séries de coupe de bois. La structure de la forêt y est moins régulière de par l'âge et présente à tous les niveaux une grande partie des caractéristiques d'une forêt naturelle. Actuellement, nous avons atteint le stade où les connaissances acquises lors de ces expérimentations vont devoir être appliquées à plus grande échelle.

Divers projets décrits dans le dernier chapitre mettent en relief les possibilités futures ainsi que les développements souhaitables. Avec la réorganisation du secteur forestier, le Ghana, revalorisant ses réserves forestières, est entrain d'exercer un contrôle plus fort de l'industrie et de l'exploitation du bois. En Côte d'Ivoire, des chercheurs allemands spécialisés dans ce domaine indiquent actuellement de nouvelles directions à suivre dans cette région pour la gestion de la forêt. Ils montrent comment prendre soin d'une forêt dévastée pour qu'elle redevienne une forêt à part entière, qui inclurait une faune importante allant des escargots aux éléphants. Les grands arbres, tellement essentiels pour la forêt africaine, nécessitent probablement une nouvelle approche d'abattage, partant du fait que leur biomasse élevée possède un potentiel important. De telles idées, plus proches de la dynamique des forêts naturelles, ont été développées dans le Parc National de Taï par des chercheurs néerlandais.

En dernier lieu, la possibilité d'introduire des espèces de bois moins utilisées et des produits forestiers non ligneux -ces derniers ayant joué un rôle primordial dans l'histoire- sont discutées. L'importance des produits non ligneux peut aisément être démontrée et deux exemples de ces multiples produits sont donnés. Le plus important en est peut être la "viande de brousse" et le second un édulcorant, d'un intérêt certain pour l'industrie alimentaire.

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Akwaaba or welcome is the first aspect of the Ghanaian culture that strikes you and will ensure that you leave this country with fond memories. We like to acknowledge the Forestry Department and in particular the Chief Conservator of Forests, Mr. John François, and Dr. Rex Chachu as well as Mr. K.K.F. Ghartey, Mr. Tim Nolan, Mrs. Julia Falconer, Dr. William Hawthorne of the Ghana Forest Inventory Project, Dr. Albert Ofosu-Asiedu, Mr. S.P.K. Britwum and Dr. Dominic Blay Jr. of the Forestry Institute of Ghana.

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A visit to Liberia was cancelled at the last minute when the exodus caused by the civil war began in 1990. Consultation of people in the field was no longer possible. However, we are grateful for the comments and information provided by Dr. Hans Jörg Wöll, Dr. Jutta Poker, Dr. Mark Taylor and Drs. Henk Dop who all worked in Liberia for some time.

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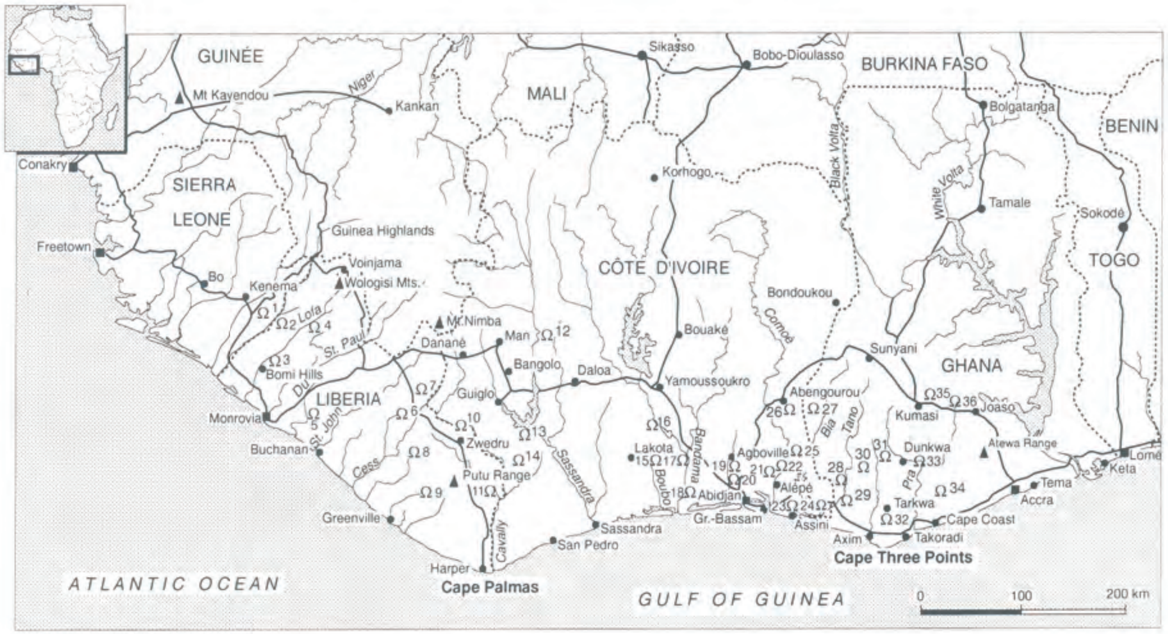
Figuur A.



LEGEND:

Ω1 = Gola-North FR
Ω2 = Gola NF
Ω3 = Bomiwood or Gola (Yoma)
Ω4 = Kpelle NF
Ω5 = Firestone Plantation Co. (Du)
Ω6 = Gbi NF
Ω7 = Gio NF
Ω8 = Krahn-Bassa NF
Ω9 = Sapo NP
Ω10 = Cavalla
Ω11 = Grebo NF
Ω12 = Haut-Sassandra FC
Ω13 = Nzo RF
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Ω15 = Divo BR
Ω16 = la Téné FC
Ω17 = Mopri FC
Ω18 = Irobo FC
Ω19 = Yapo FC
Ω20 = Banco NP
Ω21 = Teke FC
Ω22 = Comoé FC
Ω23 = Toumanguié FC
Ω24 = Eyania FC
Ω25 = Mabi-Songan-Yaya-Tamin FC
Ω26 = Bossematié FC
Ω27 = Bia NP & GPR
Ω28 = Tano Nimri FR
Ω29 = Ankassa GPR
Ω30 = Bura FR
Ω31 = Tonton FR
Ω32 = Neung FR
Ω33 = Nkrabia FR
Ω34 = Kakum FR (proposed NP)
Ω35 = Bobiri FR
Ω36 = South Fomangsu FR

Figure A. An overview of all site locations mentioned in this book. (BR = botanical reserve, FC = forêt classée, FR = forest reserve, GPR = game production reserve, NF = national forest, NP = national park, RF = reserve de faune)

1. HISTORICAL

What is happening to the forests of West Africa? Will they vanish in our lifetime? And what could humanity do to stop this disaster?

Such were the questions that have led to the writing of this book. The history of man's interaction with the humid tropical forests of West Africa is already long. Yet the decisive attack on these magnificent forests with their impressive large trees began only late in this century with the acceleration of timber felling for the nearby European market and the subsequent conversion of forest into cultivated land.

It is clear that governments in West Africa have deliberately promoted forest conversion. To a certain degree they needed to do so, in order to foster their economic development and to create more productive land use. But was it really necessary to do this in a liquidation sale of timber logging permits, even on permanent forest land? What will be left over?

Although the deforestation process seems to be similar in all three countries discussed here, there are nevertheless clear differences in the basic approaches as well as in the final outcomes.

1.1 Deforestation in West Africa: phytogeography, dynamics, causes and alternatives

1.1.1 Phytogeography

The African lowland moist forest zone shows a clear division into two blocks, separated by the 'Dahomey Gap'. The chorological[1] map of Africa identifies the African tropical forest as Guineo-Congolian Region (White 1979). A phytogeographical region is defined as having higher than 50% endemism, and more than 1000 endemic plant species.

The Guineo-Congolian Region is divided into two sub-centres of specific endemism, namely the Upper Guinea[2] Subcentre and the Lower Guinea Subcentre. Each of these sub-centres possesses a considerable number of endemics although the proportion is, in each case, less than 50% of the total flora. The Dahomey Gap is to be found between the Upper Guinea and Lower Guinea sub-centres (Fig. 1.1), and is caused by the offshore emergence of a cold Atlantic undercurrent. The Dahomey Gap forms a corridor of savanna reaching the coast from the northern savannas.

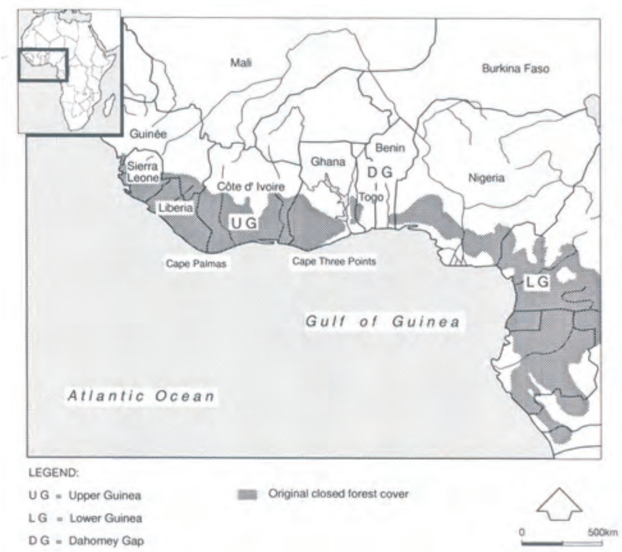

Figure 1.1 Chorological map of West Africa and its two refuge areas. Based on White (1979) and Hall & Swaine (1981).

[1] Chorology is the study of the geographical area occupied by a species.
[2] 'Guinea' is a European word derived from a berber phrase meaning 'land of the black men'.

The lowland moist forest zone from Guinée to Ghana encompasses the Upper Guinea subcentre. Liberia, the Côte d'Ivoire[3] and Ghana are important timber exporting countries. Sierra Leone and Guinée are less important timber suppliers, since their total rain forest areas are small: Sierra Leone 2560 km² (Jay 1955) and Guinée 800 km² (Rouanet 1952). In this book it is only the principal timber producing countries of the Upper Guinea subcentre which are discussed and, whenever 'West Africa' is mentioned, then Liberia, the Côte d'Ivoire and Ghana are meant.

The West African lowland moist forests are among the most depleted forests in the tropics. This depletion is caused by the historically close links of these countries with Europe, by official policies and by the high population densities. Steps to halt the trend in forest losses have to be taken swiftly and it is encouraging to see that nation-wide action is being taken in the Côte d'Ivoire and Ghana to preserve what is left with the aim of using it wisely.

1.1.2 Dynamics

To give an idea of the serious situation in which the region's forests now find themselves we will present some figures. In Sierra Leone deforestation began as early as the 1840s and resulted in a closed forest cover of only 6% by the 1930s (Gornitz 1985), and even this low forest cover has diminished yet further. Of the original moist forest zone of 31.3 million ha from Guinée to Ghana at the turn of the last century, some 8.7 million ha (see Table 1.1 and Fig. 3.1) has remained, i.e. about one quarter. This includes highly depleted forest areas still classified as forest but biologically not functioning as such.

Martin (1989a) states that the exploitation of undisturbed closed forest in West Africa (here including Nigeria) encompassed 164,000 ha annually over the period 1981-1985. The growing stock in these forests of trees ≥ 10 cm drh was found to be 172 m^3 per ha of which, on an average, 12 m^3 per ha of the best timber could be harvested. The total annual extraction from undisturbed forest would therefore be around 2 million m^3 of roundwood equivalents for all of West Africa (including Nigeria).

But it is known that the Côte d'Ivoire alone already has an annual production of 3 million m^3 of roundwood equivalents since 1987, and this had been even higher during the two previous decades. Much timber comes from already exploited 'residual' forest. And after this timber is exploited the clearing for agriculture usually takes place. During the 1970s the Cote d'Ivoire annual deforestation rate was over ten times the pantropical average rate of 0.6% (FAO 1986). Forestry has been put on a par with mining activities, and the forest has been exploited as a non-renewable natural resource. At this time this rate has slowed to a mere 1% annually over the last decade for most countries in the region (FAO 1993).

[3] According to a Presidential Decree of 1985 the Republic of the Ivory Coast is to be called 'Côte d'Ivoire' in all languages.

Table 1.1 Total original (around 1900 A.D.) and present moist forest areas (in 10^6 ha). Figures for Ghana based on Ghartey (1990); for Côte d'Ivoire on FAO (1988) and Ministère des Eaux et Forêts (1988); for Liberia on Hammermaster (1985), Hasselman (1986), WCMC (1991); for Guinée on Rouanet (1952); for Sierra Leone on Jay (1955).

	Ghana	Côte d'Ivoire	Liberia	Guinée	Sierra Leone	Total
Present moist forest area	2.1	2.6	3.9	0.0	0.1	8.7
Original moist forest area	8.1	14.5	7.3	0.1	0.3	31.3

1.1.3 Causes

To understand this gradual process of depletion it is essential to present it in its historical context. The historical development of commercial exploitation, the forestry administration and the choices that have been made in the past determine the outlook of the present silvicultural and forest management systems as described in this book. A short analysis of differences between French and British colonial administration policies will be given since these have had major implications for their respective forest policies.

British colonial policy aimed at the creation of political unities - if necessary by creating federations - that should be able to operate independently economically. To achieve this goal colonial governments established close relations with the chieftaincy.

The French on the other hand abolished the formalities of the chieftaincy. For the French economic considerations had never played the single dominant role in their colonial policy. They aimed at a complete economic, political and cultural integration of overseas territories and the mother country. To effect this the local administration was administered by the 'préfecture', an authority which had to replace the chieftaincy.

This explains the difficulties which the Gold Coast Government (presently Ghana) faced when it tried to gain control of the land and to tap its resources, problems which the Côte d'Ivoire Government never had to face. The Côte d'Ivoire Government ruled by decree, while the Gold Coast Government opted for rule by manipulation of the chieftaincy.

As early as 1825 the possession of public property in the French colonies, including forest lands 'vacantes et sans maître', was claimed by ordinance to belong to the French King and later to the French State. In 1897 a decree established control over the land by the French State while the produce of these lands would add to the budget of the colony (Méniaud 1931). In the Gold Coast however, the inherent rights over land lay in the hands of the natives and this forced the colonial government to manoeuvre more carefully than in the Côte d'Ivoire.

Côte d'Ivoire experiences. This difference in approach over the control over forest land has accelerated the deforestation rate in the Côte d'Ivoire. The Côte d'Ivoire has experienced the most rapid deforestation taking place in any country in the world since the mid-1950s. The average annual deforestation rate, as a percent of the remaining forest, rose from 2.4% in 1956-1965 to 7.3% in 1981-1985, over ten times the pan-tropical average rate of 0.6% (FAO 1986). The principal causes have been indiscriminate forest exploitation, followed by subsistence farming or the cultivation of cash crops.

The roots of this process can be traced back to the last World War and can be characterized as being difficulties of a political, economic or technical nature. We will go into this process in more detail later and it should be noted that this situation had prevailed until the end of the 1980s.

The political difficulties are grounded in the constitution of the domain of the State. All land 'vacant et sans maître' was claimed by the State as we mentioned erlier. The presumption of the vacant status of land, including forests, was criticized by almost all political interest groups. It would have been difficult for the indigenous population to claim occupation rights on large forest blocks if certain political interest groups had not, for electoral reasons, pretended that they possessed the authority to cancel the reservation or status of land. At the same time the unpopular Forest Service was not taken seriously since it lacked the means to exert sanctions. The outcome of all this was that farmers felt free to reclaim and cultivate within forest areas having a protected status. At every election campaign one could detect the general trend towards occupying the reserved domain. The essential factor which encouraged the penetration of the forests was the slow pace and inadequacy of judicial sanctions which, in the end, were often not even executed.

The efforts made in promoting the cultivation of cocoa and coffee since the late 1940s, have made the Côte d'Ivoire rank as 1st and 3rd producer of these commodities in the world in the 1980s. This policy pushed the cultivators into the forest reserves. The cultivators of these two crops obtained premiums which compensated almost entirely for the total amount of the fine they had to pay for the reclaiming of land within forest reserves. In certain cases the status of reserved forests was downgraded e.g. at Toumanguié, Miemni and Boubo. There was also a lack of personnel for surveillance and many forest reserves were not well delimited.

The deforestation process in the Côte d'Ivoire had been accelerated by a governmental development programme initiated around 1965, that had encouraged the cultivation of cash crops in the extensive forest areas of South-west Côte d'Ivoire previously almost untouched since the late 1960s (see Fig. 1.2). Small-scale commercial forest exploitation in this area started along the rivers and streams at the turn of this century but did not expand before the 1950s (Schwartz 1993), as access had been limited to the area opened up by the road network extending to Abengourou in the East and about 70 km towards the Sassandra river in the West (Chevalier & Normand 1946).

In 1969 concessionaires had to hand over large parts of their original concession areas since the government wanted to have more nationals involved in the forest sector (Schwartz 1993). Intensive logging operations were started and after deforestation large-scale industrial plantations, like rubber and oilpalm plantations were established. At the same time small-scale farmers, who mainly cultivate coffee and cocoa, were assisted by a strong agricultural extension service. The migration drive of the 1960s and 1970s was followed by an immense immigration of people originating from Guinée and Burkina Faso after the extreme drought of 1983 with its extensive forest fires, which worstened the whole situation (Buttoud 1989). The effects can be clearly seen on the maps in Fig. 1.2. Since 1967 some 1 million ha of unreserved forest had gone lost over a timespan of 25 years. South-west Côte d'Ivoire also had, and still has, to cope with a high intake of Liberian refugees since the outbreak of the civil war in Liberia in 1989.

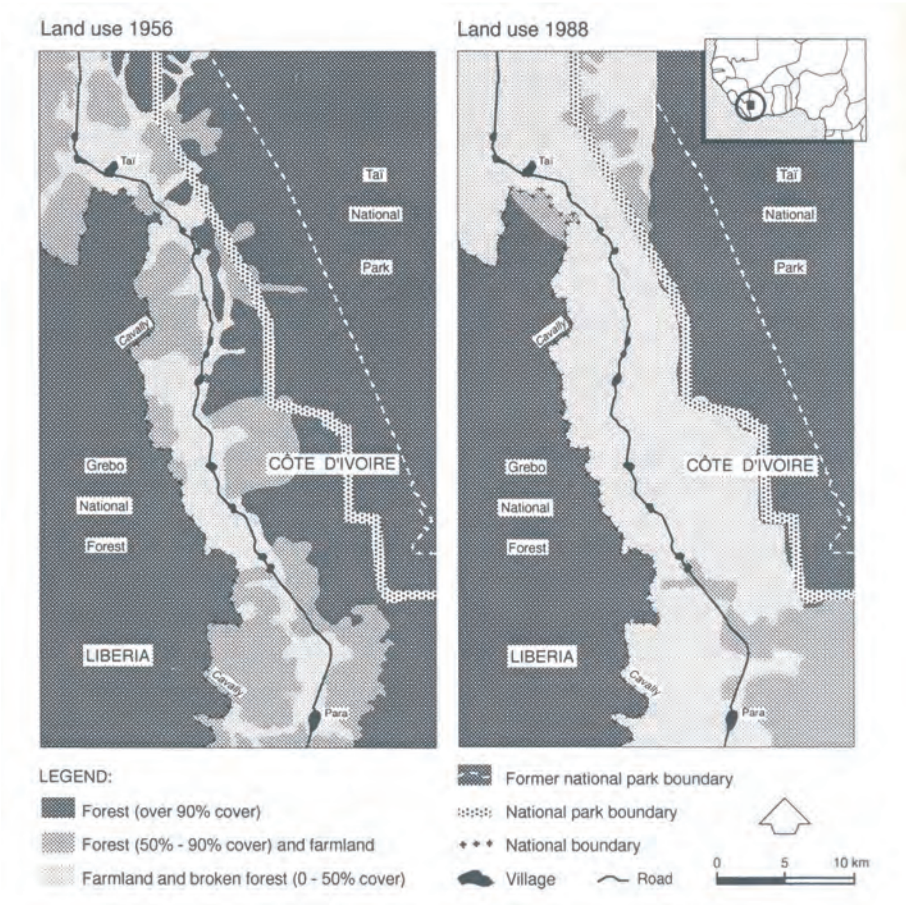

Figure 1.2 Vegetation and land use of the Taï region (SW Côte d'Ivoire) in 1956 and 1988. Based on maps in de Rouw *et al.* (1990) for the Côte d'Ivoire and Landsat TM satellite image dd. 14.12.1988 in van Rompaey (1993) for Liberia.

Ghanaian experiences. A similar process could be seen in Ghana where the cocoa boom stimulated cocoa farmers originating from the traditional cocoabelt in the central and eastern regions to cultivate in the formerly almost untouched forests of western Ghana (see Fig. 1.3). Cocoa production in western Ghana compensated for the older production areas which had gone lost due to the felling of cocoa trees affected by swollen shoot diseases (Ahn 1959). Forest exploitation was followed by the establishment of cocoa farms. The essential difference with the Côte d'Ivoire was that these farming operations were limited to unreserved forests. The legal status of forest reserves was respected for the most part, and most of the farmers did not settle permanently in this region, but continued living in their towns of origin and worked in their newly established farms only on a temporary basis.

Changes in property rights also affected the rate of deforestation in Ghana. Usufruct rights over forest resources were originally those of customary law. In the early 1970s, as an outgrowth of political conflict, all rights over natural resources were stripped from the traditional communities and taken by the central government (Repetto 1988). The benefits were no longer for the local community and the authorities lost a lot of respect from the people.

This new attitude was felt specifically in the unreserved forests where previously mature trees had been left untouched by shifting cultivators. These trees formed the next potential yield in a second felling series by the concessionaires. As a result of the changed usufruct rights, these trees were felled or killed by the shifting cultivator by applying fire to their base. The total of unreserved forest area dropped to its present low of 300,000 ha (see Table 3.1). Besides, as Repetto (1988) states, fuelwood cutting accelelerated sharply after the mid-1970s; by 1983, Ghana's per capita fuelwood consumption was one of the world's highest, and it is still rising rapidly. The fuelwood harvest is about 12 times the volume of logs harvested.

Liberian experiences. In Liberia the export of timber was almost non-existent until the 1960s because of the highly scattered and diffuse availability of commercial species in natural forests and because of transportation problems and the shortage of labour that prevailed. Until the 1960s Liberia was even to remain a lumber **importing** country since its national output amounted to only 20,000 m^3 per year (Querengasser 1965). When president Tubman opened the door to concessionaires at the end of the 1950s the transnational corporations enjoyed a relatively free hand and were able to establish very large logging operations as had been possible in the Côte d'Ivoire.

Remarks. European involvement caused rapid population growth stimulated by the introduction of modern medicine and hygiene from the end of the last century. The need for land increased accordingly and pushed people into populating formerly sparsely populated areas. In the beginning this mainly for subsistence farming which also saw the shortening of fallow periods. Later subsistence farming gave way to cash crop farming as an result of more money-orientated economy expanding into the rural areas. One conclusion could be that, even though the wainscot and furniture wood sold to Europe had already reduced the forests, it was coffee with pieces of chocolate which gave the final blow to the forest ecosystem. Current low prices for coffee and cocoa may not be the result of boycott action, but may yet have favourable effects on global deforestation rates.

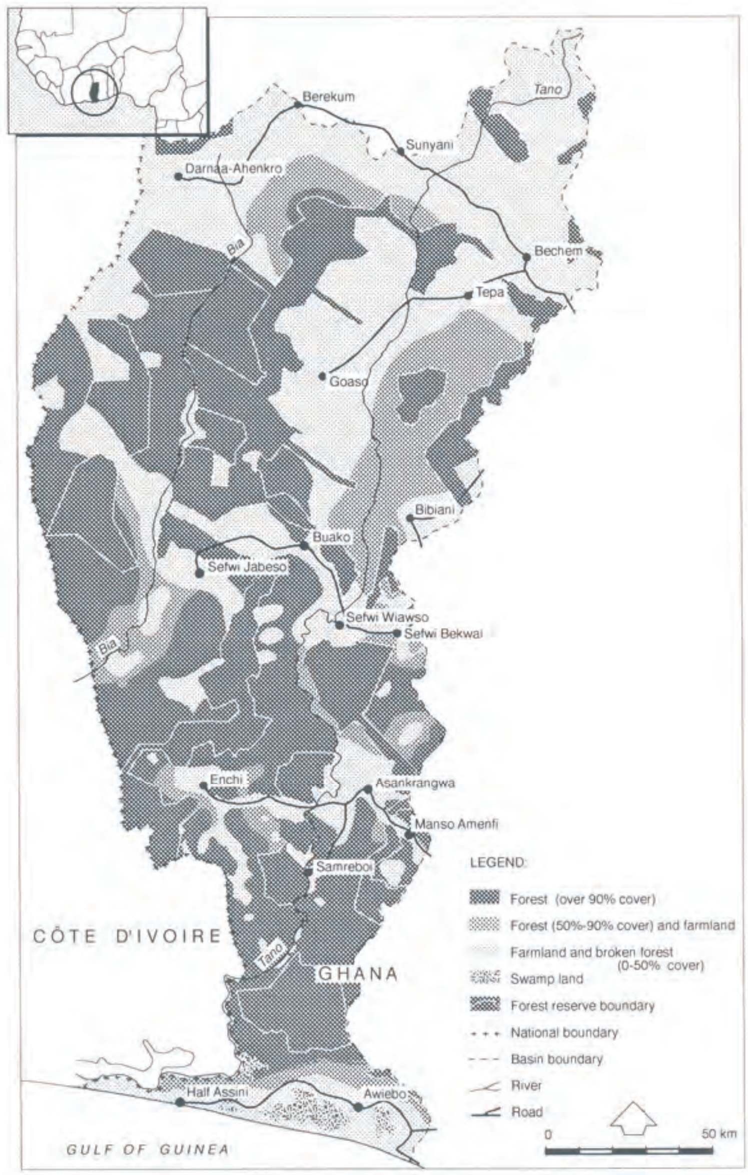

Figure 1.3 Vegetation and land use in the Tano-Bia river basin (Ghana) in 1959. Based on a map in Ahn 1959.

1.1.4 Alternatives

European involvement in West Africa has changed its social and economic life and altered its vegetation and land use drastically. Probably nowhere else in the tropics has the impact of foreign interference been so destructive and it is admirable how the people have overcome the losses caused by the large scale slave trade of former times. Many of the actual problems in Africa are rooted in the incompatibility of their colonial heritage and traditional African customs, culture and organization. Regarding deforestation there are, at present, signs of hope that drastic deforestation will be halted and that the restoration of forests is underway as the political will seems to be growing in the region to reverse the prevailing trends.

The lessons to be learned from this region are, as yet, not widely known, but they can be applied elsewhere in the moist tropics. Anderson (1990) is correct to state that the potential solutions for tropical forest conservation have gone relatively unnoticed and that viable alternatives to deforestation *do* exist.

The production and conservation value of the forest found in national forest inventories presents opportunities for matching ecological and economic criteria as can be seen in Ghana. Excellent forest management at reserve level was recently implemented in an important forest reserve in the Côte d'Ivoire. Forest dynamics after silvicultural treatments implemented since the late 1970s were studied in both the Côte d'Ivoire and Liberia. The highly interesting Liberian experience is largely unknown outside the country, and, moreover, the experiments had to be abandoned when civil war broke out in late 1989.

1.2 Botanical expeditions

Exploration and the first colonial settlement along the West African coastline date back to the 15th century and began with the Portuguese. Settlement along the Gulf of Guinea concentrated on the Gold Coast, a region where, as the name implies, gold was traded. The Portuguese were defeated by the Dutch in the 17th century, a period marking the beginning of a dramatic trade in human lives. The Dutch soon faced competition from slave traders from Great Britain, France, Sweden, Denmark and Brandenburg all of whom settled down on a small stretch of coast from Assinie to Keta. This more or less covers the entire coastal length of what is present Ghana.

Europeans paid relatively little attention to the Grain Coast (Liberia) and the Ivory Coast (Côte d'Ivoire) during the 17th and 18th centuries. Malagueta pepper (*Aframomum melegueta*) which was traded from here was replaced by more favoured peppers (esp. *Piper nigrum*) from Asia. A brisk trade in ivory during the 17th century reduced elephant populations to the extent that the trade itself began to decline (Fage 1955). Also the number of slaves to be bought here did not warrant permanent trading posts being established.

The first botanical collections in the countries of the Upper Guinea subcentre were made in Sierra Leone, Liberia and the Gold Coast by Swedish, British and Danish settlers at the turn of the 17th century and during the 18th century (Hutchinson & Dalziel 1954-72, Exell 1962, Keay 1962, Hepper 1976). These collections were made in the immediate vicinity of coastal settlements. Schumacher (1827) shows us that the specimens were shipped to the respective mother countries where they were taxonomically described by botanists and the results published accordingly. Some brief description of local uses was often given. One of the first collections from the interior of the moist forest zone was made by T.E. Bowdich and H. Tedlie on their expedition to Kumasi, Ashanti in 1817 (Keay 1962). In the early 1820s Dr M. Reynhout (1824), a surgeon and botanist in Dutch employ described plants from the Gold Coast. Since 1841 occasional collecting had taken place in Liberia by British and German botanists who participated in expeditions en route to other destinations. These collections mainly included herbs, shrubs and climbers and hardly any tree species (Mayer 1951, Voorhoeve 1965). Most of the interest was in commodities of high value and not in timber.

With the abolition of the slave trade a struggle for the interior of Africa had begun. The economic outlook was also changing as the newly created colonies had to finance themselves. New commodities had to be found and these were all types of forest products. This encouraged botanical collectors to explore the forest hinterland and discover its production potential. Such discoveries have led to the destruction of natural resources on a scale so great that it was later considered to be one of the worst of this age.

In the **Gold Coast** Captain H.A. Cummins, a surgeon who formed part of the 2nd Ashanti Expeditionary Force from Cape Coast to Kumasi in 1895-96 which penetrated deeply into the moist forests, collected 200 plants (Hutchinson & Dalziel 1954-72, Hall & Swaine 1981). After the turn of the century more attention was paid to tree species, and this marked a period in which a steady growth of the timber industry took place. Since 1908 H.N. Thompson, Conservator of Forests of Southern Nigeria, and other foresters such as T.F. Chipp and C. Vigne made botanical collections in the Gold Coast (Taylor 1960). At the present day two main herbaria exist in Ghana. The one in Legon, Accra, has mainly herbaceous specimens and the collection in Kumasi, in the Forestry Department, mainly consists of trees and lianas.

Similar expeditions started in the **Côte d'Ivoire** around 1895-96 when Pobéguin was given the order to map the coastal area. He followed the Cavally and Sassandra rivers some 85 km upstream and was able to indicate the economic potential of the area. Scientific expeditions began in 1905 and A. Chevalier played a major role until 1912[4]. Some 170 wood samples were taken and small scale forest inventories gave some data on densities thus indicating future production potential. Exudates of

[4] Note that the scientific mission of 1906-1907 (Chevalier 1909) mentions export potential of Black and white Colobus (*Colobus polykomos*) furs, already exported in large quantities from the Gold Coast. This species is presently classified as endangered, as the result of habitat destruction and hunting.

many species were also considered to have industrial potential (Chevalier 1909). A. Aubréville and several other foresters had made detailed studies of the rain forest zone from 1928 on.

A Harvard African expedition visiting the interior of **Liberia** and Belgian Congo in 1926-27 collected some 1600 plant specimens in Liberia of which only 182 or about 11% consisted of tree species (Mayer 1951). Since the 1890s other botanists, of which the German consul M. Dinklage was the most important, had frequented the Liberian interior and collected about 1100 plants of which 32 were newly described species including the genus *Dinklagea* (Hepper 1962). The clearing activities to establish vast rubber plantations in Liberia from 1904 raised the question of timber exports. In 1926 the Firestone Plantation Co. had acquired a concession of 160,000 ha on a 100 years term. This had inspired a botanical expedition by a Yale University (USA) delegation in 1928-29 to the concession in the Du river area in which 286 species were identified, many of which were tree species. Wood samples of 104 tree species were collected to determine their potential uses (Cooper & Record 1931).

1.3 Early commercial forest exploitation

1.3.1 West Africa

Logging activities can be traced back as far as the 16th century when samples of *Lophira alata* were sent to the United Kingdom. The Ashantis, a tribe dominant in the hinterland of the Gold Coast had another principal export commodity next to slaves and gold (Wilks 1985) which was kola, the seeds of *Cola nitida* (Lovejoy 1985, see Fig. 16.2 for production areas). The export of kola seeds began in the 15th or 16th centuries and finally became a major export commodity after their participation in the overseas slave trade in the 1820s had declined. This kola seed trade remained important until the rise of the wild rubber trade in the 1880s (Yarak 1990). The oil of the palm *Elaeis guineensis* was one of the first export commodities to reach Europe from the Gold Coast and Nigeria around 1790, initially from wild stock but, soon afterwards, from plantations (Moloney 1887).

In general it can be said that European commercial interference in the land use of the moist forest zone dates back to the end of the 19th century when it was that firstly British and latterly French companies began harvesting African mahogany (*Khaya* and *Entandrophragma spp.* of the Meliaceae). Around 1833 the first trunks of African mahogany appeared on the British market and from 1878 onwards their importance increased. Initially it was the trade in Acajou du Sénégal (*Khaya senegalensis*) from Gambia, Senegal and Sierra Leone which peaked during the 1850s and 1860s and then almost came to a standstill due to overexploitation (Moloney 1887). Later this species was followed by mahoganies from the entire west coast of Africa, especially the Acajou Bassam from the Côte d'Ivoire (*Khaya ivorensis*).

African mahogany replaced the highly depleted natural stocks of American mahogany (*Swietenia mahagoni*, but also *S. macrophylla*). This timber had been shipped to the court of Elisabeth I since 1595, but the export boom began around 1720 when it became one of the most sought after timbers in the world apart from ebony, *Diospyros spp.* (Chevalier & Normand 1946). Chevalier (1908) stated that out of the world demand of 107,000 m^3 for mahogany, the Côte d'Ivoire supplied 22,000 m^3 annually, while Taylor (1960) stated that Ghana supplied 88,200 m^3 in 1913.

In the early days, logging activities were concentrated in the coastal zone and along rivers in the south-eastern part of the Côte d'Ivoire, in the adjoining south-west corner of the Gold Coast (see Fig. 1.4), and, at a later stage, also along the newly opened railways. The savanna plains and mangroves stretching along the entire Liberian coastline discouraged early forest exploitation. Scouting for new areas to exploit was undertaken from 1850 to 1930, but exploitation during the early 20th century was not significant (Mayer 1951).

Figure 1.4 Squared logs lying in a creek waiting for the water level to rise to float them to the mouth of the river, Ghana. Photo 1901.

During the 1890s the rain forest zone in West Africa witnessed a major boom in the exploitation of camwood of the tree species *Baphia nitida* which produced an important red dye which has later been replaced on the market by synthetic dyes. A similar fate befell wild rubber, e.g. of the tree species *Funtumia elastica* and the climber *Landolphia sp.* Slaughter tapping of rubber was practised on a wide scale and officials feared for the future of the trade (correctly, as it turned out). The issue of tapping licences, prosecution in the case of unauthorized forest exploitation and the delimitation of reserved forests were among the important functions of the colonial administration. Those living in these areas today can still tell stories about the tapping of rubber by forced labour in the forest.

One of the first steps taken in conservation was the reservation of forest lands. Initially reservation was aimed at the conservation of forest lands and not at timber production. Later on large shares of the reserved areas were opened up for concessionaires to exploit.

1.3.2 Ghana

Since 1894 the, then, Gold Coast Government wanted to control land in order to tap its resources. To effect this control the Government passed a Crown Lands Ordinance in 1895 to vest ‘waste and forest lands and minerals’. The people of the Gold Coast opposed the Government's land policy, pointing out that it contravened the accepted fact that they had inherent legal rights as possessors of their own land. In 1898 the native people won a victory over the local British Government when Her Majesty's Government agreed to leave its natives to be the lawful owners of their own ancestral lands. This is quite contrary to what happened in the Côte d'Ivoire as we saw before. In 1900 the former ordinance was replaced by the Concessions Ordinance (Agbodeka 1972).

Following its failure to achieve an overall control of land, the Government decided to concentrate all efforts on the means of production. In 1907 the Timber Protection Ordinance was enacted in order to protect immature trees of certain species against felling. The pertinent minimum diameter limits imposed up to the late 1940s are listed in Appendix 1. Under this ordinance a Forest Officer was appointed to inspect trees before they could be felled. In 1908 a survey of the forests took place and the next year the Forestry Department was established. In the course of 1910 a Forest Ordinance was passed to empower the Governor to declare certain lands subject to forest reservation. But the Government did not dare implement the ordinance in the face of local opposition so that its implementation was delayed until 1927 (Taylor 1960).

In 1921 the introduction of the property marks under the Timber Protection Rules took place. In 1925 and 1926 amendments to the Concessions Ordinance of 1900 were made which gave the Chief Conservator of Forests power to regulate operations within concessions, to lay down directions and limitations before work commenced and to prescribe penalties for infringement.

Figure 1.5 *Khaya ivorensis* felled at Bobiri forest reserve near Kumasi, Ghana. At the time felling was mostly confined to trees over 105 cm diameter reference height of only a limited number of species. Photo G.S. Cansdale 1948. George Soper Cansdale served from 1934-1948 in the colonial Forest Service of the Gold Coast.

Until the Second World War exploitation in the region was mainly confined to trees of over 105 cm drh (see also Fig. 1.5).

The 1935 revised Forest Ordinance encouraged the reservation of forests, but its by-laws did not ensure management, and these were later replaced by Rules which caused local authorities to manage their reserves in accordance with the advice of the Forestry Department (Brookman-Amissah 1985).

1.3.3 The Côte d'Ivoire

The necessity to protect forest lands was already understood at the time of the formation of the Côte d'Ivoire as a separate colony in 1893. An ordinance of 1900 outlined the regulation of forest exploitation and prohibited the clearance of slopes with an incline of over 35° as well as all areas designated by any ordinance.

The forestry acts of 1912 and 1920 focussed on concessionary taxation and volume fees. Most early forest concessions were of areas of 2500 ha (5x5 km) and had contracts lasting only one to five years, whereas in the Gold Coast concessions were granted for 50 years, exceptionally for as long as 99 years, in order to commit concessionaires to exert responsible forest management. In 1920 minimum diameter limits (see Table 1.2) were imposed to deter the felling of undersized trees. This can hardly be called a serious regulating measure to avoid the depletion of the standing stock considering the fact that in Ghana felling was mostly confined to trees > 105 cm drh at that time. The idea of a permanent forest estate was introduced in 1913, but lack of personnel and the means to exercise control at the time, postponed reservation until 1926.

In the 1920s the idea arose that merchantable trees could be grown on cultivated land. The Service Forestier referred to the Forestry Act of 1912 by which it was forbidden for farmers to touch certain commercial species on farmland.

D'Aviau de Piolant (1952) quotes the ideas of foresters at that time:

> Il faudra qu'à chaque plantation vivrière succède une forêt de bonnes essences à laquelle les indigènes ne touchent plus, au moins jusqu'à ce qu'elle soit exploitable. Petit à petit de grandes surfaces pourront être ainsi couvertes d'une forêt riche... Ce programme est simple. Il est le seul pratiquement réalisable et son exécution sera relativement peu coûteuse.

This might explain why French foresters have directed all their efforts towards artificial regeneration since those early days.

Table 1.2 Minimum diameter limits imposed in Côte d'Ivoire by the Forestry Act of 1920. Original source: appendix C by Méniaud (1931).

80 cm	*Entandrophragma angolense*	*Khaya ivorensis*
	Entandrophragma utile	*Tieghemella heckelii*
	Khaya anthotheca	
70 cm	*Milicia excelsa*	
60 cm	*Entandrophragma candollei*	*Lovoa trichilioides*
	Entandrophragma cylindricum	*Nauclea diderrichii*
	Guarea cedrata	
50 cm	*Heritiera utilis*	*Terminalia superba*
	Terminalia ivorensis	*Uapaca spp.*
35 cm	all other tree species	

Forest exploitation in West Africa initially took place on unreserved forest lands outside reserves. Our present understanding of the pre-war forest reserve management could describe this as 'conservation forestry'. The main aim was to protect water supplies, prevent erosion and ensure the maintenance of the necessary climatic conditions favouring agricultural production. Forest reserves were considered to provide indirect benefits.

The policy of sustained yield was, and usually still is, never applied on unreserved forest lands, and these areas are subjected to virtually salvage felling. In Ghana and Liberia unreserved forest lands include all those forest lands that do not form part of the permanent forest estate, whilst in the Côte d'Ivoire it involves all lands that belong to the ‘domaine forestier protégé’. Application of the policy of sustained yield is unlikely in these areas since there is continuous destruction of the forest cover because of the pressures of agriculture.

2. BIOLOGICAL

What appearance and biological functions did West African forests have in the past and what do they have nowadays? Popular science tells us that these forests are diverse and rich in species. This is something different from being rich in commercial timber as some of these forests, indeed, were. What is there to be conserved and to what extent can it be used wisely?

What made them so vulnerable to human interference? Is there some key factor we should know in order to conserve them?

The magnificent forests as were found -and still can be found- in the humid regions of West Africa are often referred to as 'Tropical Rain Forests', but they deserve a more elaborate description. You will find wet evergreen forests as well as dry semi-deciduous forests in the sequence of vegetation types indicated as 'high forests' in this region. The different floristic composition of these forests is largely caused by site factors such as rainfall, soils and soil parent material, and frequently, a history of fire.

Little is known about the processes of death and regeneration of most of the organisms in these forests, from trees to insects, or of their adaptation to environmental factors. Scientists are learning more and more about the total picture, but the entire situation cannot yet be summed up in a single series of thoughts. For foresters, forest managers and forest users, how to obtain products from this ecosystem in a sustainable way has long been an important issue and many questions about biology and ecology have not yet been answered satisfactorily. The trees, which to a large extent determine the ecosystem, have been the focus of research for quite a long time, but even these trees, though relatively well studied, still have many secrets for us.

2.1 Lowland moist forest vegetation zones

2.1.1 Chorological relationships

The vegetation zones of West Africa are not, and never have been, in a static state (Maley in prep.). The expansion or regression of forest formations took place according to global climatic changes. During the Pleistocene glacial periods the forests were limited to refuge areas of highest rainfall. Around 18,000 B.C. the savanna and forest formations must have been far to the south if, as Shaw (1985) suggested, desert sand dunes had been formed at latitude 12°N (e.g. the present position of Bobo-Dioulasso). Shaw (1985) hypothised that, when world temperatures fell during the last glaciation, the Inter-Tropical Convergence Front (ITCF) was deplaced from its present most northern position to about 20°N latitude, southwards. The ITCF is formed where the hot and dry continental air mass meets the relatively cool, moist maritime air mass. During that glacial period the south-west monsoon winds blew less far and more weakly into the West African continent during the rainy season, whereas the dry, north-east, continental winds of the dry season, known as the Harmattan, blew longer and stronger across West Africa. It was only by 10,000 B.C. that conditions seem to have become wetter again. During this period the forest would again have spread northwards from the refuge areas near the coast where it had survived the preceding dry period.

It is hypothesised that the Pleistocene forest refugia of West Africa (see Fig. 2.1) were confined to the inland mountainous areas known as the Guinea Highlands (Schnell 1950), as well as two refugia close to the coast in a narrow zone from Liberia to Cape Palmas in the Côte d'Ivoire and inland from Cape Three Points in Ghana (Aubréville 1962, Guillaumet 1967, Maley in prep.). Great richness of species should be correlated to high rainfall and, according to Maley (1987, 1991), the flatness of the terrain would not allow adequate amounts of rainfall in these coastal areas. According to Maley, only the Guinea Highlands qualify as having been a forest refugium. One should realize, however, that during this glacial period the West African rivers were discharging into an ocean which was some 110 m below its present level because much water was frozen in the polar ice-sheets (Martin 1972). Coastal relief was much more pronounced then than it is now. Moreover, the present coastal relief around Cape Palmas has ridges of up to 750 m in Liberia (Putu Range) and 475 m in the Côte d'Ivoire (Grabo Hills) and thus cannot be considered as being flat.

Figure 2.1 The hypothetical positions of the Pleistocene forest refugia in West Africa according to Guillaumet (1967) and van Rompaey (1993). The western extent of the refugium on the hills of Grabo remains unknown.

The hypothetical positions of the two coastal refuge areas are supported by the degree of endemism. Hall & Swaine (1981, p. 39) published a list of plant endemics which showed that SW Ghana has 9 endemics, while the SW Côte d'Ivoire and Liberia have 58 endemics altogether. Recently, van Rompaey (1993) pointed out that the entire evergreen forest zone from the area around the Gola forest in SE Sierra Leone to the Grabo Hills in the SW Côte d'Ivoire could have formed one, long, forest refugium and this is in agreement with Shaw's (1985) ideas mentioned earlier. Endemic large tree species such as *Tetraberlinia tubmaniana* and *Loesenera kalantha* are confined to these Liberian evergreen forests.The two coastal refuge areas were distinguished by Aubréville as early as 1949. Latterly these refugia were accredited by the International Council for Bird Preservation (ICBP), and the one near Cape Palmas was extended to SE Sierra Leone since each refuge area showed three or more restricted-range endemic bird species (Stuart & Adams 1990).

In general, African moist forests are relatively species-poor when compared with Neotropical and Australasian moist forests. Palms, bamboos, ferns and epiphytes are not abundant in the African moist forests. On the other hand, lianas are quite common. The density of lianas ³ 2.5 cm diameter in 0.1 ha plots averaged over 100 lianas in Africa, more than in the Neotropics which averaged 69, while the Australasian forests averaged even less (Gentry 1991). This last phenomenon may have important repercussions for forest management (Putz 1991).

2.1.2 Vegetation zones and soils

Vegetation type correlates well with the total annual amount of rainfall, as well as with the total length of the dry season (with a mean monthly rainfall <100 mm; for more details see also Walter 1985). Successively drier vegetation zones can be distinguished moving from the coastline into the interior. These range from per-humid evergreen forests around Greenville in Liberia via a zone of evergreen forests running more or less parallel to the coastline of Liberia and the Côte d'Ivoire and which carve deep into the south-western corner of Ghana, to the dry semi-deciduous forest in the Côte d'Ivoire and Ghana, finally merging into a forest savanna mosaic at the fringes (see also Fig. 2.2).

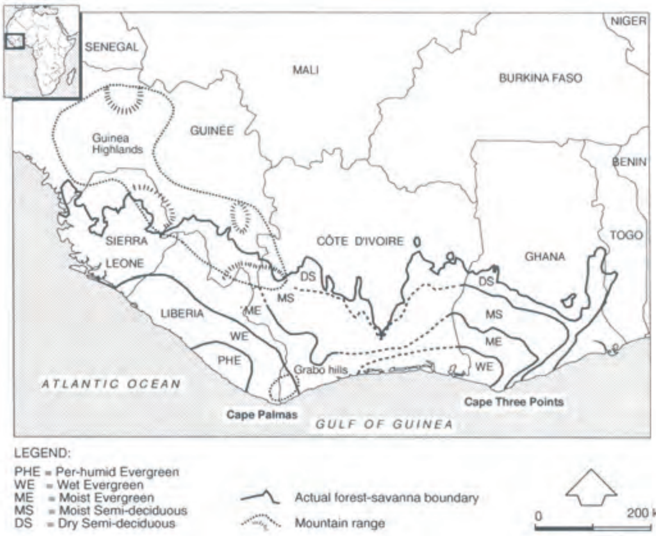

Figure 2.2 Distribution of forest zones in West Africa. The following sources were used for Ghana: Swaine & Hall (1986, pp. 68/9; Fig. 4.13); for the Côte d'Ivoire approximation (broken line): Guillaumet & Adjanohoun (1971, vegetation maps SW and SE Côte d'Ivoire; WE = cat. 22+23, ME = cat. 18+21, MS = cat. 17, DS = cat. 15), for SW Côte d'Ivoire and SE Liberia: van Rompaey (1993, p. 36; Fig. 14; PHE = DCA_1 score >200, WE = DCA_1 score 120-200, ME = DCA_1 score 40-120); for Liberia: Sachtler (1968, map 2; PHE = climatic region 13.1 and distribution area of two Caesalpiniaceae tree species, WE = to the south of the boundary between evergreen and moist semi-deciduous forest). The forest-savanna boundary is the one presented by Swaine & Hall (1986) and drawn from LANDSAT imagery.

The boundary between closed-canopy forest and savanna tends to follow geological boundaries. In the forest fringe areas in Ghana, forest is found on the Pre-Cambrian basement complex where soils have moderately good water-storage capacities but savanna on the drier, very poor sandy soils of massive sandstone origin (Ahn 1970, Swaine *et al.* 1976). West Africa is mainly on a massif of very old rocks of the oldest geological time period, the Pre-Cambrian.

South of latitude 12° N about two-thirds of the surface has soils derived from ancient Pre-Cambrian formations and one-third has soils originating from more recent formations and sediments of various types. Detailed soil classification information is given by Brammer (1962) for Ghana, by Perraud (1971) for the Côte d'Ivoire and for Liberia by Reed (1951) and Fanfant (1970). See van Rompaey (1993) for a recent lithological map of SE Liberia and the SW Côte d'Ivoire.

Wet evergreen vegetation zones occur where the south-west monsoon winds reach the West African coast in April or May on their way north-east. The determining high rainfall can be seen in Liberia which has an average annual rainfall of up to 4700 mm (Voorhoeve 1965) and at Cape Three Points with an average yearly high of up to 2200 mm (Walker 1962). Another determining factor is the soil as we saw before. The classification by Brammer (1962) for Ghana showed that the evergreen forests more or less coincide with highly leached, yellowish, very acid and nutrient-poor oxisols (ferralsols), while semi-deciduous forests occur on less leached, reddish, slightly acid to neutral ochrosols that are better supplied with nutrients.

A wedge shaped intrusion of savanna is seen in the central part of the Côte d'Ivoire, and is called the V-Baoulé (Guillaumet & Adjanohoun 1971). The western limit of this savanna intrusion is not sharp, as savanna islands on sandy soils carve deep in the moist forests on soils of granite origin. This forest-savanna mosaic gradually gives way to savanna in line with the decreasing rainfall pattern. Rainfall decreases from the Liberian coastline with highest rainfall towards the western limit of the V-Baoulé forest-savanna boundary. Both geographical boundaries stand perpendicular to the prevailing Atlantic monsoon winds. The eastern limit of the V-Baoulé extends far north into the savanna since here, moist forest occurs where schist which has a much higher water capacity is the dominant bedrock type (as in Ghana). In Ghana savanna reaches the Atlantic coast where the annual average rainfall is below 1200 mm, representing the west flank of the Dahomey Gap. This phenomenon is most often attributed to the upwelling of a cold Atlantic undercurrent off the coast from Cape Three Points eastwards (Walker 1962). The south-west monsoon loses most of its rain over the cold sea instead of over the mainland as is the case for Liberia.

2.1.3 Major vegetation zones

Strictly speaking, 'tropical rain forest' refers to evergreen forest in the moist tropical lowlands (Richards 1964), where short dry periods last only a few days or weeks. Monthly precipitation should be no less than 100 mm. This definition excludes most of West African closed-canopy forest zones. The term 'tropical moist forests' is more apt since these include all forests receiving at least 1600 mm rainfall annually and experiencing an annual dry season of 1 to 3 months with a monthly precipitation of 60 mm or less (Whitmore 1990).

Here we discuss all closed-canopy forests from evergreen to dry semi-deciduous. The transition between forest and savanna occurs at an average annual rainfall of about 1250 mm in both the Côte d'Ivoire (Spichiger & Pamard 1973) and Ghana (Hall & Swaine 1981).

Climate and soil are the most important environmental factors which determine the existance of forest. Climate is clearly of primary importance; the moister parts of West Africa are all potentially forest covered, while the drier parts are bare savanna. Various attempts have been made to make a distinction between different forest types by describing the forest composition according to dominant tree species. In West Africa some of the early classifications were made by Cooper & Record (1931) for Liberia, Mangenot (1955) for the Côte d'Ivoire and Chipp (1927) for

Ghana. Most early descriptions speak of 'closed forest', 'high forest' or 'forêt dense'.

We prefer to apply the word 'zone' instead of 'forest type' since the former term refers to a continuous zone with a fixed order (along a gradient: climatic or altitude) e.g. zonal vegetation in West Africa: coast to desert, or in Russia. The word 'type' on the other hand, includes patches without order or relationship but which are related to different management or history or lithology e.g. different stages of secondary forest, inselberg vegetation, riparian forest, elephant disturbed forest, fresh water forest. This differentiation was applied by the German forest inventory team in Liberia in the 1960s (Sachtler 1968). The word 'formation' will be used whenever vegetation can be recognized from physiognomic characteristics (not species composition) e.g. mangroves, evergreen forests, semi-deciduous forests, savannas.

The forest zones discerned will differ so much that different forest management is required for separate zones, but it should be kept in mind that the boundary between forest zones is not sharp but rather a smooth transition along the gradient, as discussed by van Rompaey (1993). Areas with forest zones as traditionally defined can carve deep into one another as vegetation maps drawn by Guillaumet & Adjanohoun (1971) show.

Van Rompaey (1993) postulated a gradual change in forest composition for West Africa along a forest gradient that is directed more or less at right angles to the coast line reaching into the interior, evidently coinciding with the pattern of decreasing rainfall amounts. This gradient is hard if not impossible to split up into forest zones, and we prefer to present here the traditionally marked out forest zones as, from a timber production point of view, we want to know the optimum habitat of certain tree species in the regional forest gradient.

Table 2.1 gives a comparison of the generally accepted classifications of today for closed-canopy forest in West Africa. For Ghana this is the classification of Hall & Swaine (1981), for the Côte d'Ivoire that of Guillaumet & Adjanohoun (1971) and for Liberia that of Sachtler (1968).

Next we will describe the major West African forest zones (see also Fig. 2.2). All forests discussed are forests on well-drained land and forests with aberrant site conditions or soil edaphic forest types such as mangrove, swamp or riparian forest are excluded. The classification of Hall & Swaine (1981) is taken as the basis, but it is extended to include forests under the very wet conditions in Liberia which we will indicate as 'per-humid evergreen forests'. In a specific forest zone present in both refuge areas (See Fig. 1.1) and determined as a zone by specific climatic conditions, the same genus may be found but with different tree species, e.g in the western refuge area only *Cola buntingii* is found and in the eastern coastal forest only *Cola umbratilis*, other large tree species such as *Gymnostemon zaizou* are restricted to the western coastal refuge area.

Table II.1 Comparison of several forest type classifications for the West African moist forest zone. Ghana based on Hall & Swaine (1981), Côte d'Ivoire on Guillaumet & Adjanohoun (1971) and Liberia on Sachtler (1968).

Ghana	Côte d'Ivoire	Liberia
		Wet Coastal Evergreen (2800 - 4400 mm)
Wet Evergreen (1750 - 2250 mm)	Forêt à *Turraeanthus africanus* (Melia.) et *Heisteria parviflora* (Olaca.) Forêt à *Diospyros spp.* (Ebena.) et *Mapania spp.* (Cyper.)	Mixed Evergreen (> 2000 mm)
Moist Evergreen (1500 - 1750 mm)	Forêt à *Eremospatha macrocarpa* (Palmae) et *Diospyros mannii* (Ebena.) Forêt à *Nesogordonia papaverifera* (Sterc.) et *Khaya ivorensis* (Melia.)	Moist Semi-deciduous (1800-2000 mm)
Moist Semi-deciduous (1250 - 1750 mm)	Forêt à *Celtis spp.* (Ulmac.) et *Triplochiton scleroxylon* (Sterc.)	
Dry Semi-deciduous (1000 - 1500 mm)	Forêt à *Aubrevillea kerstingii* (Mimos.) et *Khaya grandifoliola* (Melia.)	
fire zone subtype		

2.1.4 Evergreen forest formations

The evergreen forest is characterized by the absence of an accentuated dry season of more than one month and by sufficient annual rainfall to permit growth all the year round (more than 2200 mm around Cape Three Points, but much higher in Liberia and around Cape Palmas). True evergreen forest shows two distinct zones; the per-humid evergreen and the wet evergreen forest zone. Typical evergreen forests (cf. Hall & Swaine 1981, Voorhoeve 1965) show the strong dominance of the Caesalpiniaceae family of tree flora, e.g. *Dialium aubrevillei*, *Daniellia thurifera*, *Cynometra ananta*, *Gilbertiodendron preussii* and *Tetraberlinia tubmaniana*. The last three species may be found as almost pure stands in Liberia (Voorhoeve 1965) in which the endemic *Tetraberlinia tubmaniana* is the only economic species.

A **per-humid evergreen forest zone** with a restricted range can be distinguished around Greenville in Liberia where characteristic Caesalpiniaceae tree species such as *Loesenera kalantha*, *Tetraberlinia tubmaniana*, *Didelotia brevipaniculata* and *Brachystegia leonensis* are at their optimum (see distribution maps in Sachtler 1968). Annual precipitation amounts from 2000 mm up to over 4000 mm.

The **wet evergreen forest zone** coinciding with slightly lower rainfall is limited to a belt parallel to the coast of Liberia and extending to SE Sierra Leone and the SW Côte d'Ivoire and is more or less defined by the 2000 mm isohyet. This forest is also found around the eastern coastal refugium extending from the Boubo river in the SE Côte d'Ivoire to SW Ghana. The SW and SE Côte d'Ivoire wet evergreen forests may have formed a continuous belt in the past. In this forest *Heritiera utilis* is quite abundant and *Lovoa trichilioides*, *Lophira alata* and *Guarea cedrata* occur in small numbers and the first trees of *Khaya* and *Entandrophragma spp.* appear here. In the south-west Côte d'Ivoire, north-west Liberia and south Sierra Leone the per-humid forest gives way to moist evergreen forest (called 'fringing forest' by Cooper & Record 1931, 'transitional forest' by Mayer 1951).

These two evergreen forests later give way to the drier, moist evergreen forests, even when high annual precipitation rates of up to 3000 mm are registered (e.g. in Sierra Leone). This shift is caused by a prolonged dry season as these forests lay farther north from the equator. The height of the per-humid forest rarely exceeds 40 m and, although floristically very rich, it is poor in economic species. For forest management aimed at timber production it is the evergreen forests which are the least well stocked.

The **moist evergreen forest zone**, although not as rich as the per-humid forest, has great floristic diversity. This forest shows the dominance of Mimosaceae and Caesalpiniaceae tree species (cf. Taylor 1960), such as *Piptadeniastrum africanum*, *Parkia bicolor*, *Erythrophleum ivorense*, *Anthonotha spp.* as well as *Parinari excelsa* and *Klainedoxa gabonensis*. Deciduous trees form only a small proportion of the canopy (<20%), and the application of the term 'evergreen' is thus appropriate (Hall & Swaine 1981). The forest resembles the moist semi-deciduous forest in appearance but the tallest trees are slightly shorter, on average reaching 45 m. As for economic species, *Heritiera utilis* has become occasional or rare while *Triplochiton scleroxylon* and *Entandrophragma angolense* begin to occur. The eastern coastal refuge area shows abundant stocks of *Khaya ivorensis* with a western limit at the Boubo river in the Côte d'Ivoire (see Fig. 1.4, and Aubréville 1959) and *Turraeanthus africanus* and *Tieghemella heckelii* are at their optimum here.

In Liberia the demarcation between the wet evergreen and moist evergreen forests is situated along the December position of the Inter-Tropical Convergence Front (ITCF). South of the turning point of the ITCF wet evergreen forest is found while north of it moist evergreen forest is found. Voorhoeve (1965) states that truly deciduous forest hardly exists in Liberia.

Most authors speak of (moist semi-) deciduous forest when they refer to the moist evergreen forest type in Liberia (Cooper & Record 1931, Mayer 1951, Voorhoeve 1965, Sachtler 1968). Recently Mayers (1992) pointed out that moist semi-deciduous forest is confined to the drier north-west of Liberia, chiefly upper Lofa County. This confirms our classification, however, due to lack of detailed information, we were not able to map the boundary line between these two forest zones in north-west Liberia.

2.1.5 Semi-deciduous forest formations

The transition between evergreen forest and semi-deciduous forest formations is not abrupt. Depending upon the availability of moisture these different formations can carve deep into one another. The appearance of both forest formations is shown by the two aerial photographs taken on the same day over the Lofa river in Liberia in January 1987 during the dry season (see Fig. 2.3). Evergreen forest formations are encountered downstream while semi-deciduous formations are found upstream.

Most forests in the Côte d'Ivoire and Ghana belong to the semi-deciduous forest formations. The rainfall regime is modest with a precipitation of less than 2000 mm and a main dry season of at least 2 - 3 months. For mapping purposes the 1600 mm isohyet boundary -as suggested by Aubréville as early as 1938- seems to fit quite well. The semi-deciduous forests contained the greatest stocks of economic timber species and, together with the moist evergreen forests, they constitute the main timber production area.

The **moist semi-deciduous forest zone**, shows an abundance of more common species and these often find their optimum here. Some emergent tree species occupy the upper canopy at a height of 50 to 60 m. This greater height is commonly attributed to the soils being less leached when compared with soils in per-humid conditions with much higher rainfall levels (Hall & Swaine 1981). Characteristic species of these forests are *Sterculia oblonga* and *Sterculia rhinopetala*, the latter having its western limit near the Cavally river on the border between the Côte d'Ivoire and Liberia (in Grebo NF and Cavalla NF not found: Poker 1993, in Taï NP found: van Rompaey 1993). Other typical tree species include *Pericopsis elata*, *Daniellia ogea*, *Antiaris toxicaria* var. *welwitschii*, *Aningeria robusta*. As for economic species, the Meliaceae are well represented with *Entandrophragma spp.*, *Guarea cedrata* and *Khaya anthotheca*.

The dry semi-deciduous forest zone of Liberia is limited to a small zone in the north-west around the Wologisi Mts. where savanna is also found (Mayers 1992). Dry semi-deciduous forest is quite extensive in the Côte d'Ivoire and Ghana. Indicative tree species are *Celtis spp.*, *Mansonia altissima*, *Pterygota macrocarpa*, *Nesogordiana papaverifera* and *Morus mesozygia*. The tallest trees are mostly between 30 and 45 m in height. As for economic species, *Triplochiton scleroxylon*, *Milicia spp.* (formerly *Chlorophora spp.*) and *Khaya grandifoliola* are at their optimum here.

Semi-deciduous forest upstream

Evergreen forest downstream

Figure 2.3 Aerial photographs of semi-deciduous and evergreen forest formations taken on the same day north and south of the Inter-Tropical Convergence Front along the Lofa river, west Liberia. Photo H. Dop, 1987.

2.2 Forest regeneration processes

The tropical moist forests show a very high biodiversity as a result of various quite complex ecological processes. Only a few aspects important for the processes of regeneration of the forest can be discussed here.

First, we will briefly describe the successional processes in a forest and offer some views on plant strategies. We will then follow with an account of plant-animal interaction. This discussion should provide some insights into the ecological functioning of the forest ecosystem which insights are essential for the implementation of any silvicultural system. A fuller account of the topic including much detail about West Africa may be found in Swaine & Hall (1986), Longman & Jenik (1987) and Martin (1989b).

2.2.1 Silvigenesis

The regression and expansion of the moist forest zone over millennia can be deduced from phytogeographic accounts. When we concentrate on the forest level, here dynamic processes also appear to be continuously active. Even if a forest can be described as being virtually in biostasis, a phase in which the inputs and outputs are in a state of near equilibrium, such a characterization will apply only in part. Periods of growth and decay will always precede and succeed this phase. The complex of forest-shaping processes, only some of which are clearly successional, has been termed *silvigenesis* by Oldeman (1983).

Aubréville (1938) was one of the first to put forward a theory of cyclic regeneration of tropical moist forest when he studied in the Côte d'Ivoire. Such cyclic regeneration would result in a forest mosaic of patches in different successional stages. Watt (1947) then recognized that Aubréville's theory was akin to the plant community dynamics which he had described for the temperate zone. Many others followed Watt's observation. We choose to refer to Whitmore's (1989) review of this topic. Here we will present the successional processes as described by Oldeman (1990) briefly below as the succession from the zero-event of natural treefall (*chablis*) and gap phase, to the biostatic phase of the regeneration unit, such a unit being named the *forest eco-unit*. This approach also underlines the theory of Aubréville.

The **innovation phase** in which the propagule bank in the chablis responds to the new light conditions is characterized by stiff competition and ends with the closing of the canopy. This phase is succeeded by an **aggradation phase** dominated by woody plants, in which phase structural differentiation takes place. Saplings and poles compete, are densely packed and trees either die or remain suppressed. Finally, a limited number of emergent trees reach their maximum height under specific site conditions.

The innovation and aggradation phases are characterized by growth, especially in height, and by high mortality rates. In their evolution in time and space these two phases can be seriously hampered by abundant liana growth. This certainly applies to West Africa (Osafo 1970, Kahn 1982). The aggradation phase culminates in an equilibrium in which the eco-unit reaches the greatest biomass, the **biostatic phase** (mature phase). Finally a **degradation phase** must follow which, in the end, makes place for a new innovation phase.

For a forest management focusing on natural regeneration the latter phases are very important since they determine the reproduction potential essential for sustainable forest management. The biostatic phase and the degradation phase (the latter represented by senescent trees) the 'trees of the past' of Oldeman (1990) form the seed source for the propagule bank. Phenological studies of this reproduction process are few as yet and often superficial, e.g. for Liberia Voorhoeve (1965), for the Côte d'Ivoire de la Mensbruge (1966), Alexandre (1978, 1980), for Ghana Taylor (1960), Swaine & Hall (1986).

The harvesting of trees from the forest may fit into the cycles as described above but leaving seed bearers is essential for any silvicultural system based on natural regeneration. According to the authors, when managing under a selection system, the harvesting should concentrate on mature trees in the biostatic phase, as the danger of heart-rot in harvestable trees increases with age and should be avoided as much as possible. Senescent trees may still have excellent seed producing potential and such trees need not be removed in the first stages of selection management. They will die out gradually in the following decades. A pool of senescent trees mixed with a number of well-formed mature trees in the biostatic phase may form the reproductive pool to be set aside in the first stage forest management plan.

All stages of the respective phases are encountered in a natural forest. The phases and stages of distinctive eco-units are determined by disturbances such as storms, earthquakes, forest fires, logging activities that often have a great impact, or the activities of herbivores, falling trees, falling large branches and standing dying trees with smaller impact. Therefore, when investigating a natural forest it will, at any one time, show a patchwork of eco-units forming a *silvatic mosaic*.

Oldeman (1990) defines a silvatic mosaic as:

> Every forest surface that is situated in one continuous volume with the same resource regime of climate and soil, which shows the same complex of silvigenetic dynamics, resulting in an eco-unit composition that oscillates around a specific state and determining the architecture and ecological functioning as long as the resource regime remains unchanged.

Successional processes having the same complex of silvigenetic dynamics are cyclic in optimal situations (see Fig. 2.4). The implications of this view for forest management are, first of all, a need for the zoning of a forest area into different silvatic mosaics. The contour sampling technique along a catena tried out for the Taï forest in the Côte d'Ivoire by van Rompaey (1993) is one such option but it requires a fairly intensive inventory. Each silvatic mosaic needs its own specific section in the management plan.

2.2.2 Plant strategies

'Succession' in the terminology of Oldeman is a process of eco-units replacing eco-units. The size of eco-units in a forest determines light regimes (i.e. the amount of radiation used in photosynthesis) inside the chablis as well as in the immediate vicinity. Seed germination and the other responses of the existing seed bank depend on the size and character of the newly established chablis. Later on the fragmentation of large eco-units anew provokes responses in tree species.

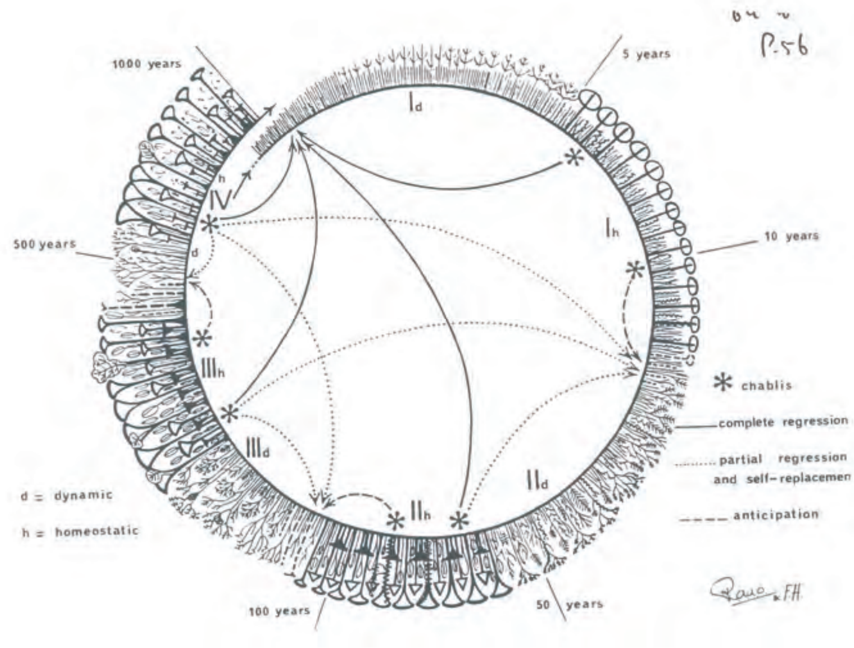

Figure 2.4 Silvigenetic cycles. Source: Hallé *et al*. 1978.

Plants follow strategies for their survival and development and these strategies can be grouped as to a plant's requirements and its behaviour for coping with its environment. Botanists and foresters alike have long tried to define plant groups with the same strategy. Such groups may be called *guilds*. Frequently used terms are 'pioneer', 'secondary', 'late secondary', 'light demanding' for species found to germinate in large eco-units, as opposed to 'climax', 'primary' or 'shade tolerant' for species found to germinate in small or late fragmented eco-units. For an overview of name pairs of guilds of tree species we choose to refer to Swaine & Whitmore (1988). Recently Hawthorne (1989, 1993) grouped tree species of the moist forests of Ghana based on their requirements for light (Table 2.2). Most

Table 2.2 Key to Ghanaian forest tree strategies in eco-unit development. Based on Hawthorne (1989).

Species requiring open conditions for germination			
	small trees, < 30 m tall at maturity		1a (small pioneers)
	species requiring light all life		
		(e.g. *Musanga cecropiodes*)	
	species tolerant of shade once established		
		(e.g. *Mareya micrantha*)	
	large trees, > 30 m tall at maturity		1b(largepioneers)
		(e.g. *Terminalia superba*, *Milicia excelsa*, *Nauclea diderrichii*)	
Species not requiring open conditions for germination (non-pioneers)			
		(can germinate in forest shade)	
	seedlings intolerant of shade,		2 (heliophytes)
	for further development light is required		
		(e.g. *Piptadeniastrum africanum*, *Entandrophragma spp*., *Khaya spp*.)	
	seedlings tolerant of shade		
		large trees, height > 30 m	3 (large sciaphytes)
		(e.g. *Celtis mildbraedii*, *Strombosia glaucescens*, *Nesogordonia papaverifera*, *Guarea cedrata*)	
		small trees, height < 30 m	4 (small sciaphytes)
		(e.g. *Panda oleosa*, *Rothmannia hispida*)	
Swamp and riparian specialists			5
Epiphytes, stranglers, saprophytes			
Savanna and other non-forest species			

economic species are to be found in groups 2 and 3, and the few remaining are large pioneers.
Long term strategies, both for animal and plant species, may concentrate on the replication and distribution of individuals, such as the widely applied r- and K-strategy. Competition has made species adopt one of these two strategies. 'Competition' however should be scrutinized as a factor, as the term may confuse and include complex situations. For tree species, strategy and competition are not only determined by such an external abiotic factor as the light regime, but also by other factors. A classification for the strategies of plants, mainly in grasslands, was made by Grime (1983) and it also applies to tree species. Grime (1983) re-defines 'competition' as 'the tendency of neighbouring plants to utilize the same quantum of light, ion of a mineral nutrient, molecule of water or volume of space'. This definition for example excludes predation or fretting, and refers exclusively to the capture of resources.

Grime's (1983) supposition is that plant habitats are influenced by two external phenomena, viz. *stress* and *disturbance*, at different intensities (see Table 2.3). Stress is defined as the group of factors that restrict photosynthetic production and growth, such as shortages of water, mineral nutrients and sub-optimal or very high temperatures. Disturbance is associated with partial or total destruction of plant

mass. Depending on the intensities of disturbance and stress Grime distinguishes competitive, stress-tolerant and ruderal plant strategies. Most trees would seem to be grouped as competitors.
Going back to Table 2.2, about Ghanaian tree species, we may conclude that groups 3 and 4 belong to a group of stress-tolerators, groups 1a, 1b and 2 belong to the competitors and some trees of 1a to the ruderals.

Ruderals are becoming increasingly important in most West African forests as open forest canopies and forest fires occur nowadays. In Ghana it is known that logged forest burns more severely (Hawthorne 1990) and in the Côte d'Ivoire frequent forest fires have been experienced where refinement operations have been applied, e.g. in FC la Téné (Bertault 1992). It is the semi-deciduous forests which are most vulnerable. As Hawthorne (1990) correctly says ‘burnt forest is dominated by pioneer trees of little economic merit, and is more likely than unburnt forest to burn in the future’.

Table 2.3 Dominant effects determing plant strategies (Grime 1983).

	Intensity of stress	
Intensity of disturbance	Low	High
Low	Competitors	Stress-tolerators
High	Ruderals	No viable strategy

The disastrous fires which swept over West Africa in 1983 underline the gravity of the situation. Recent forest inventories in Ghana reveal that some 30% of the remaining forest in the semi-deciduous forest zone has been seriously altered in structure and composition. Silvicultural rehabilitation experiments were recommended for these vulnerable zones (Hawthorne 1990). In the Côte d'Ivoire Bertault (1992) found that, after fire damage in the young and open stands, a dominance of ruderals like *Solanum erianthum, Chromolaena odorata,* as well as Marantaceae and Zingiberaceae were blocking the regeneration of most tree species. This situation prevails in most forest reserves of the Côte d'Ivoire. Whatever progress in forest structure has been made by silvicultural treatments over many years can be swept away in a day. Forest fires are a danger not to be neglected.

A patchy forest structure with all phases of eco-units is also seen when shifting cultivation with long fallow periods (15-25 years) is practised. Such long fallow periods are rare in present West African circumstances with high population densities. Nevertheless, this way of using forest land for subsistence farming alternating with long fallow periods was once common practice all over the West African moist forests. It is now practised only in Liberia (see Fig. 2.5). West African moist forest has over ages if not millenia been influenced by human activity all over the region.

Some confusion about the terms `secondary forest' and `primary forest' appears in the popular press when problems facing the tropical forests are discussed. Clearing activities (for annual crops or for tree plantations) are sometimes confused up with disturbance caused by logging. Such confusion is fed by dramatic photographs of converted (cleared) forest lands slashed and burned, depicting a field of charred stumps and some forlorn human being.

Figure 2.5 Mosaic of forest eco-units at several stages after shifting cultivation between the Cess and Sehnkweku rivers, east Liberia. Photo H. Dop, 1987.

Probably the best definition of **secondary forest** is the one which says that secondary forest grows after the vegetation of the former forest has been almost totally destroyed. The forest remaining after partial timber exploitation or other restricted canopy-opening events should be named **residual forest**. Whatever **primary forest** should be is not clear as the term is based on an outdated concept in forest succession studies.

We have seen that disturbance is endemic to forests. Accepting that fact we might then make a distinction between 'natural' and 'unnatural' disturbance. But here again much confusion exists today about how 'nature' should be defined. Is mankind inside 'nature' or outside? Is everything man does unnatural? We cannot clear up these wide issues here.

In West Africa probably no forest exists that has never been disturbed either by natural events or by man. Limiting the term 'primary' to forests which had been disturbed more than a few centuries ago is quite subjective.

2.3 The role of the forest elephant in forest regeneration in West Africa

2.3.1 Introduction

To date, faunal research in the West African moist forests is only scant. The earliest faunal expeditions were undertaken by H.S. Pel, a Dutch biologist who made his collections between 1840-55 (Holthuis 1968). Today most of the large species have been described although, as late as the 1980s, two Canadian expeditions successfully tried to verify the existence of the Liberian mongoose (*Liberiictis kuhni*) first described as a new species from skulls as recent as 1958 (Taylor 1989, Goldman & Taylor 1990). West Africa has some rare endemic forest dwelling mammal species including the pygmy hippo (*Choeropsis liberiensis*), zebra duiker (*Cephalophus zebra*), Jentink's duiker (*Cephalophus jentinki*), Diana monkey (*Cercopithecus diana*), and the above mentioned Liberian mongoose (*Liberiictis kuhni*). Little ecological information exists either about these rare endemic species or about most other forest-dwelling mammals in general.

The forest elephant (*Loxodonta africana cyclotis*) is one of the few forest-dwelling West African mammals to have been studied in more detail. This mammal once roamed all over the African moist forests but the hunting of their tusks and the dramatic deforestation process has reduced their numbers in West Africa to a mere handful. Awareness about this tragic decimation has initiated a series of more in-depth research begun in the 1970s by French and German researchers in the Taï National Park in the south-west Côte d'Ivoire (Alexandre 1978, Merz 1981). This was followed by similar research conducted in Sierra Leone and, later, also in Ghana.

Knowledge about the forest elephant which lives in the Guineo-Congolian Region is very scant, whereas extensive knowledge exists about the savanna elephant (see Buss 1990). So far, research on the forest elephant *in situ* has concentrated on examining droppings to estimate population densities and to discover their diet (Alexandre 1978, Merz 1981, Short 1981, Short 1983, Merz 1986a, Merz 1986b, Lieberman *et al.* 1987, Prins & Reitsma 1989, Dickinson 1990, Dudley *et al.* 1992). Most papers point out that the forest elephant could play an essential role in the regeneration of certain tree species and thus the floristic composition. Lieberman *et al.* (1987) have begun to demonstrate this by undertaking germination trials on fresh and ingested seeds of eight tree species and a liana eaten by forest elephants.

Martin (1989b) estimated the total number of forest elephants in West Africa in 1987 at approximately 3,000 individuals. In contrast according to 1987 estimates, in Central Africa some 332,000 forest elephants are still to be found (IUCN 1987).

2.3.2 The impact of the forest elephant and its potential as a keystone species

Paine (1969) defined a keystone species as one which plays a key role in determining the presence or absence of many other species in a community (Paine 1969). African elephants play such a key role. The savanna elephant (*Loxodonta africana africana*) is a prime example of a keystone herbivore, since it is responsible for the repeated deforestation of savannas in combination with fire influencing the vegetational composition (see Bond 1993).

To a lesser extent this also applies to the forest elephant. Forest elephants keep the forest undergrowth open with their ‘bulldozing’ activities. Sachtler (1968) stated that the influence of forest elephants on the forest structure was enormous, particularly in the South-east Liberian forest block. In the Krahn-Bassa National Forest, various parts showed between 10 and 60% of their area damaged and, in Grebo National Forest, at least two thirds of the closed forest was found to have a structure clearly damaged by forest elephants (GFML 1967, Sachtler & Hamer 1967). Browsing, pathways and 'stations' -where small herds of 4 to 5 animals habitually congregate, i.e. near fruiting *Tieghemella heckelii* trees and wallow sites- all serve to keep the forest floor open.

Dependence on a favourable biotope created by other animals is nicely demonstrated by one of Africa's most threatened birds. The white-breasted guineafowl (*Agelastes meleagrides*) an Upper Guinea endemic seems to be confined to unlogged forest in the biostatic phase, where groups forage on the forest floor for animal and vegetable matter (Francis *et al.* 1992, Bechinger 1964). This bird species seems to favour the sandy slope soils where well-drained forest of all vertical strata occurs (Francis *et al*. 1992).

Branscombe (1990) adds that they favour a relatively open forest floor beneath upper strata of closed tree canopies which is hard to find nowadays. Such favourable open forest floor conditions are provided by the forest elephants' bulldozer activities. In denser undergrowth the much more abundant forest-dwelling crested guineafowl (*Guttera pucherani*) found all over Africa, takes over (Kingdon 1990). The white-breasted guineafowl is now confined to ever-diminishing unlogged or very recently logged reserves from Ghana to Sierra Leone (Allport *et al*. 1989, Branscombe 1990). Many of these reserves coincide, not without reason, with the present range of the forest elephant.

2.3.3 The elephant as dispersal agent

Forest elephants also seem to fit into the concept of 'keystone mutualists' as first described by Gilbert (1980). By this term Gilbert (1980) meant plants which for seed production and dispersal, depend on pollinators and dispersers, but the pollinators and dispersers themselves may also act as keystone mutualists. The question as to whether the forest elephant could be a keystone mutualist is then raised. Campbell (1991) compared the light regimes (photosynthetically-active radiation) on a forest elephant trail and a control transect in the same forest in Gabon. He concluded that forest elephants are gap-builders and, given the antiquity of some of their trails, they are gap-maintainers too. Campbell speculated as to whether this would have any effect on the variety of species.

Hawthorne & Parren (in prep.) have attempted to reveal empirically whether the forest elephant enhances the fitness of tree species by being a dispersal agent, as was postulated by Soulé (1987). Most climax tree species have large and heavy seeds that contain considerable food reserves, as opposed to the light seeds of most pioneer species. The distribution of seeds of many of those climax species depends upon herbivores, of which the forest elephant is the largest in the African lowland moist forest. Alexandre (1978) and Merz (1981) have demonstrated this for the Côte d'Ivoire and Short (1983) for Ghana. Table 2.4 gives an idea of the importance of the forest elephant as a dispersal agent when compared to various other agents.

During the dry season, from December to March, a peak in the fruiting of tree species desirable to forest elephants (Fig. 2.6) occurs in the moist forests of West Africa (Taylor 1960, de la Mensbruge 1966, Alexandre 1980). The regeneration of tree species in forests where the fruits are still eaten by forest elephants seems to be better than in areas where the forest elephant has disappeared long since. An explanation for this might be that the seeds of these fruits show some type of dormancy and have to be channelled through the stomach and its acids to be able to germinate. Lieberman *et al.* (1987) tested the germination rate of fresh and ingested seeds of certain tree species in Bia National Park, Ghana, and the results indicate a significant difference.

Table 2.4 Fruit dispersal in Taï National Park, Côte d'Ivoire. Total number of tree species dispersed by different agents along a 2000 meter transect. Based on Alexandre (1978).

Means of dispersal	Tree species dispersed	%
Elephants	18	26
Wind	14	20
Mechanical (explosives)	8	12
Birds	4	6
Primates	3	4
Elephants/primates	2	3
Birds/rodents	2	3
Buffalos	1	1
Bats	1	1
Elephants/birds/primates	1	1
Unknown	16	23
Total	70	100

Longman & Jeník (1987) point out that some tree species exhibit prompt germination, in which the radicle emerges within a few days or weeks after dispersal. Other seeds exhibit delayed germination since the seeds were formed in fruits that dried on ripening or because the pericarp of the dormant seeds has to be damaged by mechanical abrasion by mouth-parts or by acids in order to admit water. In this case the passage through the gut may reduce dormancy.

In both cases, dung piles are an ideal environment for germination and give the seedlings a chance to establish (see Fig. 2.7). The moist conditions of the dung piles will benefit germination as will the nutrients in the dung which are released to the seedling.

Elephants clearly carry seeds over many kilometres and in significant volume. The forest elephant eats up to 150 kg of plant material per day and, although much of this is from a wide variety of leaves, twigs and bark, a small proportion is of seeds. Martin (1989b) notes that seeds or bits of fruit occurred in 93% of elephant droppings in Bia National Park. Since elephant digestion is superficial, the material deposited daily by forest elephants amounts up to 135 kg of droppings per elephant (Wing & Buss 1970) on an average daily defecation of 17 to 18 droppings (Wing & Buss 1970, Merz 1986b). This contributes considerably to seed distribution. Forest elephants move an average of about half a kilometer per hour (Merz 1986c) and can wander over considerable distances.

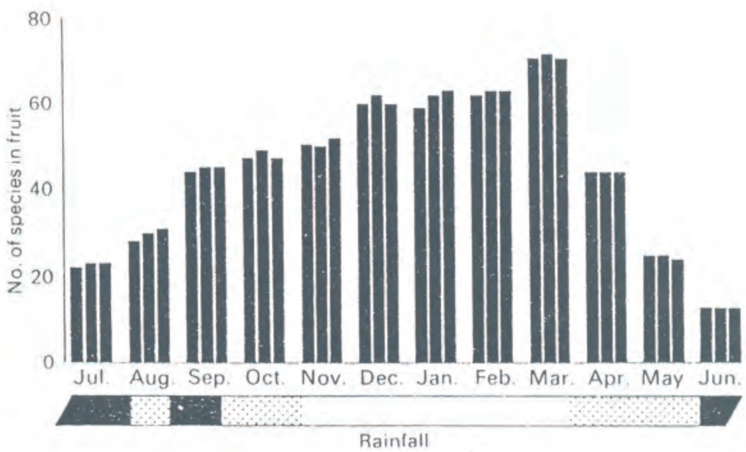

Figure 2.6 Fluctuation in fruiting levels in 158 tree species through the year in Ghana. Source Longman & Jeník (1987) based on Taylor (1960).

Figure 2.7 Elephant droppings, already partly decomposed, showing seeds of *Balanites wilsoniana* and other unidentified seedlings. FC Bossematié, Côte d'Ivoire. Photo M.P.E. Parren, 1992.

According to Terborgh (1990) large birds and/or mammals are often the only seed dispersers of mature trees of climax species. Even for those climax species that attract a wide range of potential dispersers, the larger dispersers are generally found to be more effective because:

- They tend to be more selective of large-seeded primary species
- They consume more fruit per feeding bout
- They tend to carry the seeds farther before regurgitating or defecating

The forest elephant is a non-selective or opportunistic frugivore, as termed by Snow (1971). McKey (1975) postulated that opportunistic frugivores were unreliable dispersers in contrast to specialised frugivores. Nowadays a strict coevolution between plants and their dispersers is being questioned as a more diffuse coevolution between groups of plants interacting with groups of animals is considered to be more likely. Even though forest elephants belong to a group of opportunistic frugivores, they are the largest ones in the African moist forests. The selection of tree species as presented by Hawthorne & Parren (in prep.) has been made on the criteria of whether the fruits are large, are scented and/or whether their seeds are hard. It could be that for some of them it is the forest elephant that is the only potential disperser.

The impact on floristic composition of the disappearance of the forest elephant is still unknown. Regeneration density in those areas where the forest elephant still lives is expected to be higher than in those areas where the forest elephant is no longer to be found. As early as 1934, Martineau expressed the fear that the disappearance of animals in the Banco NP, Côte d'Ivoire and surrounding forests would lead to a diminishing number of tree species. This idea was confirmed by de Koning (1983) only a couple of decades later. De Koning could no longer find certain woody species which Martineau had collected in the Banco forest and which specimens are now stored in the Paris herbarium. The last forest elephant would have disappeared from the Banco forest more than a century ago. Voorhoeve (1965) and Martin (1989b) suggest that, without forest elephants, there would be no makoré. Makoré is the vernacular and trade name of the large tree species *Tieghemella heckelii*, useful for its nuts and its timber.

The empirical data provided for the entire moist forest formation of Ghana by Hawthorne & Parren (in prep.) does however reveal that the number of tree species depending absolutely, or even almost exclusively, on forest elephants for regeneration may be as low as two, *Balanites wilsoniana* and *Panda oleosa*, and even these can regenerate occasionally in their absence. All other species, including *Tieghemella heckelii* are apparently able to germinate easily without passing through an elephant gut.

Forest elephants depend on certain fleshy fruits in a time of food scarcity. In Ghana and the east Côte d'Ivoire this period is from May to October. Plant species which are identified as providing the major sources of nutrition for the population through the period of scarcity are called ‘keystone plant species’ by Gilbert (1980). This certainly applies to *Tieghemella heckelii* which fruits during September - October, and in that period attracts forest elephants to gather around these trees to feed. Other tree species of which the fruits form a special attraction to the forest elephants are *Parinari excelsa*, *Balanites wilsoniana*, *Panda oleosa*, *Duboscia viridiflora* and *Sacoglottis gabonensis* (Sachtler 1968, Martin 1989b). To preserve viable forest elephant populations more attention should be paid to these tree species at management level, as is currently happening in Bossematié forest reserve (see Chapter 5).

2.3.4 Network areas

Zoologists and botanists alike have tried to calculate the minimum viable population of mature individuals to ensure the long term survival of the population. When a population falls below this level, local extinction due to various causes becomes more probable. So far it has not been possible to work out a reliable prediction of the size of such a minimum viable population, although Erich (1989) is convinced that a predictive value can be reached in future when more thorough empirical data will be available. Exchange of genetic material between subpopulations is important, but the large scale deforestation process in the region, leaving only scattered forest remnants, prevents such exchange at the moment.

Eisenberg & Harris (1989) argue that large herbivores and carnivores with high space requirements are the most valuable elements of an ecosystem, and Prins & Reitsma (1989) showed that forest elephants make up the bulk of the mammalian biomass (52% of the herbivores) in the moist forests of Gabon. The estimated total of 3,000 individuals for the entire forest elephant population of West Africa (Martin 1989b) implies that cooperation and management plans should go beyond the strict national level. The *in situ* conservation of separated elephant populations should be assisted by linking the territories by forest corridors (see also Primack 1993: chapters 14 and 15).

Shafer (1990) points out that such a network area would conserve the most valuable elements, perhaps some keystone species *and* also conserve many or most of the smaller organisms in the ecosystem. This networking idea also follows Ashton's (1981) statement that first priority must be given to the conservation of sites rather than of individual species. On the other hand the discussion about reserve design and whether the survival of the West African forest elephant requires a single large reserve or several small reserves is now behind us (for an overview see Shafer 1990). Forest elephant populations are scattered over highly fractionized forests. These are almost entirely confined to the permanent forest estate since the unreserved forests have been largely converted to other land uses. The only place for such a discussion might be in the extensive forests (reserved and unreserved alike) of eastern Liberia. An example of this networking will be given for the so-called ‘Transboundary Bia-Bossematié network area’.

2.3.5 The Transboundary Bia-Bossematié network area

Forest elephants once roamed over the entire closed forest zone of Ghana[5] and the east Côte d'Ivoire but they are now restricted to some six areas (see Fig. 2.8). Martin (1982) estimated the Bia population at 200 individuals and, according to the densities given by Dickinson (1990), the Goaso population should be of the same order of magnitude, whilst the Kakum population is estimated by Dudley *et al.* (1992) at 100-150 individuals. No density information is available concerning the Ankasa population, as this population retreats into extensive swampy areas of the 513 km² reserve, but their numbers may well equal the Kakum population. Waitkuwait (pers. comm.) estimated the Beki-Bossematié population at 20-50 individuals and Merz & Hoppe-Dominik (1991) estimated the Bettié population at about 150 individuals.

The total forest elephant population in the Transboundary Bia-Bossematié network area here proposed could therefore be estimated to number 800-1000 individuals at the present day. Poaching and culling operations (at present suspended) threaten the total population (see Appendices VIII and IX).

From the above it has become clear that we have to deal with a metapopulation scattered over several reserves. Individual population areas will have to be linked by corridors since the minimum reserve size necessary to achieve a reasonably long persistence time is extremely large on demographic grounds alone. Belovsky (1987) states that, for larger mammals (> 50 kg) to persist in evolutionary time (10^5-10^6 years), regions of one million to one billion square km are required, assuming that major climatic variations do not occur. Such extensive single large reserves are no longer possible. Several interlinked greater reserve areas are preferable, to a single large reserve, provided that there is at least a low rate of natural or managed recolonization of reserves which have experienced local extinction (Goodman 1987, for discussion see also Shafer 1990). This is precisely the objective of the proposed Transboundary Bia-Bossematié network area (see also Table 2.5).

[5] Cansdale (1943) noted that several small forest elephant herds were to be found in the central and western regions of the closed forest zone of Ghana and states '.. in the latter [region] they have considerable freedom of movement, but in the former [region] they are in a small forest area well surrounded by cultivation.' At the present time it is only the Kakum population which has survived in the central region.

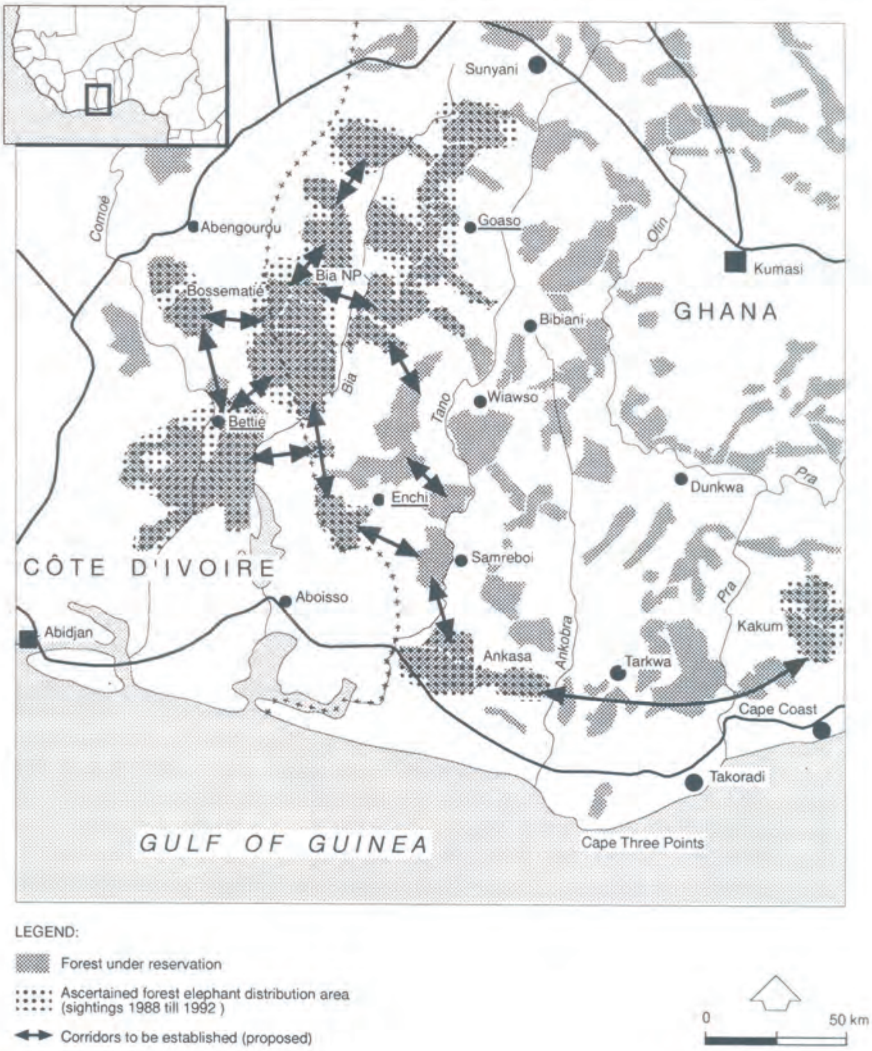

Figure 2.8 Proposed Transboundary Bia-Bossematié network area composed of existing forest reserves, national parks, game production reserves and corridors yet to be established. Locations of forest elephant populations are indicated as dotted areas.

Table 2.5 Proposed Transboundary Bia-Bossematié network area

Conservation network	Reserve area	Approx. network area	Factor of increase
Trans Bia South	100,720 ha	200,000 ha	1.9
Trans Bia North	66,060 ha	102,000 ha	1.5
Goaso	208,940 ha	540,000 ha	2.6
Enchi	155,940 ha	283,000 ha	1.8
Bossematié	70,750 ha	200,000 ha	2.8
Bettié	135,300 ha	307,000 ha	2.3
Bia-Bossematié	737,710 ha	1,632,000 ha	2.2

The detailed network information is found assembled in Appendix X. The approximate network area has been found by taking some two to four points at the outmost edges for each congruent group of reserves belonging to a forest elephant population area. These points delineate a circle or rectangular form for each distinctive forest elephant population area. These areas calculated form the theoretical potential ranges of each distinct population. By linking these potential ranges by means of corridors the total network area will increase proportionally in comparison to the total of the originally reserved areas. Accordingly a value of increase can be calculated which is a theoretical value for enlarged forest elephant living range and thus conservation.

The Trans Bia South transitional axis should form the core of the Transboundary Bia-Bossematié network area. The following measures concerning the Transboundary Bia-Bossematié network area are recommended:

1. **Securing the legal forest reserve status** of the above mentioned reserves (i.e. Bia Tawya FR, Dadiaso FR and Sukusuku FR are known to be unoffical, but to have a proposed status).
2. **Total ban on the logging** of *Tieghemella heckelii*, *Parinari excelsa*, *Balanites wilsoniana*, *Panda oleosa* and *Klainedoxa gabonensis* should be considered.
3. **Prohibition of farming** activities within existing forest reserves except for legally admitted farms within the reserve boundaries.
4. **Respecting several non-logging core zones** within forest reserves of at least 2,000 ha each to favour fruiting trees and rare tree species and which will constitute essential fauna niches.
5. **Silviculture with natural regeneration should be applied** in timber production areas. This will ensure favourable foraging grounds in the residual forest for forest elephants by functioning as bufferzones surrounding strict conservation areas.
6. **Establishment of corridors** which will form passages for wildlife, essential in the natural regeneration process.

Each subpopulation must be managed so as to benefit the entire population, since it is the entire population which is at risk. Forest elephant populations are scattered over several reserves. At the Ghanaian site the reserves concerned fall under the jurisdiction of the Forestry Department and the Department of Game & Wildlife, while on the Ivorian site they fall under the jurisdiction of SODEFOR. Cooperation across national boundaries has to come about.

The separated conservation areas should be linked by *corridors* with a minimal width of approximately 2½ km, preferably established along stream- and river-banks. Dickinson (1990) mentions that, during 1988-1989 in the western part of the Aboniyere Shelterbelt, occasional sightings of forest elephants were recorded and, in the Bia Shelterbelt, which links Mpameso FR with Bia Tano FR, there were regular sightings. Both shelterbelts are only 2½ km wide, while the latter shelterbelt is even crossed by a road. Forest elephants clearly use such corridors.

A one hundred meter wide protection zone along **all** streams and rivers within the Transnational Bia-Bossematié network area should also be striven for, as these watershed management measures will, next to the prevention of erosion, provide the sorely needed interlinking corridors and niches for all kinds of fauna.

A full map and listing of all forests under reservation in western Ghana and the eastern Côte d'Ivoire is found in Appendix XI.

3. FOREST EXPLOITATION

In the eyes of many in northern countries, forest exploitation in southern -less developed- countries is the equivalent of plunder. There is much to be said for this view as far as the history of forest exploitation in West Africa is concerned. But did it happen out of necessity? Why did exploitation evolve into plunder?

On the one hand colonial rulers attempted to control the exploitation of valuable raw materials, but on the other hand they introduced social and economic developments that frequently undermined their own controls. Northern countries have to accept that their economic thinking - since the beginning of their industrial development - was accompanied by the conviction that raw materials could be taken at will if they were available at competitive prices.

Of course this was so in the context of mining ores, coal and oil, but the borderline with harvesting from ecosystems was vague, and -worse- could not be well argued. The prices for energy and raw materials were largely set by mining enterprises, while other commodities, such as fuel wood and timber, which were largely replaceable, had to follow these principles. This is still true today: sustained management of many living renewable systems is under threat. Rich countries are privileged as they are able to protect their systems, whereas poor countries are vulnerable.

The colonial powers, keen on conservation, established permanent forest estates in West Africa, as a result of their recognition of the destruction wrought in their own forests in medieval and more recent times. These controls were operated in various ways in the countries studied here. The system of concessions applied to the forest certainly did not help to steer developments in the direction of sustained management and even managed to detach the local population from the forests they had originally made use of. The Forest Service, often powerful as far as the ordinary man was concerned, was powerless against the big men going after the timber hoard, was unable to prevent the drama and was finally forced to play the role of Cassandra[6].

[6] Cassandra, a Trojan princess, rejected the love of the Greek deity Apollo, who, as a punishment gave her the gift of clairvoyance. The sting in this gift, however, was the total disbelief of her audience. She died in captivity after the fall of Troy.

3.1 Concession rights and consequences

3.1.1 Period without Forest Service

With timber extraction by Europeans expanding rapidly since the late 19th century an urgent need arose to regulate these indiscriminate activities. In his book *Sketch of the Forestry of West Africa* (1887) A. Moloney, Governor of Lagos says : ‘It can be stated without fear that in our possessions on the coast of Africa the timber is rapidly and visibly diminishing, and that ... re-planting and preventing waste, has become worthy of early consideration.’ In those early days forest exploitation resembled an operation similar to salvage felling. The initial forest exploitation took place in unreserved forest lands outside reserves.

The colonial administration of both Ghana and the Côte d'Ivoire attempted to regulate forest exploitation by handing out concession rights and by implementing regulations to avoid the destruction of this renewable resource. In Ghana the first regulations were laid down in the Concessions Ordinance of 1900 followed by the Timber Protection Ordinance of 1907 to prohibit the felling of immature trees of certain tree species (Troup 1940). The Côte d'Ivoire saw an Ordinance in 1900 that regulated the forest exploitation of units of over 400 ha and the imposition of a planting obligation for every tree felled. This Ordinance also arranged for protection forest in steep terrain (Ibo 1993).

What were the reasons behind these protective measures? They were mainly driven by the guidelines received from the colonial mother country that the colonies should be self-supporting financially. In the Côte d'Ivoire financial autonomy was imposed by a Law dated 13th April 1900. One of the outcomes was that the richess of the forest resource had to be evaluated and optimized, while, at the same time, destructive methods of exploitation had to be brought under control. Accordingly the Forest Ordinance was proclaimed on the 20th July 1900. Around the same time similar measures were taken in Ghana as we have seen before.

However, no specific control instrument or forest service existed at that time as the forest services were not created before 1909 in Ghana, 1912 in the Côte d'Ivoire and as late as 1953 in Liberia.

3.1.2 Period since the creation of a Forest Service

The control of concessionaires by foresters has always been a problem since other, often more powerful, political interest groups intervened on behalf of the concessionaires. Concession rights were handed out to private interests both national and international. The handing out of these rights most often fell within the responsibility of departments other than the forest service. Many differences concerning concession rights can be observed between the three countries.

Until 1972 in Ghana, concessions were granted for compartments of 130 ha (0.5 square mile) valid for a period of 50 years and, exceptionally, for as long as 99 years. Since 1972 the duration of concessions has been set at a minimum of 5 years and a maximum of 25 years for areas exceeding 800 ha and up to 3 years for smaller areas.

Liberia, unlike its neighbours, had no forest administration nor any regulations for the felling of trees until the 1950s (Cooper & Record 1931, Forestry Development Authority 1981), but hardly any commercial forestry activities existed at that time. The 1957 Supplemental Forest Act provided the first detailed regulations on concession grants. Concessions were granted for compartments of 4,050 ha for 40 years, with the option of an extension for another 20 years. The first concessions were handed out in 1957 and, until 1959, they did not exceed 41,000 ha, but thereafter single concession areas of 180,000 ha and more became common (McLaughlin 1966). The national forest inventory of the 1960s and the extensive road development in the formerly inaccessible eastern region of the country where the largest forest areas are to be found, accelerated this trend. Concessions obtained since 1973 are for 25 years.

Until 1912 the authorities in the Côte d'Ivoire chose to grant chantiers (compartments) of 2500 ha for just one year. With the new Forest Ordinance of 1912 they tried to favour concessionaires willing to penetrate deeper into the interior away from the over-exploited zones along the existing transport network. These concessionaires, who had higher costs, were to be favoured and, accordingly, their concessionary rights could last up to 5 years subject to renewal.

The short timespan of the concessions was counter-productive and provoked corruption to obtain permits. The compartments were exploited in a way similar to salvage felling even though minimum diameter limits were imposed. A lower limit of just 35 cm drh for some tree species (as introduced in 1920) did much to promote these practices. Permitting re-entering of compartments after too short an interval also stimulated depletion (see Table 3.1; logged-over forests). Responsible management of the forest in the Côte d'Ivoire by the concessionaire could not be stimulated because of a lack of effective controls. These regulations remained in force until 1965 with some amendments being made in 1935 to regulate differentiated exploitation licenses.

After 1965, large concession areas and longer contract terms were granted to firms in the Côte d'Ivoire who were willing to start processing. But the damage had already been done. Foreign investors continued to export the most desirable timber species as logs. The Ivorian government then limited the export of these species and linked new concession terms to the degree of industrialization. This step also failed, as the transnational corporations merely regarded the required investments as being a relatively small added cost of roundwood exports. All operating rights were negotiable, resulting in the subcontracting of concessions and export quotas (Repetto 1988). Regeneration by the concessionaire of the depleted forest stand was never effected.

It is encouraging to see that, since the early 1990s, a gradual shift away from the old policy can be discerned, a shift induced by the programme launched under FAO's Tropical Forestry Action Plan. The effects have been especially visible since the handing over of all forest reserves to SODEFOR at the beginning of 1992.

3.1.3 Appraisal

Concession rights covering a lengthy timespan may be considered to stimulate responsible management aimed at sustained yields. Effective control by an independent agency, however, seems to be essential as conflicts of interest exist. A good forester aims at a stable and an ecologically sound forest, and financial returns should never dominate his decision making. Concessionaires mostly have quite different objectives, as the conservative timber market and short term financial interests are often the most pressing for the concessionaires, whose circumstances may easily lead to the creaming of the forests. Such creaming can best be defined as: `take the best and leave the rest'. The forest service often possesses no means to impose strict conditions on the allowed yield to be taken by the concessionaire.

The policy of sustained yield in West Africa has, until the present, been controlled through the primitive instrument of minimum diameter limits. Until recently the concessionaire had a virtually free hand to take his pick in the Côte d'Ivoire, while in Ghana the forest service determines the yield but the concessionaire actually only fells approximately 30% of the allowed yield, to fulfil his orders for a limited number of species. Re-entering of compartments in the course of some years when new orders where available was common. The foresters oppose these practices which contradict the concept of sustainability, but the strong lobby of the concessionaires has so far prevented sanctions being taken. At the present time Ghana is in the process of halting these practices.

Before forest management can be made to work, successful silvicultural systems have to be developed to form the core of such a management system. Silvicultural systems cannot be easily copied from existing systems in other regions but rather have to be built from examples, adapted and further developed to fit the regional ecological and socio-economic conditions. Concessionaires cannot usually be expected to be really interested in such research work, so the forest service has to struggle to find such systems for themselves. Financially speaking such government institutions were bound hand and foot. The central government would not give them the financial means to effectively control the operations of the concessionaires nor the funds to do the silvicultural and management research needed to gain information on how to manage the forests on a sustained basis.

3.2 Permanent forest estate

3.2.1 General

Establishing a permanent forest estate for protection purposes and to ensure future timber production is a fundamental forest policy issue. Our present apprehension of the pre-World War II management of forest reserves by colonial governments can be described as one of conservation. The main aim was to protect water supplies, to prevent erosion and to ensure the maintenance of the climatic conditions in favour of agricultural production (see Unwin 1920). Forest reserves were considered to provide indirect benefits. This is also reflected by the title of the head of the forest service who is called *Chief Conservator of Forests* in Ghana, and *Conservateur* in the Côte d'Ivoire. The task of the forest service changed in the Côte d'Ivoire in 1938 to a mere controlling function described in French as *Inspection Générale des Eaux et Forêts et Chasse*.

In Ghana, reservation was established in close cooperation with the chieftaincy as described in Chapter I. The reservation in the Côte d'Ivoire and Liberia was declared by ordinance. In the near future the permanent forest estate will be all of the forest that is left (Fig. 3.1), as all unreserved forest lands risk being converted to other land uses (see also Table 3.1). The opening up of these forest reserves with the object of managing them for timber production on a sustained yield basis in order to provide direct benefits is the official policy applied on a large scale since the end of World War II in both the Côte d'Ivoire and Ghana.

3.2.2 Forest reservation in Ghana

The people resisted the local government's forest reservation policy at the turn of the century (see Chapter I). By 1923 only some 26,000 ha had been reserved, since the gazetting of the Forest Ordinance of 1910. The reservation aimed at 1.5 million ha of forest reserves for the moist forest zone. The 1935 revised Forest Ordinance encouraged a more rapid reservation of forests and in 1939 the goal had been achieved. At present the total forest reserve area covers 1.7 million ha or 20.4% of the total land area of the moist forest zone (see Fig. 3.1).

As for forest reservation, in theory the Forest Service itself acted as advisor to the chieftaincy, being the owners of the land. In practice the Forest Service carried out all maintenance work at government expense, while the forest revenue went to the chieftaincy. Until World War II the Forest Service concentrated on the programme of reservation rather than on silviculture, as opposed to what happened in the Côte d'Ivoire.

Table 3.1 Total moist forest area estimates (in 10^6 ha) and status. Figures for Ghana based on Ghartey (1990); for the Côte d'Ivoire on FAO (1988) and Ministère des Eaux et Forêts (1988); for Liberia on Hammermaster (1985), Hasselmann (1986), WCMC (1991).

Status	Ghana	Côte d'Ivoire	Liberia
production	1.4	1.0	1.5
protection*	0.4	0.6	0.1
Total reserved	1.8	1.6	1.6
% of original area	22 %	11 %	22 %
Total unreserved forest	0.3	1.0	2.5
Grand total	2.1	2.6	4.1
of which logged-over forest**	1.0	2.0	0.1

* Forests under a protection working circle and all forest areas proclaimed national park, flora and fauna reserves.
** Logged-over twice or more times during the last 60 to 80 years.

Changes in property rights affected the rate of deforestation. Usufruct rights over forest resources were originally those of customary law. In the early 1970s, as a result of political conflict, all rights over their ancestral lands were stripped from the traditional communities and assumed by central government (Repetto 1988). The outcome was that traditional communities lost the incentive to maintain the forest resource and an ever-increasing deforestation of unreserved forest lands took place (see Table 3.1: total unreserved forest). A similar process could be seen in the Côte d'Ivoire.

3.2.3 Forest reservation in the Côte d'Ivoire

The need for forest reservation was first discussed in 1913 but the lack of personnel and the means to exert controls, postponed reservation until 1926. Initially the government aimed at establishing a permanent forest estate of 20 to 25% of the total land area, about 6 to 8 million ha. In Europe at that time a forest cover of 30% was considered the minimum for reaching a harmonious equilibrium (Chevalier & Normand 1946). The Côte d'Ivoire was the first French colony to establish forest reserves when, in 1926, the Réserve de Faune du Haute-Sassandra was proclaimed. In 1929 some twenty forest reserves (of which five were botanical and tourism reserves) covering almost 100,000 ha were created (Chevalier 1930).

The French 'Forêt Classée' has been used in a wider context than the English 'Forest Reserve'. 'Forêts Classées' (after 1978 called 'Domaine Forestier Permanent') were meant for production, but they also included national parks and fauna reserves until the late 1960s.

As we saw before, the reservation aimed at 6 to 8 million ha of forest reserves for the entire Côte d'Ivoire. In 1937/38 some 1.5 million ha were 'réserves forestières de protection' from which timber exploitation was excluded. Concession rights granted in productive forests covered 2.7 million ha of which 400,000 ha were being exploited at the time. With an annual harvest of 113,000 m^3 this implies a very low production level of 0.3 m^3/ha (Chevalier & Normand 1946, Schnell 1950). By 1951 some 2.7 million ha or 8.4% of the total land area had been reserved (d'Aviau de Piolant 1952).

By 1956 this had risen to 6.8 million ha of which 4.3 million ha were in the moist forest zone but it dwindled down again later to 2.9 million ha of which 1.6 million ha were in the moist forest zone (1987 figures).

The difference between the peak figure of 6.8 million ha and the present 2.9 million ha may be caused by a difference in status. The 2.9 million ha have always belonged to the ‘domaine forestier classé’ and the remainder to the ‘domaine forestier protégé’. The latter includes all forests ‘vacantes et sans maître’ the transitory domain as d'Aviau de Piolant (1952) calls it. A complete conversion of the ‘domaine forestier protégé’ to agricultural purposes has occurred, with the effect that this category of forest lands no longer exists. Even some of the reserves once belonging to ‘the domaine forestier classé’ are now declassified, mainly because of occupation by farmers. The changes in the extent of the permanent forest estate can be mainly attributed to a process of initially partial and later complete declassification of forest reserves started as early as 1946 as Ibo (1993) informs us. This was not compensated by the enlarging of some reserves nor by the creation of new ones since 1946.

This process was seen on a much smaller scale in Liberia and, since 1992, also in Ghana where forest reserves were partly declassified in favour of open cast mining activities.

The goal of 20% permanent forest in the moist forest zone has not yet been reached in the Côte d'Ivoire. So far 1.6 million ha or 11% has been designated as forest reserves and, in order to reach the 20% target, a further 1.2 million ha should be reserved. The latest figures available indicate that there are still 1 million ha of unreserved forest available for this purpose. Although highly depleted of timber these forests should receive official protected status within a short time. Compared with Liberia and Ghana, the Côte d'Ivoire falls short in effective forest reservation (see also Table 3.1).

3.2.4 Forest reservation in Liberia

A programme to reserve 1.2 to 1.6 million ha of closed-canopy forest as a permanent forest estate was proposed in 1951 as a means of assuring a continuous supply of timber products (Holsoe 1961). The delineation of national forest reserves began in 1953 at the same time as the approval of the first Forest Act.

The term Forest Reserve used in the two Forest Acts had, in Liberia, been replaced by the term National Forest by 1960. This is because, in the U.S.A., a forest reserve is generally considered to be an area in custodial status. In 1906 a policy of use rather than protection only was adopted in the U.S.A., and the term ‘reserve’ was changed to ‘national forest’. So the Liberian term ‘National Forest’ and the Ghanaian term ‘Forest Reserve’ have more or less similar status.

The 1960 forest land use policy paper of the Bureau of Forest Conservation excluded the utilization of the National Forests until forest inventory and management plans were made. Between 1954 and 1961 some 1.4 million ha had been reserved in Liberia, which is 20% of the original moist forest zone area. Later some National Forests were given up because of poor timber stock and for reasons of mining activities, but new ones were proclaimed and, at present, there still remain some 1.5 million ha of National Forests (WCMC 1991, Hammermaster 1985). The National Forests are confined to the north-west and south-east of Liberia, while the central part is mainly agricultural land (see Fig. 3.1).

3.2.5 Demarcation

The demarcation of the permanent forest estate is implemented in quite different forms and its effectiveness is rather doubtful. Most forest reserves in Ghana have not or only slightly, been encroached upon by farmers, while in the Côte d'Ivoire encroachment is in a far stage now and in Liberia it is of growing concern. In Ghana only a narrow boundary line is needed to convince farmers not to cross the line (see Fig. 3.2A). Every month this line is cut open by a forest guard. The forest reserve was created in cooperation with the chieftaincy so few will try to revoke it. In the Côte d'Ivoire it is only recently that clear boundary lines have become operational (see Fig. 3.2B). The line is made with a bulldozer and is followed by the planting of rows of trees, usually teak, *Tectona grandis*. In Liberia hardly any effective controls exist but, fortunately, population pressure is very low, although encroachment does exist. A notice board alongside the road entering the forest warns people that they are entering a forest reserve.

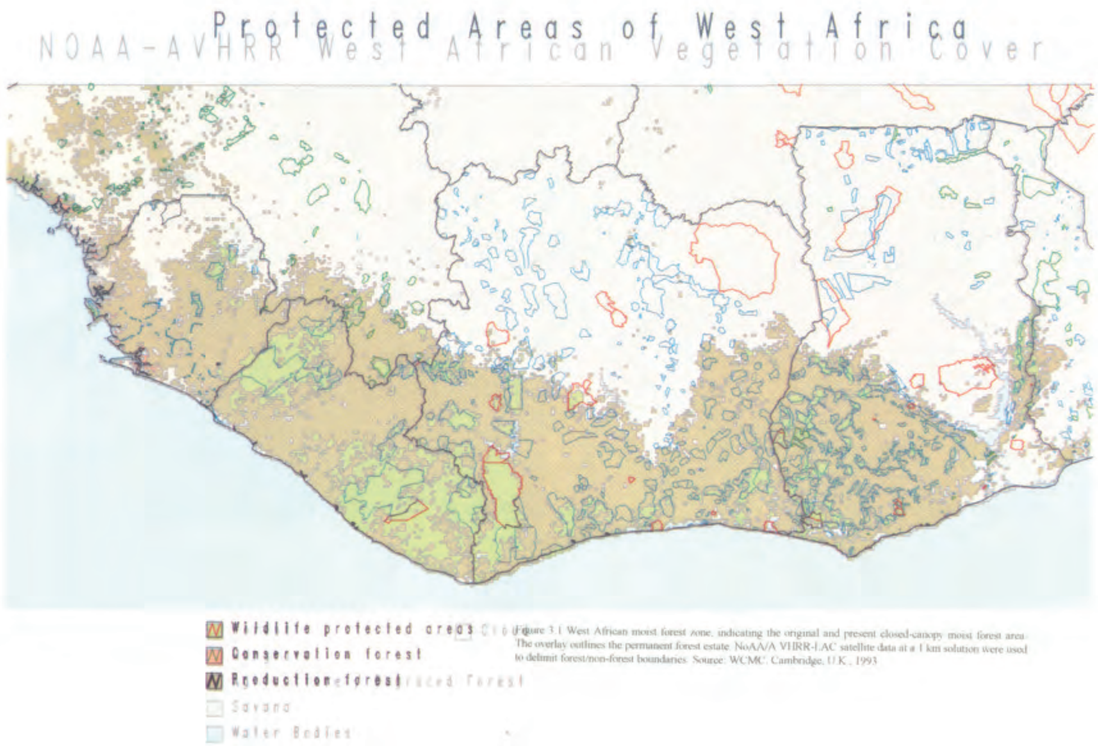

Figure 3.1 West African moist forest zone, indicating the original and present closed-canopy moist forest area. The overlay outlines the permanent forest estate. NoAA/A VHRR-LAC satellite data at a 1 km solution were used to delimit forest/non-forest boundaries. Source: WCMC, Cambridge, U.K., 1993

NOAA-AVHRR West African Vegetation Cover

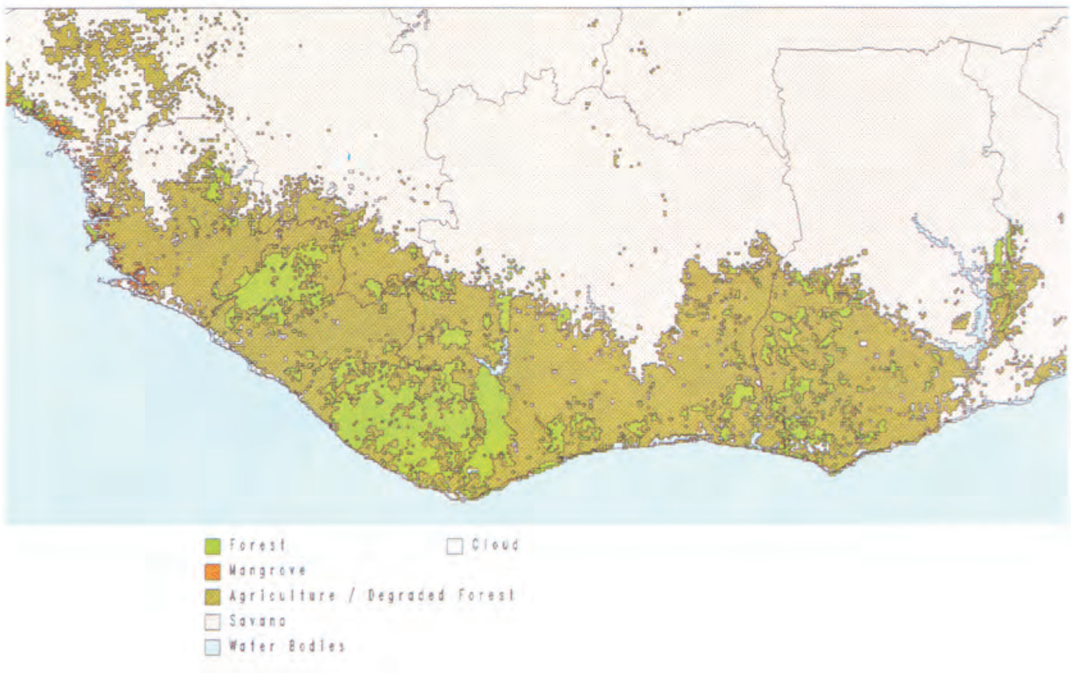

Figure 3.2 A,B. Various boundary line types.
A: Narrow boundary line around Bura Forest Reserve in Ghana. Photo M.P.E. Parren, 1990.
B: Very wide, bulldozed boundary line around the Haut-Sassandra Forêt Classée in the Côte d'Ivoire. Photo M.P.E. Parren, 1992.

3.3 Steps in natural forest management

3.3.1 Forest inventory

Introduction. To assess the production potential of forest areas and to promote rational utilization, basic information on the composition of tree species and the diameter structure is required. Traditionally forest inventories were also considered to be a tool for finding out whether it was economically profitable to start commercial activities.

Most forest inventories could be characterized as being static, giving a momentary picture of the state of the forests. The latest West African inventories are essentially different since they aim to reveal the forest dynamics by establishing permanent sample plots, which give a more accurate picture of the production potential and possibly enable the prediction of the allowable yield. Most forest inventories concentrated their attention on commercial tree species often supplemented by a list of future potential ones, commercial tree species often being defined as a small group of highly valuable timber species accepted by the conservative timber market.

Until World War II, forest inventories were conducted only by the concessionaire and most were confined to relatively small concession areas in the three countries we are considering. After the war the forest services found it important to assess the state of affairs of their forest on a regional or national scale. This enabled them to direct future operations in almost untouched forest areas which were designated to be opened up to develop those 'backward' areas for the benefit of the national treasury. The natural resources available but with unknown potential so far, were to be assessed, often implying the first step towards a kind of land use planning. These inventories were all conducted with the assistance of teams of expatriate specialists (DRC 1965, 1967). The inventories often made a distinction between assessments within reserved and unreserved forests, the latter often being designated for conversion under salvage felling licenses. Salvage fellings are meant to recover all marketable timber before it is lost. The inventories enabled the forest service to predict harvesting levels for the coming years, if not decades, to forecast the revenue falling to the government.

3.3.2 Forest inventories in Ghana

Some 700 permanent sample plots were laid down in Ghana during the 1960s and 1970s. These were 5x5 chain square plots, totalling 1 ha [2.5 acre] (Alder & Synnott 1992). Valuable information on the condition and composition of about 1.4 million ha state managed production forest was obtained by this national inventory.

In 1970 gross standing volume of trees ≥ 70 cm drh of class I, II and III (together 48 tree species, see Appendix II) in forest reserves was estimated at 115 million m^3 of which 43 million m^3 in trees larger than 110 cm drh. This implies an economic stock averaging 82 m^3 per hectare. See Table 3.2 for the most abundant species.

Table 3.2 Most abundant species by gross standing volume and percentage (trees ³ 70 cm drh) in Ghana (1970). Source Borota (1991).

Species	Family	10^6 m^3	%
Triplochiton scleroxylon	Sterculiaceae	20.2	17.6
Piptadeniastrum africanum	Mimosaceae	14.8	12.9
Antiaris toxicaria	Moraceae	14.6	12.6
Nesogordonia papaverifera	Sterculiaceae	6.8	5.9
Mansonia altissima	Sterculiaceae	4.4	3.8
Turraeanthus africanus	Meliaceae	4.2	3.6
Lophira alata	Ochnaceae	3.0	2.6
Entandrophragma cylindricum	Meliaceae	2.9	2.5
Khaya spp.	Meliaceae	2.8	2.4
Milicia excelsa	Moraceae	2.7	2.3
Guarea spp.	Meliaceae	2.7	2.3
Entandrophragma utile	Meliaceae	1.8	1.6
Pericopsis elata	Papilionaceae	1.7	1.5
Entandrophragma candollei	Meliaceae	1.6	1.4
Entandrophragma angolense	Meliaceae	1.3	1.1

In the late 1960s, the (Ghana) Selection System then applied, with felling cycles of 25 years, was assessed. The felling cycle of 25 years was regarded as rather too lengthy by both concessionaires and the timber industry as, according to them, it led to over-maturity and the reduction of timber quality. However, the preponderance of over-mature trees in the allowable yields was because most reserves were being exploited for the first time (Ghartey 1990). Over-mature trees are senescent trees or Oldeman's (1990) 'trees of the past'. Accordingly, the felling cycle of 25 years was abandoned by Ghana to enforce salvage felling of all over-mature trees in a reduced felling cycle of 15 years in all productive forest reserves. This was done in an attempt to remove all over-mature trees, since it was felt that there remained an overstock which could be harvested without cost from the forest reserves.

The idea of an excess stock of over-mature trees is confirmed by the national inventory data presented above in which 43 million m^3 or 34% of the total growing commercial stock consisted of trees of over 105 cm drh. Reliable data on ecological and silvicultural processes was not available, but the forest service was searching to find and subsequently introduce a new system within the next 15 years. As Brookman-Amissah (1985) remarked, over-mature trees among the less popular species tended to remain unexploited and, in effect, a more severe creaming of the forest was one of the consequences.

In 1980, with the assistance of the FAO and later of the ODA a national forest inventory in Ghana was begun (François 1989). This inventory will be mentioned in more detail in Chapter V which discusses future developments.

3.3.3 Forest inventories in the Côte d'Ivoire

The first national forest inventory took place in 1966. It was mainly conducted by the CTFT (Centre Technique Forestier Tropical), while the last remaining vast forest areas in the south-west Côte d'Ivoire (see Fig. 1.2) were inventorised by an American team (DRC 1967). Two supplementary CTFT inventories took place in this region; one in 1970 of the Taï forest (SODEFOR 1971) and one in 1973 in which 225,000 ha were inventorised near San Pedro in order to investigate its potential for supplying a projected pulp and paper factory (Clément 1973). This project never has been realised. Actualisation of the 1966 inventory took place between 1974-1976 by SODEFOR. All these inventories were conducted at a sampling intensity of 0.5 to 1%.

It was not until 1990 that the Côte d'Ivoire started a new national inventory of all forest reserves at an intensity of 1.5% for all trees > 20 cm drh. The overexploitation that had taken place in previous decades had made such a move necessary. This inventory was to allow for the more precise management planning of forest reserves. The reserves, which had mostly been overexploited showed zones that will have to be restocked by planting, while other reserves will be allocated for natural regeneration techniques to be applied according to stock levels.

3.3.4 Forest inventories in Liberia

As early as 1928-29 a Yale University (USA) delegation made a forest inventory of the 160,000 ha concession area of the Firestone Plantations Co. The commercial stock might have been expected to be poor since this is a forest of the per-humid forest formation. Sampling of 52 0.2-ha (half acre) plots in three strips was undertaken, recording all trees over 5 cm drh. The delegation concluded that, although African mahogany was scarce, other commercial species were present in sufficient quantity to make the forest important and valuable. This statement was doubtful since only some 10% of all measured trees belonged to a group which at present is considered to be commercial (see Table 3.3). It is surprising that Cooper & Record (1931) qualify *Sacoglottis gabonensis* as mahogany and not a single Meliaceae species. (In the Côte d'Ivoire and Ghana, the name mahogany referred only to *Khaya* and *Entandrophragma spp.* at the time.)

This inventory did not encourage forestry activities by foreign interest groups in Liberia. Only in 1944 did the Liberian government request the assistance of U.S. expertise in surveying their natural resources and in advising and assisting them in the development of these resources.

Aerial photographs were taken in the dry season of 1945-46 over Liberia and examined by stereometry. Early 1947 field trips were made to forests in the Côte d'Ivoire and Ghana as a background for future operations in Liberia. This practice had hardly any follow-up in the region in the next decades. From 1947 to 1949 a general ground survey of forests was carried out in Liberia (Mayer 1951), in which a very superficial line sampling of 20 m wide strips totalling almost 8,000 km of line was conducted. On each km line a sample of 2 ha was taken. More detailed volume sampling took place in a sample of 16.8 ha, with subsample plots of 0.4 ha, and it should be noted that tree identification had no priority because of a lack of time and because of the nature of the inventory. The forest resource potential had been assessed and recommendations for a forest reservation programme made.

Table 3.3 Total number of trees presently (since 1976) accepted as commercial species (trees ³ 5 cm drh) in a sample area totalling 10.5 ha in the Firestone Plantations Co., concession area at Du river, Liberia. Modified after Cooper & Record (1931).

Species	Family	N
Mammea africana	Guttiferae	163
Lophira alata	Ochnaceae	50
Sacoglottis gabonensis	Humiriaceae	50
Symphonia globulifera	Guttiferae	28
Nauclea diderrichii	Rubiaceae	14
Heritiera utilis	Sterculiaceae	13
Hallea ciliata	Rubiaceae	13
Erythrophleum ivorense	Caesalpiniaceae	9
Canarium schweinfurthii	Burseraceae	5
Pycnanthus angolensis	Myristicaceae	4
Milicia excelsa	Moraceae	3
Terminalia superba	Combretaceae	2
Daniellia ogea	Caesalpiniaceae	2
Daniellia thurifera	Caesalpiniaceae	1
All other species		3208

A national forest inventory was carried out by a joint Liberian-German team starting in 1960. In 1951 Mayer had concluded that 5.7 million ha or 58% of Liberia's surface was covered with closed moist forest. Some 3.7 million ha or 38% according to Mayer consisted of primary (unlogged) moist forest and 2.0 million ha or 20% of residual (logged-over, sometimes wrongly called ‘secondary’) moist forest. Sachtler presented national forest inventory results in 1968 and concluded that 2.4 million ha or 25% of the land area was covered with closed moist forest. Half of the forest was exploitable, the other part was found to be either too poor in merchantable timber or it was inaccessible forest on rough terrain. Of the closed forest area, 1.4 million ha had been declared National Forest and 1 million ha remained unreserved.

One of the conclusions drawn was that, over the period 1951 - 1967, some 3.3 million ha of closed forest had been lost at an annual average deforestation rate of 200,000 ha. The losses were mainly confined to central and western regions as a result of expanding farming activities.

Sachtler (1968) stated that 90% of exploitable forests were located in south-east Liberia and that this would be the major exploitation area of the future. He estimated the total exploitable area in south-east Liberia at 1.1 million ha of which some 40% were unreserved forest lands. Most of the reserved and unreserved forests can still be characterized as being closed forest formations.

It is particularly interesting to notice that, in the large forest areas of south-east Liberia, damage caused by forest elephants (*Loxodonta africana cyclotis*) was found to be considerable. The inventory of the 1960s in some cases found up to 60% of the area had been damaged by forest elephants. The continuous destruction of the regeneration of tree species as well as the debarking of mature trees results in a negative selection. The abundance of *Sacoglottis gabonensis*, *Parinari spp.* and *Calpocalyx aubrevillei* in certain stands was striking, and the overall stock of tree species was about 40% lower in those areas. The forest elephant population has been reduced alarmingly by poaching in recent years.

3.4 Actual standard management operations

3.4.1 Species classification

In Ghana the species were grouped into four distinct classes (see Appendix II) according to their economic value. Class I consisted of some 14 especially valuable timber species, class II of 12 species of general utility, class III of a fair number of species of possible future economic importance and class IV of all other tree species. Recently a classification system in which species have been classified into three classes according to their present utilization for export and on their size and availability within Ghana has been proposed by an inventory team assisted by the Overseas Development Administration of the U.K. (Wong 1989).

The class I and II species combined were divided into two groups, a and b, on the basis of growth rate (see Appendix II). Until 1958 the minimum diameter for class Ia was 86 cm, for class Ib and IIa 67 cm, and for class IIb 57 cm. An exception was made for the species *Heritiera utilis*, designated as class Ic with a minimum diameter of class IIb. In the classes III and IV a minimum existed for only *Terminalia superba*; the remaining species were unclassified (Foggie 1959).

As from 1958, the minimum diameter limits for Trees and Timber (control and cuttings) Regulations were raised to 86 cm for all class I species, to 67 cm for class II and to 57 cm for class III (Ghana Forestry Department 1958). To the present day the law is silent on diameter limits for class IV species.

In the Côte d'Ivoire the species were also grouped into four distinct classes (see Appendix VII) according to their timber quality. It is striking to find that the class I species list of the Côte d'Ivoire makes up almost the entire listing of species of the class I-III species list of Ghana before 1989. It is evident that the Côte d'Ivoire marketed a wider list of utility timber species and applied relatively low minimum diameter limits of either 50 or 60 cm drh.

The first harvesting regulations in Liberia were the minimum diameter limits imposed in 1957 (Table 3.4). Indiscriminate creaming of the forests took place wherever exploitation was carried out.

Table 3.4. Minimum diameter limits imposed in 1957 in Liberia. Original source: Appendix I by Burgh & Friedrich (1965).

78 cm	*Canarium schweinfurthii*	*Lovoa trichilioides*
	Entandrophragma spp.	*Tieghemella heckelii*
	Khaya spp.	
68 cm	*Anopyxis klaineana*	*Nauclea diderrichii*
	Erythrophleum ivorense	*Oldfieldia africana*
	Lophira alata	*Petersianthus macrocarpus*
	Milicia excelsa	*Piptadeniastrum africanum*
58 cm	*Berlinia confusa*	*Sacoglottis gabonensis*
	Mammea africana	*Terminalia ivorensis*
	Hallea ciliata	*Terminalia superba*
	Parinari spp.	*Tetraberlinia tubmaniana*
44 cm	all other tree species	

Around the time that the Forestry Development Authority was established in 1976, new minimum diameter limits were announced and species were grouped into 'obligatory' and 'future obligatory' species (see Appendix III). Obligatory implied that all stems of this species which had reached the correct size had to be harvested.

3.4.2 Enumeration

Before a compartment can be exploited, an enumeration of the standing stock has to be made. In Liberia this is done by the concessionaires and subsequently the stand figures are handed over to the forest service. Until 1972, harvesting methods in the Côte d'Ivoire were not prescribed in the contracts and concessionaires had a free hand to select and fell species. An enumeration was conducted by the concessionaire, but no obligation existed to hand over this information to the forest service. After 1972, concessionaires were required to submit information on logging and road construction operations.

In Liberia a 2½% strip enumeration of all trees of over 42 cm drh resulted in a listing of obligatory and future obligatory species (see Appendix III). According to the prescriptions of 1976 all obligatory species had to be felled and an additional 20% of this yield had to consist of future obligatory species. Yield regulation was effected by imposing minimum diameter limits. Since 1988 20% of the export volume has to be in the form of processed timber. A felling cycle of 25 years was enforced.

In Ghana a complete enumeration and the compilation of a stock map which indicates the exact position of all economic species over 67 cm drh, was made by the forest service (see Figs 3.3 and 3.5). From this stock map the allowed yield is selected. From 1956 until 1971, improvement thinning of the immature stock and selective fellings were also carried out and on a 15 year cycle which was later extended to 25 years. This pre-exploitation operation took exploitation damage to regeneration for granted and made no provision for post-exploitation tending operations. This system, often referred to as the (Ghana) Selection System persisted until 1971, and 300 to 385 km² were treated annually at an average cost of 3.7 man-days per ha (Baidoe 1970). Compiling stock maps and yield maps from the enumeration of compartments by the forest service is still done on a national scale.

Figure 3.3 Enumeration provides commercial trees with permanent numbers to compose stock- and yield maps (Ghana). Photo M.P.E. Parren, 1990.

3.4.3 Yield regulation

General remarks. The same **yield regulating instruments** are used in each of the three countries discussed here and these instruments are mainly confined to the implementation of minimum diameter limits. Restrictions on basal area reductions are not imposed, and a calculated allowable yield based on increment data has become available only recently. The yield removed consisted of a limited number of species for a period of nearly 100 years, and regeneration problems are on the increase. Selective logging means a creaming of the forest and has little to do with a silvicultural selection system which focuses its attention on the remaining stock of trees.

Yield regulation in Ghana. The first yield regulating method to be used in Ghana was the Brandis method. The **Brandis method** is applied in a polycyclic system where the yield is calculated according to the number of trees in the exploitable diameter class and the required timespan for a tree to grow from a certain minimum diameter to an exploitable size (Osmaston 1968). Later the yield was regulated using the Kinloch method as well as the Jack method and both were used as a check on each other. D. Kinloch and W.H. Jack were both Gold Coast forest officers.

The **Kinloch method** is a very simplified form of the 'French method of 1883' and has as its starting point the assumption that it is not possible to affect the increment of trees over 48 cm drh by any form of treatment. The French method of 1883 is actually a volume method which divides the total rotation period into three equally long successional periods. The total growing stock volume will show a tendency towards linear regression over the total rotation period. The ratio of normal volumes under this regression line would be 1:3:5 with increasing maturity (Fig. 3.4). The yield is calculated by taking into account volume and increment over three successional periods. The whole concept is based on a normal, even-aged forest structure and on correct information on increment (Osmaston 1968).

The complex nature of the West African forests makes applying this method to the situation in Ghana doubtful. The yield as calculated by the French method, should be checked by another method and the value found should be regarded as rather an indicator than as a decisive result.

The felling of trees over 48 cm drh was regulated to give equal annual yields for the period up to the time that the trees which were still under 48 cm drh attained exploitable size. Since reliable volume tables were unavailable, the yield was calculated by basal area, which was believed to bear a direct relationship to the volume of trees of over 86 cm drh.

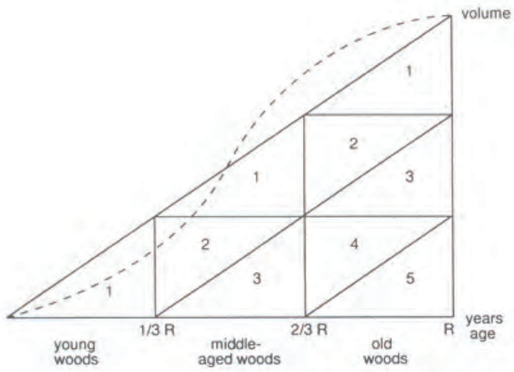

Figure 3.4 Model of the relationship between growing stock volume and age structure of a normal even-aged forest over one rotation period (Osmaston 1968).

The **Jack method** was based on the total basal area of trees ≥ 48 cm drh and the period needed to reach exploitable size. The periods needed by a tree to grow from 48 cm drh to exploitable size, as determined by Jack (1958) in the 1950s from a study of increment sample plots in the moist semi-deciduous forest, are as follows:

(a) Class Ia	48 - 86 cm drh	60 years	(± 6mm/yr)
(b) Class Ib	48 - 86 cm drh	45 years	(± 8mm/yr)
(c) Class IIa	48 - 86 cm drh	50 years	(± 7mm/yr)
(d) Class IIb	48 - 67 cm drh	30 years	(± 6mm/yr)

The exploitable annual yield was calculated by dividing the total basal area of all trees over 48 cm drh by the estimated time for a 48 cm drh tree to grow to exploitable size.

To illustrate this the example of Brookman-Amissah (1985) for the Kakum Forest Reserve class Ia species is given:

The total productive area was 2,678 ha which would allow an annual coupe of 107 ha at a felling cycle of 25 years. The total basal area of class Ia trees over 48 cm drh stood at 2,600 m² for the total area. The annual yield by Kinloch and Jack for class Ia species with a time span of 60 years as stated above would give: 2,600/60 = 43 m². This yield had to be selected over 107 ha which would mean, on average 43/107 = 0.4 m² ha^{-1}, which is just one tree of 60 - 70 cm drh. In practice, the concessionaire would enter the total productive area of 2,678 ha in just a few successive years, and he would not be allowed to return before the next felling cycle. Under these conditions he would then be allowed to take a total yield of 2,678 x 0.4 = 1,071.2 m² at one turn.

The yield was selected from the upper diameter classes downwards until the prescribed yield was reached, minimum diameter limits being enforced.

Kinloch-Jack methods appraisal. The **Kinloch method** is conservative since no allowance for increments on trees of over 48 cm drh, nor any account of mortality is made. For a climax forest it is assumed that mortality will equal increment but, after felling in the upper diameter classes, this balance is destroyed and increment will surpass mortality. The calculated yield is compared with the yield found by using the Jack method which takes into account increment and mortality over a period which spanning at least 50 years.

The **Jack method** is suited to long felling cycles since it balances the present yield against estimated stock available in the following cycles. It projects the growing stock by using assumed periods for trees to reach an increment of 20 cm. For classes I and II species the period used was 25 years, 20 years for *Triplochiton scleroxylon* and *Terminalia ivorensis*, and 30 years for all other species. The exploitable annual yield was calculated as described above. The growing stock less the yield was then projected onto the next felling cycle assuming a 75% survival rate in order to ascertain the sustainability of the calculated yield in subsequent cycles. If the calculated yield proved unsustainable, it was reduced to a level that could be sustained, at least for the next three felling cycles of 25 years. Provision was also made for areas differing significantly in stock from the average to be worked, on a variable coupe basis with reference to the mature class I species, in order to ensure equal annual yield (Ghartey 1990).

Yield regulation since 1971. Until 1971 the felling cycle was 25 years and the area of the annual coupe was obtained by dividing the area of the total felling series by the period of the cycle. In selecting the yield the largest trees were first taken going progressively down in size until the allowable yield was obtained. From the stock map (see Fig. 3.5) a selection was made by the District Forest Officer to ensure that the remaining stock was well distributed over each compartment of 65 ha (0.5 square mile). The idea was that an even distribution would ensure sufficient seed for regeneration. The allowed yield was selected from the stock map and no trees below the felling limit were to be taken.

From 1970 to 1990 only minimum diameter limits with a felling cycle of 15 years were in force. A serious drawback was that only about 30% of the allowed yield was actually felled. Since 1990 a 30% allowed yield reduction, new felling limits and, for some species, a special felling permit was introduced. The list of those tree species now also includes some species that are not exploited very much but that have proved to be rare in the latest inventory. The felling cycle has been extended to 40 years.

Yield regulation in the Côte d'Ivoire. At present the Côte d'Ivoire forest service has in mind a national annual harvesting level of 2-3 million m^3. A Côte d'Ivoire annual harvest of less than 1 million m^3 seems to be more realistic, as the forest reserve area (productive and unproductive) covers 1.6 million ha in the moist forest zone (1987 figures). This is confirmed by the national forest inventory data for Ghana for which the annual allowable yield was estimated at 1.2 million m^3 over a productive forest reserve area of 1.16 million ha. This means an average production level of 1 m^3 per ha. It should be noted that the condition and commercial stock of the forests is, on average, far better in Ghana than in the Côte d'Ivoire.

Yield regulation in Liberia. In Liberia since the introduction of a new species classification in 1976, the concessionaire was forced to enumerate all trees of obligatory and future obligatory species above 42 cm drh and had to map these trees. The concessionaire was further obliged to fell all obligatory species above the minimum diameter limit and at least 20% of the total harvest should consist of future obligatory species. These regulations have never been put into effect again, because of the lack of controls.

Appraisal and the steps to be taken. Yield regulations have to be based on data obtained by inventories both of a temporary and of a more permanent character. These have been undertaken in Ghana where a national forest inventory was begun in 1985 and has been recently completed. It was concluded that the resource of the traditionally desired species is likely to be exhausted within 2-3 decades at present rates of felling. *Triplochiton scleroxylon*, *Piptadeniastrum africanum*, *Antiaris toxicaria* and *Turraeanthus africanus* were some of the noteworthy species presently felled at a sustainable level or even under-utilized. A shift to the utilisation of presently not so highly demanded species was found to be necessary.

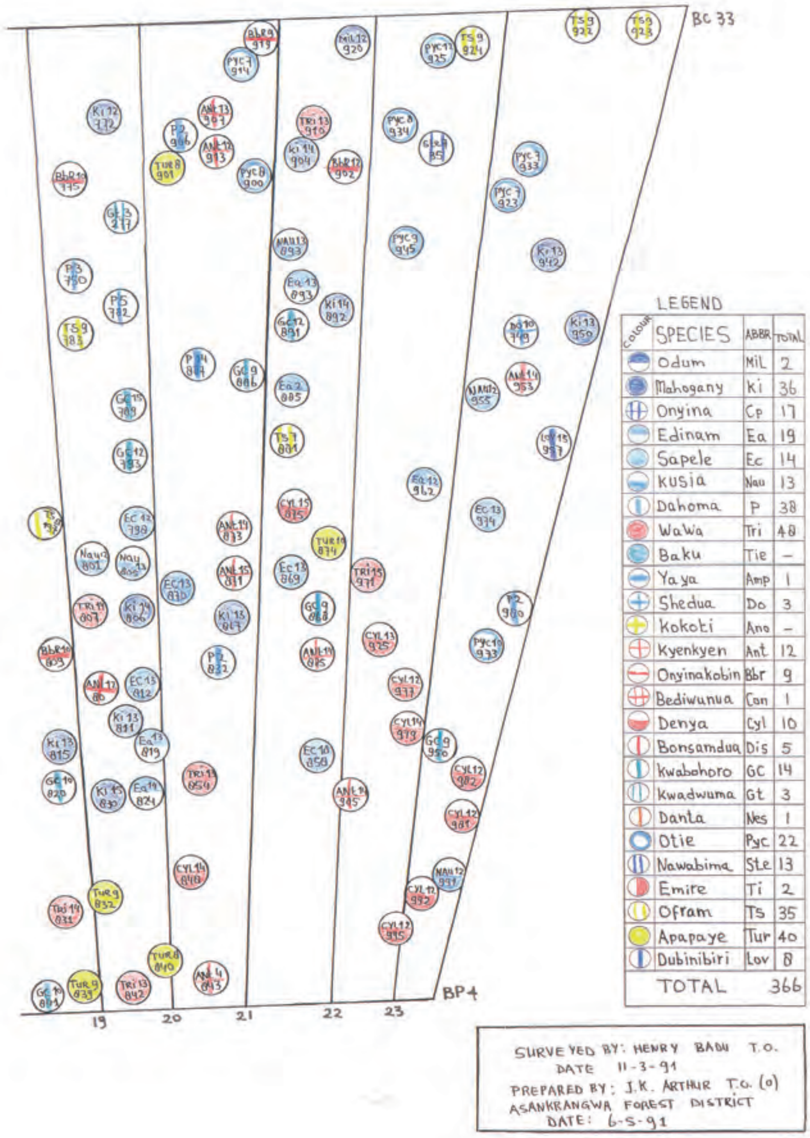

Figure 3.5 Part of yield map of 127.5 ha compartment in Bura River forest reserve (Ghana) with trees marked for harvesting. (Original was redrawn for this illustration.)

To improve the use of forest resources, sawmill capacity is being streamlined in Ghana according to the allowable annual yield as determined by the national inventory. Sawmill over-capacity was evident and a restructuring of this sector is underway. The next step, which is the allocating of concession sizes according to sawmill capacity has been delayed, because of political pressure from interest groups, but has to be the line to be followed for most timber producing countries.

3.5 Selective logging systems

Systematic selective exploitation is based on the preference by the customers on international and national markets for certain species. This selective exploitation should not be confused with a silvicultural selection system which focuses its attention on the selection of trees to be preserved, usually the most vital and best performing individuals, to assure a high per-tree volume increment. Selective logging is not concerned about the residual stand. An extreme form of selective logging is creaming, in which only the best grade timber trees are taken, thus also removing the best formed seed bearers. Such creaming may cause genetic erosion.

The re-entering of compartments over a period of several years as is usual in selective logging under permissive concession conditions does damage to recently established small natural regeneration following first fellings. The actual felling direction often deviates drastically from the proposed one (see Fig. 3.6). Training felling teams can avoid much of the damage presently being done to the forest structure during operations. Strict control of logging operations and access only over a limited time span are important measures to be enforced (see also Nuys & Wijers 1991, and Hendrison 1990).

The forest composition will alter in favour of non-commercial species if such selective logging takes place over several felling cycles, so it can never be an option for the forest service. It is surprising to find that the Liberian forest service has favoured such a selective logging system for some time as we will now see.

Strategies chosen in Liberia. When President Tubman of Liberia opened the door to concessionaires at the end of the 1950s, transnational corporations enjoyed a relatively free hand and were able to establish very large logging operations as in the Côte d'Ivoire. Their drive was directed towards economic profitability without having a simultaneous strategy for securing future timber supplies in the second and later felling cycles based on sustained forest management.

Although statistics about the deforestation rate are not reliable, a conservative estimate would be the annual deforestation of 20,000 ha since the early 1960s.

It is this information, combined with the fact that the Bureau of Forest Conservation had neither the staff nor the mandate to carry out the necessary controls on the concessionaires which finally alarmed the Liberian government.

This concern led to the establishment of the Forestry Development Authority (FDA) in 1976, just three years before the end of the boom. In 1978/79 timber exploitation peaked at over 0.8 million m^3 of roundwood equivalent before a sharp decline set in. With the establishment of the FDA, overall control improved and local processing was favoured. Selective exploitation has been called the Liberian Selective Logging System by the Forestry Development Authority. The FDA claimed that this exploitation system ensured the good and adequate natural regeneration of the stand but, from the above mentioned effects, this has to be considered to be a doubtful statement. During the 1970s and 1980s about 50% of the production was exported, 95% of which was in the form of logs, mainly *Heritiera utilis* (Anon. 1979, 1988). The decline led to a stagnation of the forestry sector because of the high cost of the Liberian dollar (officially 1 Lib$ = 1 US$) that made exports expensive. Additional to this came political instability following the 1980 revolution by the late President Doe. The mid-1980s showed a sudden increase in the export of green logs caused by several factors. The then low exchange rate of the US dollar as compared to the European currencies made exports relatively cheap, the ban on the export of green logs of certain species from Ghana since 1979 reduced competition, as did the over-exploitation of the traditional export species in the Côte d'Ivoire. This all favoured timber exports from Liberia. A regulation introduced in 1988 prescribed that some 20% of the export volume should be in the form of processed timber.

Figure 3.7 shows the ‘production’ (harvesting) levels for Côte d'Ivoire, Ghana and Liberia. Since the 1983/4 low of around 0.4 million m^3 the production of Liberia peaked in 1989 at over 1.1 million m^3 roundwood equivalent before the civil war in 1990 brought matters to a standstill for a brief period (FDA 1990).

Figure 3.8 gives some impression of the ways selective exploitation is conducted. The trees are felled, cross-cut into logs, transported and either processed in a sawmill or exported as roundwood.

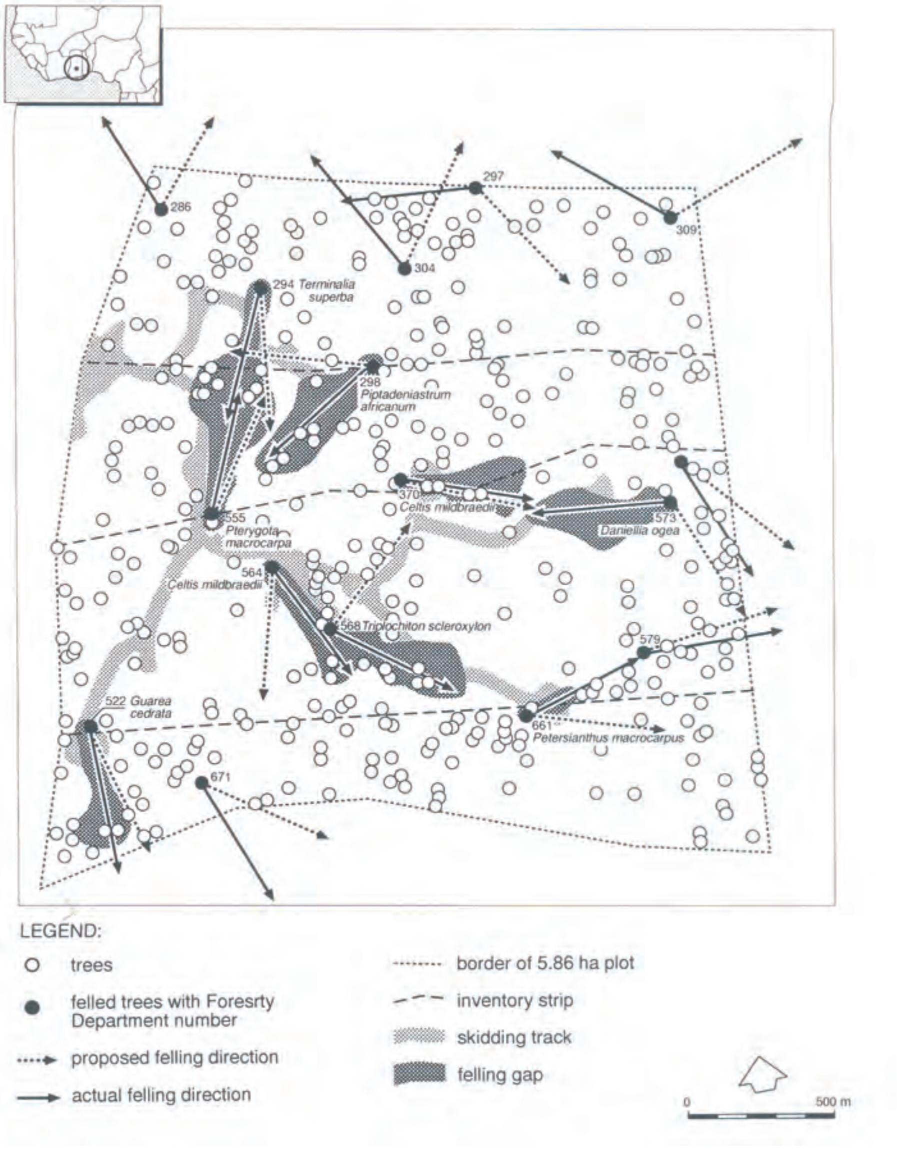

Figure 3.6 Stock map with felling gaps and skid trail pattern in a 5.86 ha logging damage assessment plot in Nkrabia forest reserve, Ghana. Uncontrolled logging. Source: Nuys & Wijers, 1991.

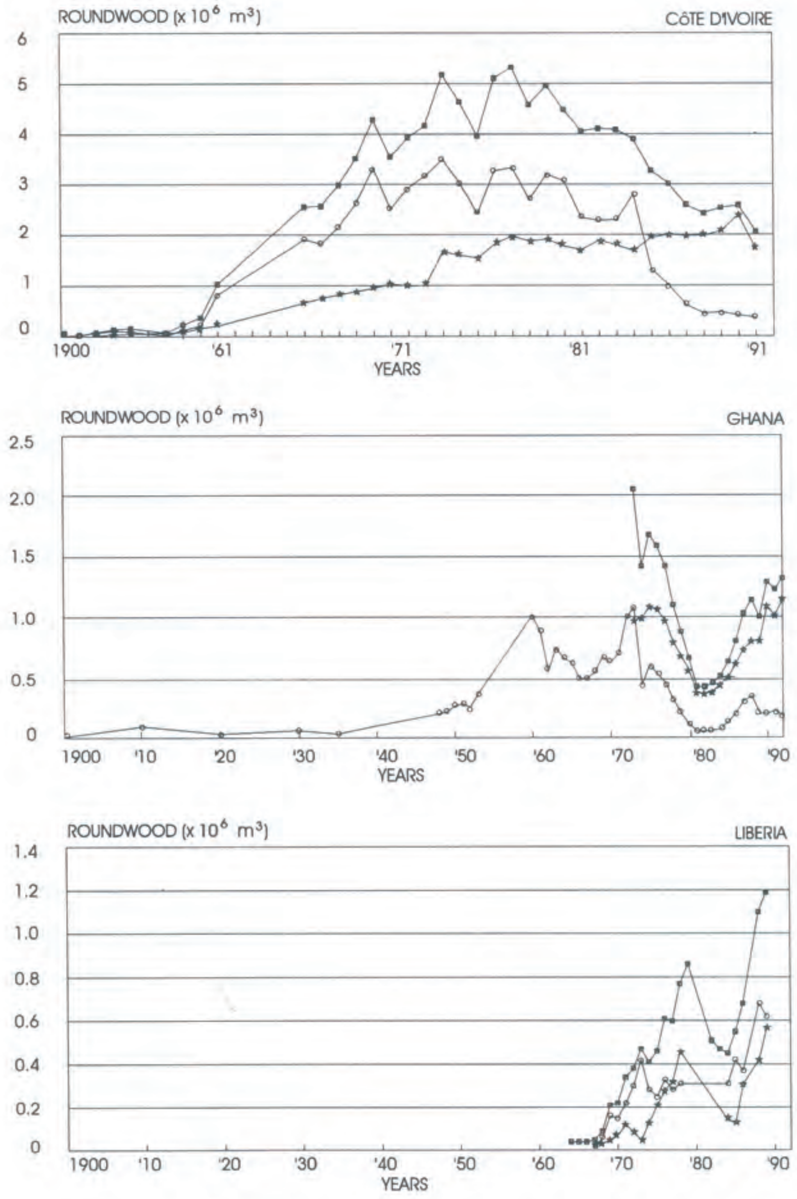

Figure 3.7 Total production (■), local consumption (★) and exports (O) in roundwood equivalents for Ghana, the Côte d'Ivoire and Liberia since 1900. Sources: Timber Export Development Board (Ghana), SODEFOR (Côte d'Ivoire) and Forestry Development Authority (Liberia).

Figure 3.8A Felling of a large *Ceiba pentandra* (Bombacaceae) in the Faunal Reserve of Nzo, Côte d'Ivoire. Photo M. de Klerk, 1990.

Figure 3.8B Unpaved forest exploitation road north of Sapo National Park, Liberia. Unreserved forest. Photo H. Dop, 1987.

Figure 3.8C Log yard and sawmill at Manso-Amenfi, Ghana. Photo M.P.E. Parren, 1992.

Figure 3.8D Export log yard in Buchanan, Liberia. Photo H. Dop, 1987.

4. SILVICULTURE

'To plant or not to plant, that is the question.'
This theme, the choice between artificial regeneration and natural regeneration in West African forest management, has been the subject of much discussion. French foresters were much in favour of planting valuable commercial species, either in monoculture or by enriching the residual forest, and they are able to point to successful examples of the artificial regeneration of productive stands. British foresters, experienced in the management of tropical forests in the Far East, largely chose for natural regeneration. Both approaches were stimulated by the desire to establish a forest rich in commercial timber, sustainably managed, and to the maintenance of a lasting forest.

This book only considers the natural regeneration work as attempted in West Africa, and plantation forestry is left aside. We are still in a situation where no sound, successful and cheap silvicultural system, or group of systems, to obtain a forest full of commercial timber has been developed for West Africa. As far as management is concerned however, the harvesting of timber need not be the first and only final goal and the view that the forest is more than simply a timber yard is now held by many people in Northern countries. In the Southern, less developed countries, forests have been seen in this light for many years. Should the target really be a stand full of commercial timber? What about other important products, functions and services?

Changing the objectives of forest management for a particular forest is not only a matter of ideas, but also a matter of methods, manpower, money and economics. Local forest uses, the providing of food and other materials as well as services, have not yet enough importance for central government to change its priorities which are themselves the result of other problems government has to solve.

Concentrating on the silvicultural problems in the larger context of forest management, we may consider the big trees as forming the core structure of the forest, and the commercial timber species as the financial mainstay of management. Regeneration and better growth of these important forest components is then a central issue to sustained yield. The other concerns of forest management and the generation or continuation of forest products or services, can be considered as being derivatives, subordinate or co-ordinate to this central issue, finding their place and their possible solutions in overall management schemes. Regarding important long-term stability, more is nowadays expected of natural forest, whether manipulated or not, than is expected from plantations that frequently lack a number of essential forest components, and which may also miss the optimal structure for effective resistance against destructive influences. It could be this fact that could finally turn the scales in the debate about artificial or natural regeneration.

4.1 Silvicultural systems

A suitable definition of **silviculture** might be: 'the wilful establishment and steering of forest stands, with the intention of keeping the forest ecosystem functioning or even improve it with regard to the desired effects'. Silviculture plays its role in the larger context of forest management and is largely confined to the biological aspects of the manipulation of the subject.

The results desired are not so much set by silvicultural considerations alone but are rather assessed in agreement with socio-economic wishes as indicated in the over-all management plan. The final outcome of all wishes is usually limited by biological/silvicultural constraints, often experienced in quite a late phase of the project. Society frequently has high expectations of forests, and when keeping the public informed, experts should also make clear its biological limitations. In matters of e.g. sustained yield such silvicultural information, or the lack of it, may have strong effects on the further development of the forestry branch.

A **silvicultural system** is, consequently, a series of silvicultural interventions, but it is more than that alone. The system must be based on a way of thinking which has been developed after close observation and with great understanding of the forest ecosystem. Such understanding helps in steering the right course when managing the forest, avoiding misuse, abuse or under-use. Socio-economic wishes and biological limitations as well as opportunities, have to be combined to reach an effective solution on the question of imput, production and services. Many silvicultural systems in the past seem to have been the outcome of one person's deliberations; in future such work will probably best be done by a team.

Some silvicultural systems have already been briefly mentioned in the foregoing chapters. For tropical moist (closed canopy) forests a number of silvicultural systems have been known in the literature since colonial times. Pre-colonial, indigenous, systems of silviculture have undoubtedly existed and still exist, but the amount of written information about these is still low. Non-timber forest products played the main role in these systems, which is not to say that large trees were not important. For example, in boat building it is usually the large individuals of certain tree species which are preferred. Large dominant trees usually fruit more abundantly, and it is self-evident that liberating suppressed trees will improve their fruit production.

Even without steel tools it must have been well within the technical limits of local people in former times to influence trees and forests to provide more food and other products and services. Useful trees such as the oil palm (*Elaeis guineensis*) in Africa and the Brazil nut (*Bertholletia excelsa*) in the Amazon region will have been dispersed and promoted, unintentionally as well as intentionally. When large populations of such trees are found in regions now devoid of their original human populations, only a naive observer would ascribe this to natural causes and leave it at that.

Studies of indigenous forest people undertaken by anthropologists often include remarks on the use and culture of forest trees. Only recently has more coherent information on the manipulation of trees and forest appeared, e.g. in Gómez-Pompa *et al*. (1991), and Anderson (1990). The steadily more popular notion that shifting agriculture should be included in the range of forest management systems is not one adopted by the authors. Such cultivation should be seen more as an intermittent stage in which the forest has to be removed to make place for other crops which cannot stand the forest microclimate or compete with forest vegetation.

In general, the exploitation of tropical forest for timber on a large scale began in colonial times and associated silvicultural systems that have been reasonably documented date from that period or later. An overview is found in textbooks by Lamprecht (1989) or Matthews (1989).

A number of popular misunderstandings exist about tropical forest exploitation and silviculture respectively. Here we are not referring to the idea that most timber exploitation looks like plunder as we can agree that there is much truth in that. We want to point here to the popular view on possibility of achieving good, sustainable, forest management by silvicultural means. As such, two are worth mentioning, viz. the planting of a number of seedlings for every tree taken and the conservation of the productive capacity of the forest by simple diameter limits for felling in selective felling systems.

Planting a number of seedlings or saplings in the forest where large trees had been harvested may seem a good idea to outsiders, but the chances of survival of such treelets are usually poor to nil. Really effective planting requires much preparation of the terrain and much aftercare to help planted stock attain size and, finally, maturity in a highly competitive environment.

In Chapter 3 we remarked that selective exploitation is not the real production of timber but only the harvesting of it, by felling and transporting the trees that grew the timber. Neither should such selective harvesting be confused with real selection management which is concerned with sustainability and focuses on the quality of the remaining forest rather than on taking what timber is now the most in demand.

Silviculture in selection felling tries to maintain the increment of valuable products, - mainly timber in classic systems- by selecting trees or forest components for harvesting that are slowing down in production and which can be missed from the stand from other points of view as well (seed production, shelter and as a food source for important animals etc.). Liberating potential crop trees from competition by less valued forest components such as badly shaped trees or from competition by climbers usually forms part of selection felling silviculture.

From selective exploitation to sustainable forest management with selection felling is a long and complex process and basic information on the necessary details on the execution in the field is needed. Furthermore, the organizational and financial consequences have to be faced as well as the political problems which emerge from the fundamental changes in present day forest management needed for the successful implementation of selection felling systems. But selection felling, though being among the most conservational silvicultural systems, is not the only silvicultural system to be considered for application in tropical moist forests.

4.1.1 Domestication

Lamprecht (1989) used the concept of the '*domestication'* of forest. Such domestication is done by applying various silvicultural interferences (e.g. refinement, which is comparable to thinning, and comprises removal or *in situ* destruction of unwanted, non-commercial trees and climbers) or by enrichment planting etc. Domestication may be reached through the gradual transformation of the forest or by conversion, the latter being a total change in most forest components.

All-important in this whole procedure is what final state of the forest i.e. what objective the manager wants to achieve, or rather: believes he/she should and could achieve. Lamprecht (1989) considers three groups of forest objectives:

1 Natural Forest with sustained yield
2 Uniform High Forest
3 Selectively Managed Forest

Usually conditions in highly mixed tropical moist forests are not conducive to adopting the first objective (1) *Natural Forest with sustained yield*. But, if conditions are favourable, as in natural or semi-natural stands with one or only a few species (like Pine stands or Mangroves) no domestication is needed and classic sustained yield regulations will do. In most cases however, the views of the managers have been over-optimistic. For example the ubiquitous adoption of simple diameter limits for harvesting in order to 'manage' highly mixed tropical moist forest in concessions has been a failure. Not even the regeneration of the desired species is obtained in most cases.

In the group *Natural Forest with sustained yield* only a few documented systems can be classified. Lamprecht (1989) includes the (Ghana) Selection System, which he indicates by the name Improvement Thinnings. His description of silvicultural interferences is not fully confirmed by our information from the literature. Improvement Thinnings can be seen as bordering Selectively Managed Forests.

The largest number of systems has been documented for the transformation or conversion to (2) *Uniform High Forest*. Amongst these the Malayan Uniform System for example, the Tropical Shelterwood System and systems derived from them such as the Post-Exploitation System and the Amélioration des Peuplements Naturels can be ranged, combined in a subgroup that is composed of systems which concentrate on producing regeneration. Another subgroup in the Uniform High Forest group is that which concentrates on the stock improvement of the existing forest. Systems in this group include: Improvement Fellings (former British India), the Amélioration des Peuplements d'Okoumé (Gabon) and the CELOS System (Suriname, although not yet operational). Systems promoting Uniform High Forest stands by planting in various ways are Strip Planting, Méthode du Recrû, and Taungya (much used in Teak cultures).

The category (3) *Selectively Managed Forest* includes systems whereby trees are selected for felling and much of the forest stand is left after harvesting to continue production and other functions. The stands under such selective management are usually more uneven in age and have a larger variation in diameters than stands under Uniform High Forest management. The category includes systems that may not yet have reached a sustained yield by selection felling but which are expected to do so in due time (Philippine Selective Logging, Indonesian Selective Logging). The execution of selection felling and silvicultural operations associated with such systems is usually quite more labour-intensive as compared with just selective logging and, if the task force of the executing agency is not of the required quality and establishment, some doubt about the realization of such systems is justified.

Most silvicultural systems using **natural regeneration** aim at assisting seedlings, saplings and premature trees of desirable species in the stand. There are several different approaches which focus their attention either on establishing of adequate regeneration in the innovation phase or on assisting selected trees in the 10 to 40 cm drh class in the aggradation phase. The final goal is that a certain number of commercial trees become emergents in each sequence of felling cycles. The silvicultural systems are all aimed at achieving -or maintaining- a situation of a maximum sustained yield of timber and associated products.

Some of the systems mentioned have been abandoned because of the rising cost of labour for their extensive numbers of complicated operations, or simply because of changes in the market for the main product or because the forest has been converted to other uses in a situation of high population pressure. For more detailed information we must refer the reader to the literature.

The systems that have appeared in the three West African countries discussed here, have been grouped into two categories for further discussion: early systems, those from before 1970, and present systems yet to be further developed in pilot projects. A map indicating the location of these projects can be seen in Figure 4.1.

4.2 Early silvicultural systems

4.2.1 Experimental period before World War II

With the arrival of French foresters in the **Côte d'Ivoire** in 1924, several natural regeneration experiments were started up. According to Chevalier & Normand (1946) and Schnell (1950) these experiments were inspired by the encouraging work undertaken by Kramer in the Dutch East-Indies, the present Indonesia. Kramer treated some 110 ha of montane forests on Java by removing less than 10% of mainly non-commercial species in chablis to encourage the natural regeneration of the primary species. Two types of silvicultural treatments were applied for a brief period; refinement operations based on minimum diameter limits later followed by liberation thinning of selected trees (Kramer 1926). Chevalier & Normand (1946) pointed out that 30% of all species in Kramer's research could be considered to be commercial timber species.

Natural regeneration experiments in the Côte d'Ivoire were evaluated a few years later. The conclusion drawn was that exploitation was limited to a few export species in the Côte d'Ivoire, which lacked a local timber market. The exploitation had consisted of the selective removal of large trees of the few commercial species, leaving trees of no commercial value untouched. Not more than 2 to 3 trees per ha were felled, providing insufficient light and space for adequate regeneration and observations after one year had led to the conclusion that the seedlings of the commercial species had disappeared, even after opening the canopy. Seed trees had often been removed by logging (Schnell 1950, d'Aviau de Piolant 1952, Catinot 1965).

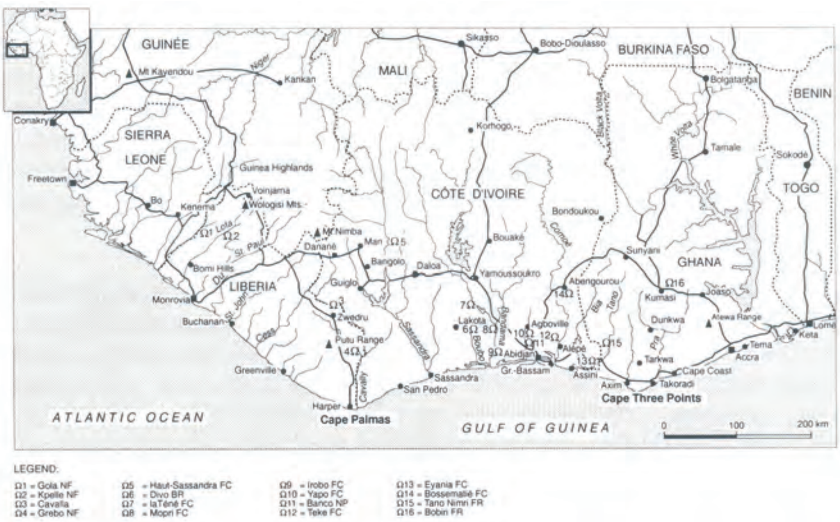

Figure 4.1 Experimental sites and project locations aimed at providing natural forest management in West Africa.

The first large scale reforestation activities started in 1928 on the coastal belt. They had been based on experience gained from 1924 in the Banco forest reserve on the outskirts of Abidjan. From that time on all efforts had been directed towards artificial regeneration in order to ‘enrich’ the exploited forest with commercial species. This policy was accelerated by the Forestry Code of 1935 (d'Aviau de Piolant 1952).

Since the early days of forest management a striking difference in approaches can be observed between the francophone and the anglophone African countries. The overall forest policy in the francophone countries put much emphasis on artificial regeneration techniques. This was quite the reverse of the policies in the anglophone countries where the forest services concentrated on natural regeneration techniques.

In **Ghana** very few species were exploited until the Second World War. The high quality standard at that time led to timber companies felling only large trees, often those with a diameter of 145 cm or more at the convergence of the buttresses. As a result, exploitation was very light and limited to the highest diameter class of which, even in the most productive forest, it was unusual to find more than one tree per 4 ha (Taylor 1960).

In 1946 the forest policy in Ghana was revised to manage the forest reserves for timber production on a sustained yield basis in order to provide direct benefits. Soon after the forest reserves were opened up for exploitation, the search for selection systems which could promote natural regeneration began. Simple yield regulatory procedures such as the Brandis Method were laid down in the beginning (Osafo 1970). This method however lacks prescriptions for silvicultural treatments.

4.2.2 (Ghana) Selection System

The selection system practised in Ghana dated from 1956 and lasted until 1971. It involved the stock mapping of all economic trees over 67 cm drh, the improvement thinning of the immature stock and selective fellings on a 15 year cycle (Catinot 1965), which was later extended to 25 years (Baidoe 1970), with the aim to provide a predictable yield. The steps are described below.

The (Ghana) Selection System was based on the assumption that a minimum number of 23 potential crop trees (PCT) per ha in the 10 - 48 cm drh class was required (Henriques & Pierlot 1958). This selection system has been applied all over the Ghanaian moist forests. At the same time the Tropical Shelterwood System was applied in the moist semi-deciduous forest of Ghana and Nigeria when existing regeneration was insufficient or when the number of PCTs was less than 23 per ha.

Stock survey. A stock survey was done of all economic species, whether defective or not, with a lower limit of 67 cm drh or at 30 cm above the buttresses, to compile a stock map. The trees to be exploited were selected on the basis of the stock map. A general plan of the distribution of merchantable tree species and the positions of the seed bearers which were to remain was established. This work was carried out by the Forestry Department and is still part of regular management.

Standard silvicultural operations. After the stock survey a contractor was given permit to exploit the selected allowable yield on the basis of working plan prescriptions. Only approximately 30% of the allowable yield was actually felled and the log volume extracted mainly covered a limited number of species. This situation still prevails.

After exploitation, **improvement thinning** was carried out. This technique consisted of two silvicultural operations favouring the class I and II species of 10-48 cm drh. To release class I species, thinning took place of all less valuable species and climbers within a radius of 4 m. Beyond 4 m, any poor tree of class II and trees of the other two species classes suppressing the class I species were also felled or poisoned. Good class II trees were assisted by felling or by the poisoning of any poor class II and less valuable trees, as well as by the cutting of climbers hampering the development of the crown. During operations an inventory of all class I and II trees from 10 to 67 cm drh was made with separate records for assisted and non-assisted trees.

In 1958 **stock survey and improvement thinnings** were combined to become a pre-exploitation operation. This technique was called '**combined operations**'. It took the exploitation damage to regeneration for granted while making no provisions for post-exploitation tending operations. This system persisted until 1971 when 30,000 to 38,500 ha were treated annually at an average cost of 3.7 man-days per ha (Baidoe 1970).

Yield regulations. The yield was regulated using the Kinloch method and the Jack method and they were used to cross-check each other. The two methods have been described in the previous chapter.

Critical assessment of the standard selection system. In the late 1960s the growth performance of the selection system was assessed critically. The average annual increment data in the 48-86 cm drh range of some class I and II species in 6 forest reserves were compared. The figures indicated that the mean annual diameter increment was less than 0.6 cm, which was regarded as being poor (FPRI 1968, Osafo 1970). However, this verdict is unfair when this increment rate is compared with normal rates in other lowland tropical forests. In Liberian research the maximum mean annual increment rate after treatment was about 0.6 cm (see chapter below on Liberian experiences). In Malaysia increment rates of over 1.0 cm (Whitmore 1984) in natural or semi-natural *Shorea* forest are common and it could be that this comparison has been the cause of the negative appraisal.

Generally speaking silvicultural treatments had good effect. The increment rates of sample plots, for instance in FR Asenanyo where improvement thinning was applied, did show improved diameter increment from an annual average of 0.2 cm to 0.6 cm (FPRI 1970, 1971).

Because of inadequate increment data, it had to be concluded that the effects of the standard selection system could not be confirmed by test results, but it could be seen to be a system well suited to aiding the regeneration of those forest reserves of Ghana that were well stocked with commercial species. At the same time doubts arose as to the efficiency of the system (in fact of the **list** of species used) as one of the species that was usually poisoned, *Pericopsis elata* had in the mean time become one of the highest priced timber species. As a result poisoning became a dubious technique to operate as changes in the timber market could not be predicted. The previously widely used term 'non-commercial species' had taken on another meaning.

This type of incident shows the folly of simply following the -often conservative- market. A thorough laboratory testing of all potential timber tree species on timber properties will make clear which species could be potentially commercial in the future (see also Chapter 5 on lesser used species). Such species should not be automatically condemned by their low classification forever because of their low commercial value at a particular point in time. On the other hand, a stand full of second class timber is not ideal; some place should remain reserved for the prime species at the cost of lower priced timber species.

4.2.3 Tropical Shelterwood System (TSS)

During the Second World War a number of foresters who had had previous experience in Malaya started serving in Nigeria where they helped to formulate and implement the TSS, a technique similar to the Malayan Regeneration Improvement Felling System (RIF) which consisted of a sequence of felling operations introduced in 1926 (Wyatt Smith 1963).

The historical background of related systems. The TSS introduced in Nigeria in 1944 (Table 4.2) was a monocyclic system based on the European Uniform or Shelterwood Compartment System, which had been modified for tropical conditions (Kio 1987). In Malaya the RIF had been abandoned and had been replaced by the Malayan Uniform System (MUS) introduced shortly after the Second World War. The MUS was a monocyclic system with just a single felling operation applied in the lowland Dipterocarp forests of Malaysia. The Dipterocarp lowland forests usually show a prolific regeneration of desired species, in contrast to what is the case in most lowland moist forests in the rest of the world. The main aim of the TSS is to help ensure the successful regeneration of the desired species under less favourable conditions.

In **Nigeria** the minimum regeneration required was 100 1-m tall seedlings per ha established over a five year period. If this was not achieved, the opening up of the canopy continued (Lamprecht 1989). Canopy opening was usually drastic, removing between 65 and 80% of the basal area (Kio *et al.* 1986). Two hundred thousand ha of forest had been given the TSS treatment by the Nigerian Forestry Department between 1944 and 1966, after which the method was abandoned (Schmidt 1987).

Ghana tried the TSS on an experimental scale in 1947 (Osafo 1968) and later adopted it for areas where it gave promising results. The TSS concentrated its efforts on the regeneration of the Meliaceae, i.e. *Entandrophragma spp.*, *Guarea spp.*, *Khaya spp.* and *Lovoa spp.* These species produce abundant seeds, and the establishment of numerous seedlings every year is assured (Taylor 1954).

General description of the TSS system. Briefly, the system comprises of a series of operations designed to open the canopy in order to induce regeneration and stimulate the growth and development of existing young stands. The TSS can regard as being a monocyclic system since the entire marketable standing stock is felled at the same time. When regeneration is rated as being successful, the temporary shelterwood, which functions both as shelter and source of seeds, is removed leaving only small young trees in the stand. The aim is to create a uniform high forest with a pre-determined rotation and regeneration period. The diameter class which the regenerated stand has to reach before felling, is the 60-80 cm drh class. The opening of the canopy encourages the rapid growth of pioneer species as well as climbers which, if unattended, smother the regeneration of the desired species. To avoid this, tending operations, weeding out undesirable species, are carried out beginning 6 years prior to exploitation.

Table 4.1 Sequence of operations of the Tropical Shelterwood System in Nigeria. Based on Kio (1987); 100 years rotation.

NIGERIA

Year	Operation
E-4	a) Demarcation of compartment of some 250 ha
	b) 1st climber cutting and seedling assistance
	c) 1st poisoning (= 1st canopy opening)
E-3	a) 2nd climber cutting and 1st regeneration count
	b) 2nd poisoning
E-2	a) 1st and 2nd cleanings (= under-storey opening)
E-1	a) 3rd and 4th cleanings and 2nd regeneration count
E	a) Exploitation in the case of sufficient regeneration, otherwise the whole procedure shifts acccordingly
E+1	a) 5th cleaning and 3rd regeneration count
	b) Repair of exploitation damage
	c) Removal of overwood depending on light demand of regeneration
E+6 or up to E+10	a) 6th cleaning
	b) Removal of overwood
	c) 4th regeneration count

Experimental operations and comparison with the Nigerian system. Tending operations consisted of climber cutting, cleaning and thinning to open the canopy. Cleaning was aimed at freeing desired seedlings and saplings from weeds and climbers.

Treatments were given to obtain three canopy densities as distinguished below:
Heavy density (HD) - the removal of all undesired trees and shrubs up to 6 m in height, leaving higher trees.
Medium density (MD) - the removal of all undesired trees and shrubs > 10 cm drh.

Light density (LD) - the removal of all undesired trees and shrubs > 10 cm drh and all large crowned understorey trees except those of the desired species.

In Ghana, during the experimental stage, plots were laid out and thinned to the three canopy densities given above. The thinning comprised of the felling or poison girdling of the trees. The three treatments employed in the temporary sampling plots were assessed for the effectiveness of the regeneration over a number of years. The criteria for determining the success of regeneration work were based on a minimum number of 1-m tall seedlings of class I species per ha having established themselves. The objective was to obtain at least 625 seedlings per ha over five years (Osafo 1968). The general conclusion was that, whilst regeneration was sparse and died off quickly under HD treatment, it was profuse and to some degree sustainable under MD and LD treatments. It is astonishing to discover that the minimum required number of 1-m tall seedlings per ha for the TSS was 100 seedlings in Nigeria whereas in Ghana the minimum number was 625 seedlings. Which of these two figures should be the optimum?

For those that have no educational background and experience in silviculture the following remarks may be enlightening. Such young seedlings and saplings as mentioned above still have a very uncertain future. The vegetation around them is usually highly competitive, and risks of mutilation or death are high for small individuals. Here silvicultural interferences can help a lot to improve survival and growth. Without help by man such a number of 100 saplings and seedlings of commercial species in a multitude of non-commercial regeneration may be reduced to nearly zero in a few years. However, with adequate help the survival and growth may be improved so much that a final number of twenty, thirty or even more large trees of commercial species can be produced, in a stand which for the rest consists out of non-commercial trees. Mortality (in numbers) usually is much reduced when trees have reached heights of more than 10 metres, or diameters above 10 cm drh.

In Ghana a sequence of operations was developed forming a standard technique with a regeneration period of 10 years. Table 4.2 shows both the experimental and standard TSS of Ghana which was based on the Nigerian initial experience.

From the above it will be clear that the system involved many operations all of which have to be undertaken with skill and experience. The gradual opening up of the canopy from below in order to promote regeneration was not a standard technique and it was labour intensive. All these pre-exploitation operations assured adequate regeneration, but the permitted yield -consisting of all trees that had reached the felling limit- was not fully harvested. Important revenue was not gained and the shelterwood still retained a harvestable volume of commercial species. In the authors' opinion the highly selective timber market, which still dominates, has frustrated the work of the Forest Service to a large extent.

Table 4.2 Sequences of operations of the Tropical Shelterwood System in Ghana. Experimental sequence based on Osafo (1968); standard technique based on Foggie (1959) and Osafo (1970); 80 to 100 years rotation.

GHANA: Experimental sequence (based on Osafo 1968)

Year	Operation
E-6	a) Canopy opening to HD
E-5	a) Canopy opening to MD
E-4	a) Canopy opening to LD
E-3	a) 1st regeneration count
E-2	a) 1st cleaning and 2nd regeneration count
E-1	a) 3rd regeneration count
E	a) Exploitation
	b) 2nd cleaning and 4th regeneration count
E+1	a) 1st climber cutting
E+2	a) 3rd cleaning
E+3	a) 5th regeneration count

GHANA: Standard technique (based on Foggie 1959 and Osafo 1970)

Year	Operation
E-5	a) Demarcation of compartment of some 24 ha
	b) 1st climber cutting and canopy opening to MD
E-4	a) Canopy opening to LD
E-3	a) 1st cleaning and regeneration count
E-2	a) 2nd cleaning and regeneration count
E-1	a) 3rd cleaning and regeneration count
E	a) Exploitation
E+1	a) 2nd climber cutting and coppicing damaged regeneration
	b) 4th regeneration count
E+4	a) 3rd climber cutting and 5th regeneration count

The obligation to harvest should have been enforced and adequate control should have been affected. The Forest Service seems to have been immobilized and bound hand and foot politically.

It is strange to observe how much effort the Ghanaian Forest Service has put in TSS, with its expensive poisoning and the additional thinning required. According to Karani (1970) the Ghanaian foresters considered their (Ghana) Selection System with just thinning as treatment to be highly successful. The required regeneration was obtained by the (Ghana) Selection System, but because of the lack of sufficient sample plots this success could not be demonstrated.

Appraisal at the end of the 1950s. In 1959/60 the TSS was critically assessed and the following remarks were made.

(a) Osafo (1968, 1970) states that successful regeneration under the TSS is an accomplished fact. TSS treatment is effective in influencing the regeneration and increment of natural forest stands; selective poisoning or exploitation and climber cutting respectively accelerate the development of poles and trees and improve the stock of saplings; the distribution of regeneration is strongly associated with features of seed bearers (Kio 1987).

(b) Cleaning should consist of eliminating only those undesired species that smother desired saplings. The remaining undesired trees were left standing to obtain a closed canopy at an early stage to reduce climber growth.

(c) The shelterwood should be completely removed at the earliest possible opportunity after a closed lower canopy had been obtained. Removal of the shelterwood proved beneficial to increment.
(d) During exploitation only part of the allowed yield was felled by the concessionaire (Stevenson 1952).
(e) Costs were high at 6.25 man days per ha per annum.

On the basis of the above information the number of treatments were reduced in order to establish a standard technique (see Table 4.3). In Nigeria where the TSS was adopted as the major silvicultural system, the system had been revised in 1956. Pre-exploitation treatments had been omitted and treatment was reduced to one climber cutting and the removal of shelterwood after exploitation. This proved to give the greatest diameter increment (Kio 1987).

In 1969 the TSS was abandoned in Ghana, all experiments and research were concluded and it was decided that only tending treatments would continue (Osafo 1969, FPRI 1970). By that time about 4800 ha had been treated (Ghartey 1990).

Some final remarks about TSS. The TSS produces even-aged forest as adequate regeneration is obtained by the drastic opening of the canopy by applying liberation thinning and refinement and a total removal of the shelterwood. The rotation period is set at 100 years and this implies that, for a tree to reach harvestable dimensions of around 70 cm drh, the felling cycle equals the rotation period. We therefore have a monocyclic system in which all merchantable trees will be harvested at one time. Regeneration in the second rotation will most probably be through a shelterwood system. Doubts could arise about the sustained functioning of a forest ecosystem in the long term when this forest is composed of only a handful of successfully regenerating commercial species. The list of tree species to remain in the forest ecosystem should be much longer than it was in the 1950s to avoid an excessive simplification of the ecosystem.

The early negative appraisal of the TSS stems from the nature of the West African moist forests. Most desired species are shade-tolerant species which demand a reduced shelterwood environment at the sapling and pole stages. Since their growth rates are slow they tend to be suppressed by fast growing species and lianas which show vigorous growth.

In Malaysia, the related Malayan Uniform System as applied to the lowland Dipterocarp moist forests was positively appraised during the same period. The system comprises of an exploitation resembling salvage felling and is followed by regeneration improvement after 4-6 years. The post exploitation vegetation is dominated by climbers but most Dipterocarp seedlings and saplings are not hampered unduly by this, growing vigorously during this early phase of their development. The system is less intensive and the percentage of merchantable species is higher than in West Africa. As a result the system is cheaper.

If we assess the performance of individual species under the TSS the following conclusions can be drawn. Of the class I species only *Entandrophragma utile* proved to successfully regenerate. This species made up for about 39% of all class I species (FPRI 1966). Average results were shown by *Khaya ivorensis* and *Entandrophragma angolense* while *Chlorophora milicia*, *Tieghemella heckelii*, *Entandrophragma cylindricum* and *Terminalia ivorensis* were among the failures. Of the class II species *Guarea cedrata*, *Piptadeniastrum africanum*, *Nesogordonia papaverifera* and *Mansonia altissima* have been successful.

4.2.4 Post-Exploitation System (PES)

The other silvicultural system with natural regeneration attempted for a brief period in Ghana was the PES. This system was tried particularly for economic reasons, since TSS requires expenditure before an income can be obtained whereas an immediate income was forthcoming from PES (Stevenson 1952).

The PES system in Ghana consisted of exploitation in the first year, followed by climber cutting, canopy opening and cleaning (as in the TSS applied in Nigeria since 1956). A tangle of lianas was found (FPRI 1968). Regeneration counts showed that regeneration mainly consisted of class II species, notably *Guarea cedrata*, *Piptadeniastrum africanum* and *Nesogordonia papaverifera*. There seem to be two reasons for this. On the one hand the regeneration of class I species was poor since most of the potential seed bearers had been felled during initial exploitation. On the other hand the majority of the parent trees of the class II species had been spared and these are fairly regular seed bearers. As a result PES was abandoned and TSS adopted where it gave more promising results (Osafo 1968).

4.2.5 Amélioration des Peuplements Naturels (APN)
[Natural forest stand improvement]

In the **Côte d'Ivoire** experiments with natural regeneration on a larger scale had not begun before 1947, long after silviculture with artificial regeneration had started (see Table 4.3). This new approach was inspired by the finding that some forest reserves were well stocked with *Heritiera utilis* and *Turraeanthus africanus*. During the evaluation of the natural regeneration experiments of the early 1920s these two species had shown natural regeneration potential. It was thought to be a less expensive and easier alternative to artificial regeneration practices (d'Aviau de Piolant 1952).

Table 4.3 Silvicultural systems as applied in the moist forest zone of the Côte d'Ivoire until 1950 and their area of application. Based on d'Aviau de Piolant (1952).

Applied method	Treated surfaces	
	1924 - 1947	1947 - 1950
Natural regeneration	-	4,555 ha
Artificial regeneration		
- tree plantations	200 ha	46 ha
- taungya system	700 ha	-
- enrichment planting	12,410 ha	864 ha
Total	13,310 ha	5,465 ha

Preliminary Côte d'Ivoire trials, 1947 - 1950 period. Following exploitation, treatments were conducted in several forest reserves. Treatments were a climber cutting and the poison girdling of undesired species. This was to assist the regeneration of desired species and improve their survival rate. The following information is based on what d'Aviau de Piolant (1952) presents.

In FC Toumanguié an inventory of 15 1-ha plots over a total area of 650 ha was conducted, and 95% of the young trees of commercial species were found to be *Turraeanthus africanus*. Some 1300 saplings in the 1 - 10 cm drh class and 32 trees of the 10 - 70 cm drh class were present.

In FC Comoé an inventory of 18 2-ha plots over a total area of 471 ha was conducted and, of the young trees of commercial species, 85% consisted of the Meliaceae *Turraeanthus africanus*, 6% of *Guarea cedrata* and 4% of *Lovoa trichilioides*. Just 117 saplings in the 1 - 10 cm drh class, 31 trees in the 10 - 20 cm drh class and 15 trees in the 20 - 70 cm drh class represented the commercial species. The overall impression gained from this data is that the stock of commercial species was, in general, insufficient to guarantee a sustained yield in the future.

At the same time natural regeneration was found to be abundant on old skid tracks. Natural regeneration on such tracks in the present day is usually poor, and this difference might be the result of hauling methods. In the early days hauling from stump to road side was done manually or by a relatively light tractor such as Logan (1947) describes for the Gold Coast (Fig. 4.2). In the Côte d'Ivoire it is likely that the same methods were also employed, as Méniaud (1931) confirmed. At present, very heavy skidders are employed which change the physical properties of the topsoil in a far more unfavourable way.

The preliminary costs of silviculture were found to be low at 10 man days per ha for climber cutting and 7 man days per ha for poison girdling (nowadays this is not true anymore because of the present Ivorian labour costs). Natural regeneration was judged to be much cheaper than artificial regeneration methods which required 80 man days per ha.

In 1950 the above experimental results were developed into a standard technique which was named Amélioration des Peuplements Naturels (APN). The process of favouring the natural regeneration concept was accelerated and inspired by the first published results of the TSS applied in Nigeria and the TSS experiments in Ghana.

At first, APN was implemented in exploited forests, but later it was also practised in unexploited forest. The principal prerequisite was that the natural stock of desired species should be such as to give promising prospects for adequate natural regeneration.

Figure 4.2 Manual hauling of mahogany squares in Ghana during the 1940s.

Sequence of operations in APN. The system involved an inventory of the commercial stock, the opening of the canopy and treatments to favour the desired species. The steps will be described in turn.

(1) An **inventory** with an increasing intensity over 100 ha, 20 ha and subsequently 1 ha blocks was the starting point. All commercial species (divided in two users classes) were measured and grouped in diameter classes.
(2) **Climber cutting** followed. In general climbers fall within 4 months of cutting. Afterwards the **opening of the canopy** takes place at two 6 month intervals. This opening is done by poison girdling of the seed bearers of undesired species and the removal of large-crowned trees in all strata. It was not deemed necessary to open the canopy by treating each successive crown layer (Gutzwiller 1956). It was precisely this view which distinguishes APN from TSS. Trees that did not smother the natural regeneration were left standing, even when these were trees in the upper crown layer. The idea was that the natural regeneration in the gaps created would be conducted by well-formed surrounding trees. According to Lamprecht (1989) this would give a kind of Group Selection Forest with, in the course of time, increasing numbers of commercial species. The minimum required number of saplings and poles per ha amounted to 100. If numbers were found to be inadequate, enrichment planting would take place (Foggie 1960).
(3) During the following 10 years natural regeneration would be assisted. This was done in three rounds of 3 years each, and mainly consisted of **climber cutting and the refinement** of the young stand.
(4) Finally, **diagnostic sampling** at an intensity of 1% took place to determine the development of the regeneration. According to Catinot (1965) total costs stood at 50 man days per ha for the above described operations.

Appraisal. Gutzwiller (1956) evaluated the APN system as beneficial and concluded that the regeneration of *Heritiera utilis*, *Turraeanthus africanus*, *Guarea spp.* and *Entandrophragma spp.* proved to be successful. It is very surprising to learn that Catinot (1965) judged the APN system negatively only a few years later. It seems that his personal appreciation of the future development of the treated forest stand guided him in his decision in 1960 to abandon the APN system.

Catinot (1965) doubted as to whether he was able to give the correct appraisal of the system in the absence of data covering growth performance and the abundance of the commercial stock. As a result he was left with a purely visual evaluation. The treated forest stand made a disorderly impression. Catinot also commented that many released trees were still overshadowed because of inadequate refining. He expressed the opinion that the newly created environment favoured climber growth.

According to the present authors' opinion, the data collected about APN by the research section of the Côte d'Ivoire Forest Service should be reassessed in order to make a new judgment. The authors were not able to lay their hands on this data. In 1957 the Conservator of Forests, Mr. de la Mensbruge, mentioned in a discussion with Catinot the existence of inventory plots of 10 x 5 m as well as a kind of line sampling but he gave no results (Catinot 1965). Much information is missing in literature, such as the basal area reduction, species removed, volume per ha removed etc. It would be worthwhile conducting research in order to retrieve these data. The question remains as to whether the three refinements were adequate and as to whether the tending operations should have been altered in nature, sequence and timespan.

Catinot (1965) airs his doubts about whether it is worthwhile to put so much effort into something so uncertain as APN when compared with the expensive but familiar methods of artificial regeneration. Consequently he once again opts for enrichment planting.

APN must have been applied in FC Téké (about 5,000 ha), in FC l'Eyania (22,700 ha) and in FC Yapo (5,000 ha), but the actual surface treated cannot be traced with certainty (Aïdara pers. comm.). When implementing a silvicultural system with natural regeneration in FC Yapo, in the 1980s (see chapter below on the Yapo project), the Forest Service found evidence of application of APN over 442 ha in compartment 15 (SODEFOR 1986 and Fig. 4.8 for location of the compartment). The forest proved to be very rich in commercial species, mainly *Heritiera utilis*, of which over 20 trees per ha of over 50 cm drh were present. The overall stocking of the APN treated forest proved to be significantly higher than the untreated natural forest. It was observed that the richness in commercial species was distributed uneven over the compartment. The treated forest resembled an almost pure stand of commercial species or tree plantation resulting from silvicultural interventions that took place some 30 years ago. This gives ground to Gutzwiller's idea that the APN system was beneficial. The successful regeneration of those days seems to have survived since commercial species are significantly present in all strata.

Brief comparison with enrichment planting in strips. In brief, the enrichment planting method (la Méthode des Layons) means strip cutting at 25 m intervals and planting seedlings of commercial species at intervals of 2 - 2.5 m within the strip. The canopy of original forest between the strips should gradually be opened and finally completely removed to favour the development of the planted trees.

The final stage would give a virtually closed canopy of even-aged planted trees. This may ultimately lead to a harvesting system equal to salvage felling, taking away all saleable timber in one operation. If no natural regeneration is possible after such harvesting, replanting becomes a necessity, and most probably this will be open planting. In that case the top soil will subsequently be exposed to insolation and direct precipitation and physical and chemical properties will be drastically changed. The question then remains as to whether even after a successful first rotation of the system described above, growth conditions will remain sufficiently favourable to enable a second rotation with planted forest. But maybe TSS will be applicable when the forest ecosystem is not gravely degraded by oversimplification. Another possible form of regeneration of such even-aged stands might be strip planting after a brief interval with secondary (pioneer) forest.

Serious doubts about the sustainability with forest regeneration through open planting in this region occur since the favourable environment of the original species-rich and heterogeneous forest disappears. It is already known that such plantations face serious problems under West African conditions. Danso (1977) demonstrated this by describing the extensive die-back occurring in *Terminalia ivorensis* artificial regeneration trials all over Ghana. The effect was confirmed by the first author's personal observations at several of such areas in the late 1980s (see Fig. 4.3). An ecologically much healthier silvicultural system based on natural regeneration in order to preserve some of the heterogeneity of the original forest is much preferable to artificial regeneration systems.

Figure 4.3 Die-back of *Terminalia ivorensis* taungya plantation in South Fomangsu forest reserve, Ghana. Photo M.P.E. Parren, 1987.

4.3 Evaluation of early systems

A number of approaches and solutions to the problems of silviculture in natural forest have been attempted in colonial times and nearly all have been abandoned. The reasons for abandoning such approaches do not always appear realistic with the benefit of hindsight. The cases often are difficult to verify after such a long time but it does appear that in most cases a sound base for the evaluation of the experiments and of the crudely formulated systems was absent. Some intensive detective work in archives might reveal more of the truth. During the writing of this book, Dr. Alder re-assessed some of the old sample plots data sets of the silvicultural experiments at Bobiri FR, which data had been unearthed from old archives in the Forestry Research Institute of Ghana (the former Forest Products Research Institute).

It seems that, on various occasions when land use decisions had to be made, the potential for timber production of natural forest has been exaggerated and raised above realistic expectation levels for such ecosystems. Such stress on production has led to quite intensive interference in the forest and the approach has subsequently had to be discarded as being too expensive. The approach of low input - low output has often been refuted by the argument of high overhead costs for security and for the road system, or by pointing to increasing population pressure. Such overhead costs however, when calculated per unit valuable timber produced plus all non-timber products and the services produced by natural forest, could well be bearable. And, of course, the high per ha productivity of plantations has its costs too both in money as in environmental effects.

A too superficial weighing of the productivity of natural forest against the productivity of artificial ‘forest’ -better described as tree plantations- has done much damage to forest land use. Such comparisons may easily give false results which are based on somewhat baseless assumptions about future productivity, sustained yield and the stability of tree plantations. Natural forest has proved stable, tree plantations often have yet to prove to be so, and this takes many, many years.

Advocates of tree plantations have now shifted towards the accentuating of the possibilities of planting on already cleared and abandoned former forest land and this seems quite reasonable. The return of more natural forest is, however, largely blocked by such forestry. The nature conservation movements have also turned toward advocating tree plantations, in order to ‘spare’ -as they say- natural forests. Such natural forests as have remained should then be ‘left alone’ and not managed for timber production. This would, however, put a heavy claim on scarce resources in a poor economy, and can only be justified when natural forest is indeed scarce in the region and functions as a sanctuary rather than as production forest. The final decision is up to the authorities, with perhaps financial support from outside.

Most West African countries probably won't be willing to leave a large part of their forest zone untouched, as there is still a considerable need for more land to cultivate.

Current fashion sees much promise in non-timber forest products as the base for forest management in such native forests. This can well be an important function but, again, is a one-sided approach, in a similar way as was the earlier approach which appeared to have concentrated on timber. Both functions can probably be easily combined in a sound forest management system with the accent laid wherever opportune for the optimal fulfilling of functions as desired by society.

4.4 Current pilot projects: forest dynamics after silvicultural interventions

New ideas and concepts have entered in forest ecology since colonial times. What do these imply for silviculture? In various pilot projects known from Liberia and the Côte d'Ivoire the old question of regeneration of commercial species and sustained timber yield is tried to solve by focussing on the commercial timber species. These species with their big individuals are indeed important for ecology and management, but are not the sole forest components involved in survival of the forest.

It is not quite fair to criticize the former concentration on timber production which had been directed at just a few species when taking into account the situation of forest management and silvicultural research prevailing in West Africa at that time. The prime need was -and often still is- to demonstrate to central government the possibilities of and also the attraction of regular forest management by concentrating on the proven money-maker: timber. Most other functions and forest products can be combined with such silvicultural regimes that promote growth and the regeneration of the large trees and, indeed, will be combined as soon as regular forest management is established with the cooperation of local authorities. This will be better for the viability of forest management, provide additional income and other stimuli for forest conservation for those living close to the forest.

4.4.1 Silvicultural potential of logged-over forests: Liberian experiences

Starting in 1978 several pilot projects were established by a German-Liberian team to determine the silvicultural potential of logged-over forests in **Liberia**. The team monitored and analyzed the forest structure, the effects of treatments and the increment rates. Their results combined with those of diagnostic sampling should culminate in the introduction of Forest Management Units in the concession areas.

The remaining forests of Liberia can be divided into a South-east and North-west Liberian forest block. Research undertaken and the results reached for four sites: *Cavalla; Grebo; Gola, and Kpelle* (see also Fig. 4.1) will be discussed below.

Cavalla: the effect of silvicultural treatments on the growth of individual trees. Cavalla site lies in the moist evergreen forest zone, where the annual average rainfall amounts to 1600 mm. The research objective was to determine the effect of silvicultural treatments on the growth of individual trees.

Selective exploitation mainly for *Entandrophragma utile* and *Nauclea diderrichii* began in 1969-70 and was repeated in 1975-76. The extraction rate was approximately 0.5 tree per ha for trees above felling diameter.

Between 1978 and 1980 diagnostic sampling took place at an intensity of 10% of the area, including only the obligatory and future obligatory species (commercial species). All trees above 10 cm drh were measured and recorded as well as all saplings above 1 m height. A total of 690 ha were surveyed, and half of this had such poor commercial stock that it was ultimately destined for forest plantation. The remaining half was found to be of rich natural stands, which, in future, would be worked by silvicultural systems with natural regeneration. According to Wöll (1986) the minimum number of potential crop trees (PCTs) should be 20 trees per ha in the 20 - 40 cm drh class to ensure sufficient ingrowth in the diameter class above the felling limit for future felling cycles.

From the inventory data Wöll (1981) concluded that there was sufficient regrowth provided logging damage were kept to a minimum, but this seems doubtful. He states that the overall diameter distribution for all 'commercial' species on all sites was "normal", i.e. in the form of a reversed letter J. Though this might be correct, the low number of PCTs indicates that, after the next felling cycle in 25 years, the stock will not be sufficient and will not guarantee a sustained yield for these species. Also, the felling cycle of 25 years applied in Liberia is not based on increment data.

Table 4.4 The stock of PCTs for dry land, sandy soils and fresh water swamp in Cavalla; compared with the total commercial stock and Wöll's standard of adequate PCT stocking. Based on Wöll (1981).

	Dry	Sandy	Swamp
% of plots well stocked	20,2%	33,1%	42,8%
Total commercial stems per ha	23,7/ha	43,3/ha	65,4/ha
Total commercial stems > 50 cm	5,7/ha	9,0/ha	12,8/ha
PCTs 20 - 40 cm drh class	6,3/ha	11,9/ha	19,5/ha
PCT standard according to Wöll	-	-	+

For the silvicultural treatment in Cavalla 12 1-ha plots which formed a coherent block dominated by *Gilbertiodendron preussii* with a high percentage of *Heritiera utilis* were selected (see Fig. 4.4).

During 1981-82 various silvicultural treatments were applied to induce higher increment rates of commercial species. Liberation thinning around PCTs and the freeing of individual trees from competition was undertaken or refinement done by a systematic basal area reduction through the girdling of non-commercial species and the removal of all poorly shaped trees (Wöll 1986).

Permanent Sample Plots (PSP) were remeasured after six years in 1986 by Wöll and the unpublished results of one control plot [1] and two plots where liberation thinning was applied [5,6] were given to the authors. The control plot showed an average annual diameter increment of 0.34 cm for PCTs above 10 cm drh, while the treated plots showed average annual diameter increments of 0.54 cm [5] and 0.51 cm [6] respectively. The productivity of the stand had therefore improved considerably by the treatment, while the cost of such a girdling operation, including assessment, stood at 6 man days per ha.

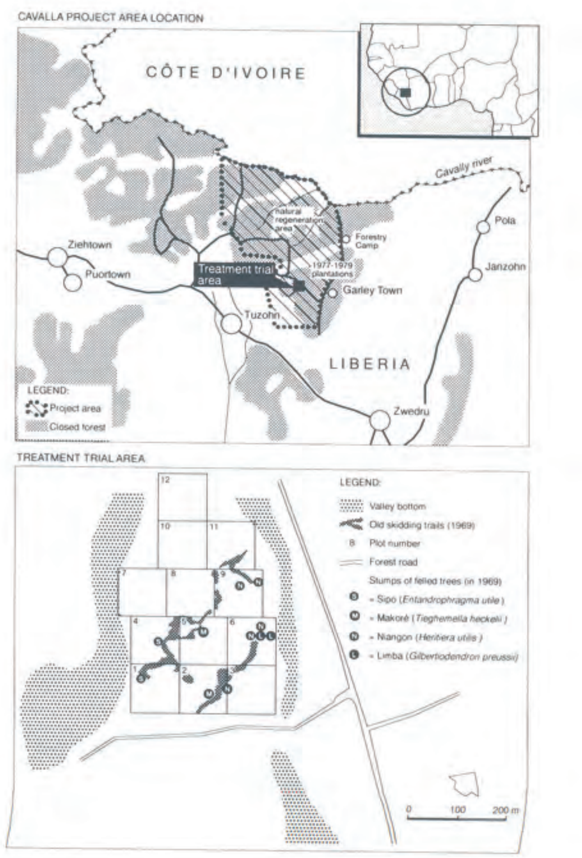

Figure 4.4 Outline of Cavalla treatment trial, east Liberia, showing the location of trees exploited in 1969 and related skid trails. From records of H.J. Wöll.

Table 4.5 Silvicultural treatments applied in Cavalla, (plot numbers in brackets). Based on Gatter (1984).

a) Control plots [1,8,11]
b) 20% basal area reduction of non-commercial species (all diameter classes) [2]
c) 40% basal area reduction of non-commercial species (all diameter classes) [9]
d) Removal of all non-commercial species ≥ 60 cm drh [3]
e) Removal of all species ≥ 60 cm drh starting from the highest diameter classes [4]
f) Removal of all non-commercial species [10]
g) Liberation thinning around PCTs (10-40 cm drh) [5,6]
h) Liberation thinning around PCTs (10-20 cm drh) [12]

Grebo: stand development after logging. The Grebo site lies in the moist evergreen forest zone where the annual average rainfall amounts to over 2000 mm. Extensive selective logging took place around 1963 in parts of Grebo National Forest (Poker pers. comm.). The research objective was to monitor the development of the stand after logging.

In Grebo an area of 900 ha was selected for study. Twenty 1-ha plots were located at random (Poker 1989). These permanent sample plots were established and measured between 1978 and 1985. Re-measurement took place in 1988. Measurements were the same as in Cavalla but in Grebo only logging took place and no treatments comparable to those in Cavalla were applied.

The overall annual mortality was found to be 0.7 to 2.0% for trees of all species ≥ 10 cm drh, the average over the 20 plots being 1.25%. Mortality was concentrated in the 10 - 20 cm drh class, amounting to 65% of dead trees, while 10% of dead trees were > 60 cm drh. The annual ingrowth rate was found to be 0.1 to 1.7%, with an average of 1.2% (Poker 1989). A silvicultural treatment, reducing the competition in the stand, e.g. by refinement or other basal area reduction, could have improved the increment.

The annual diameter increment in the 30 - 60 cm drh class averaged 0.4 cm (Poker 1989) and this class is the most productive for diameter increment (see Figure 4.5). The required time to pass the 30 - 60 cm drh class at this increment rate would be 60 years. A maximum of 40 trees per ha was assumed to occupy the top crown layer at the final stage.

Taking some mortality into account we should then select at least 40 Potential Crop Trees per ha. These would be hard to find if only the usual, very limited, selection of top-class commercial species were taken into account. If, however, all species listed as commercial were acceptable then reaching the required 40 PCTs per ha might yet be possible.

Reaching a sustained yield would depend on the volume harvested and on reducing logging damage. If 12-15 m^3 were required per harvest it would mean 3-4 trees being taken (see Table 4.8). The trees selected should not be a limited selection of only preferred commercial species as happens today but should be from all the commercial species on the list. This means the timber market would have to accept these species throughout the year and not only when contracts were available.

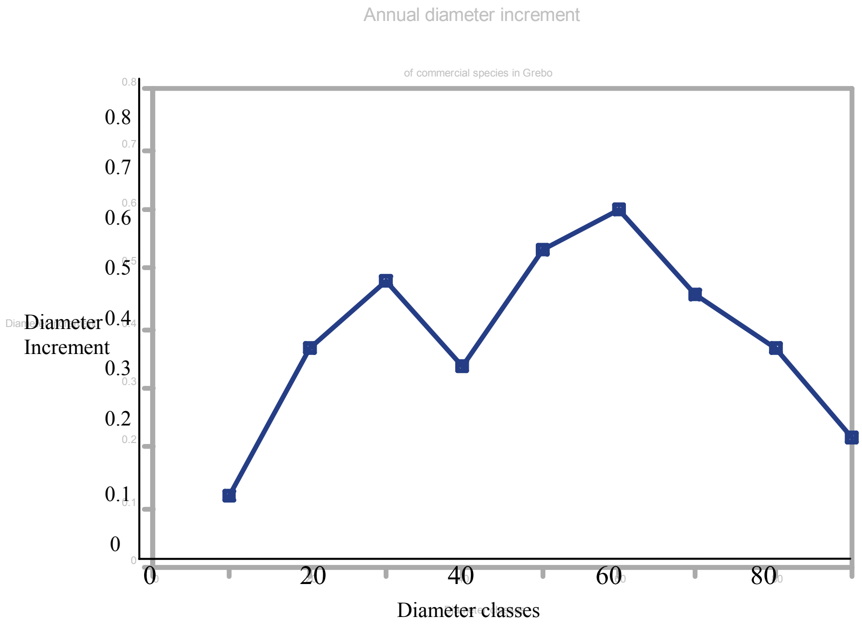

Figure 4.5 Annual diameter increment of commercial species in Grebo, Liberia. Source Poker (1989).

Different management plans for different sites within a large forest block such as the Grebo National Forest will be very important for assuring timber production based on the principle of sustainability for the entire forest block. Poker (1989) confirms this for the 20 1-ha plots. She divides the plots according to silvicultural criteria and stock into:

1. Plots to be logged, where 4 years later PCTs [10-60 cm drh] should be selected followed by liberation thinning
2. Plots where PCTs [10-40(60) cm drh] are selected, and which then are logged, finally followed by PCT liberation thinning
3. Plots where PCTs [10-40(60) cm drh] are selected, after which a liberation thinning aiming at basal area reductions of up to 30% or 40% is prescribed

In each case half of the plots would remain untreated to serve as control plots.

Gola: logging damage and the effect of silvicultural treatment after logging. The Gola site lies in the transitional zone between wet evergreen and moist evergreen forest formations and the annual average rainfall amounts to 2900 or 3100 mm. The research objective was to quantify logging damage and to determine the effect of silvicultural treatment after logging.

In 1985 a detailed stand analysis was carried out in three 1-ha plots which had never been logged before. The plots were selected from three representive site types: rolling hills with well drained soils; mountainous steep slopes with rocky out-crops; fresh water swamps.

Table 4.6 The basal area and stock of trees ³ 10 cm drh before logging for rolling hills, mountainous steep slopes and fresh water swamp in Gola. Based on Jordan (1985).

	Hills	Slopes	Swamp
Total basal area	38.5 m^2/ha	40.3 m^2/ha	35.6 m^2/ha
Basal area commercials	11.0 m^2/ha	4.7 m^2/ha	15.4 m^2/ha
Total stems all species	608/ha	557/ha	495/ha
Total commercial stems per ha	92/ha	31/ha	94/ha
Total commercial stems > 50 cm	30/ha	16/ha	24/ha
PCTs 20 - 40 cm drh class	15/ha	6/ha	26/ha
PCT standard according to Wöll	-	-	+

The basal areas of the three sites showed that Gola National Forest was well stocked when compared with data from elsewhere. Values ranged in the upper limit of the range of 23 - 37 m^2ha^{-1} for African lowland moist forest as given by Dawkins (1959). A decreasing stand curve could be observed for some species in Gola but the overall stock of PCTs was too low to comply with Wöll's standard of 20. Only in the fresh water swamps did the potential exist for sustainable yield over several felling cycles.

Logging by BOMIWOOD in 1985 took a volume of 10 - 20 m^3ha^{-1}, about twice as much as was taken in neighbouring concessions where mainly export logs were taken. BOMIWOOD utilized a great variety of tree species.

According to Wöll (1986) post-logging treatment comprised of:

1. Liberation, if the share of PCTs in the 10 - 40(60) cm drh class was above 20 trees per ha.
2. Refining, if the share of PCTs in the diameter class was less than 20 trees per ha.

Liberation implied the freeing of individual trees from competition by increasing the exposure of their crowns to light. The trees to be removed or killed could be either the less valuable or the more valuable species. Climber cutting was included.
Refining implied the removal of inferior elements all over the stand. In this case, all non-commercial trees above 30 cm drh would be girdled with the exception of the well shaped, non-commercial trees above 60 cm drh that would be spared. Misshaped and faulty trees would be girdled, even those with a diameter of under 30 cm. According to Wöll (1986) this refinement should reduce basal area considerably to 12-15 m^2 ha^{-1}.

In practice, refining and liberation are usually carried out in combination. Whilst, in the first treatment after logging, more refining than liberation may have to be undertaken, in later treatments the liberation of the favoured tree assumes major importance (Poelker & Wolf 1989). Refining usually provides more opportunities for small, non-target trees (under the diameter limits) to grow up than does liberation, and hence helps to improve future stock numbers.

The estimated costs (Wöll 1986) of post-logging treatments -including preliminary jobs like the surveying of roads, cutting lines and diagnostic sampling if necessary- were as follows:

> Liberation, including the marking of PCTs and competitors and climber cutting, took 6 man days per ha when competitors were girdled, or 4 man days per ha when competitors were poison girdled.
>
> Refinement in which unwanted trees were girdled took 6 man days per ha or when trees were poison girdled 4 man days per ha.

During 1987-88, diagnostic sampling was done over an area of 354 ha. Four Permanent Sample Plots (PSP) were established and post-logging treatment covering ca. 300 ha was carried out. In the logged area diagnostic sampling at an intensity of 10% was undertaken and an average basal area of 22.8 m^2ha^{-1} was found. The logging of 10-20 m^3ha^{-1} should have killed a few m^2ha^{-1} basal area, in harvested trees and damaged trees together, resulting in a figure of some 25 m^2ha^{-1} for the basal area before logging. Information from Jordan (1985) about logging damage in this concession does however indicate an excessive number of trees damaged and killed.

Jordan (1985) calculated a total basal area in as yet unlogged forest of 38 m^2ha^{-1}. He stated that about 20% of the commercials were left damaged and another 25% were lost during logging and the data of Poelker & Wolf (1989) confirm his statement. Nearly half of the trees below the felling limit were destroyed or damaged, especially the smaller diameter classes. More than half of all commercials in the 10 - 20 cm drh class were destroyed during logging operations, and 90% of all losses refer to trees of a drh below 40 cm (Jordan 1985). The already inadequate number of PCTs is therefore even further reduced. Logging this way is unlikely to fit into the concept of sustained yield. An explanation for the excessive damage sustained may be found in the steep terrain.

A combination of refining and liberation was practised as a post-logging treatment. The average basal area girdled per ha equalled 1.4 m^2ha^{-1} only or approximately 5 - 6 trees per ha (Poelker & Wolf 1989). (It is not clear why this light treatment should take so many man days as stated above). When we take Jordan's (1985) data on basal area of 38 m^2ha^{-1} as a base for non-logged forest, then the basal area after logging of 22.8 m^2ha^{-1} and an additional basal area reduction of 1.4 m^2ha^{-1} by treatment gives a total basal area reduction of ca. 44% of the pre-logged basal area, mainly reached because of the logging damage.

Reduction of the total basal area to a residual 12-15 m^2 ha^{-1} as advised by Wöll (1986) would be a very extreme intervention in the forest structure. It would mean a reduction by 60-70%. Even if this were to lead to successful regeneration it would show many of the negative aspects of the TSS as applied in Ghana which was described in the foregoing pages.

When we compare Table 4.6 and 4.7 then the following features are striking:

- A stock of about 600-550 before logging and about 350 after logging an average of 8 to 18 trees (Jordan 1985) means that logging damage must have been very severe!
- Total number of commercial trees per ha must have been heavily reduced by the logging.

Table 4.7 Post-logging but pre-treatment basal area and stock of trees ≥ 10 cm drh for four Permanent Sample Plots in Gola National Forest. Based on Poelker & Wolf (1989).

	PSP1	PSP2	PSP3	PSP4
Total basal area	23.8 m²	21.1 m²	23.3 m²	23.0 m²
Basal area commercials	8.2 m²	3.9 m²	5.5 m²	3.5 m²
Total stems all species	332/ha	311/ha	365/ha	338/ha
Total comm. stems per ha	56/ha	34/ha	58/ha	36/ha
Total comm. stems > 50 cm	17/ha	9/ha	10/ha	7/ha
PCTs 20 - 40 cm drh class	17/ha	7/ha	6/ha	9/ha
PCT standard according to Wöll	-	-	-	-

In the residual forest about 11 trees of commercial species exceeding 50 cm drh are present. These trees are the major constituents of the second harvest in 25 years time. According to Jordan (1985) a yield of 25-35 m^3 would be realistic.

Table 4.8 Log volume table for standing trees. Single log volume figures (m^3) per diameter class (cm drh). Based on Sachtler (1968).

	45	55	65	75	85
Calpocalyx aubrevillei	0.9	1.7	2.4	3.2	4.2
Gilbertiodendron preussii	1.1	1.8	2.5	3.5	4.5
Hallea ciliata	1.2	2.2	3.4	4.8	6.4
Heritiera utilis	1.1	2.1	3.3	4.5	5.9
Lophira alata	1.3	2.4	3.6	5.1	6.6
Average single tree volume	1.1	2.0	3.0	4.2	5.5

To obtain a yield of 30 m^3 at the next felling, approximately 10 stems of a diameter of 65 cm drh are required. For Grebo, Poker (1989) found an average annual diameter increment of 0.5 cm after logging, without silvicultural treatments. For Gola, Finke (1989) found an average annual diameter increment of 0.4 to 0.6 cm after logging, again without treatment, and an increment of 0.6 to 0.7 cm when treatments were applied in addition. This is confirmed by Krumah (1970, in Jordan 1985) who found an average annual diameter increment of 0.65 cm for the 26-44 cm drh class of commercial species over the period 1966-70 in Gola-North forest reserve, Sierra Leone.

Accepting this data would mean that the approximate diameter increment over a felling cycle of 25 years would be 15 cm drh, at an average annual diameter increment of 0.6 cm. A residual stock of 11 trees exceeding 50 cm drh which remained after logging may be some basis of a next potential yield, but some mortality should also be expected, and a post-harvest stand of more than 11 commercials per ha larger than 50 cm drh are needed to give the predicted yield of 30 m^3. This could only apply provided that the silvicultural treatments stimulate increments at the above mentioned rate. It is doubtful if the minimum required number of commercials of more than 50 cm drh will be present. Moreover, the 11 trees that constitute the residual crop are trees of very large diameter as well as some just above the limit. The 45 - 65 cm drh class trees are under-represented and their numbers will probably not provide a sustained yield over several felling cycles.

A polycyclic system with a felling cycle of 50 years, and reduced harvests in the second and third harvest is clearly more realistic than the present felling cycle of 25 years.

Kpelle: logging damage and the effect of silvicultural treatment after logging. The physical conditions in Kpelle National Forest are similar to those of the Gola National Forest. Logging activities by BOMIWOOD began in 1985 and the treatments in Kpelle were the same as for Gola. Since no separate report on Kpelle exists data from Weingart's (1990) report on the Forest Management Unit of the Bomi Hills for both Kpelle and Gola will be discussed here. Whenever plots are mentioned, the 6 1-ha plots in Gola and 4 1-ha plots in Kpelle are meant. At both sites half of the plots consisted of 'control' plots where no post-logging treatments were applied.

The number of trees of primary forest (about 620 stems ≥ 10 cm drh per ha) was reduced by half to c. 336 stems per ha by logging. The damage was mainly confined to the 10 - 20 cm drh class. The pre-logging basal area was 31 m^2 ha^{-1}, and this was reduced to 18.1 - 24.6 m^2 ha^{-1} (av. 22.0 m^2 ha^{-1}) by logging. The basal area reduction of 1.7 - 2.1 m^2 ha^{-1} (av. 1.9 m^2 ha^{-1}) by cutting selected trees caused a further basal area reduction of 6-7 m^2 ha^{-1} by felling and skidding damage. Such high losses can be explained by the steep condition of the terrain in Gola Forest. Under such difficult conditions a strict damage-controlled logging system as decribed by Hendrison (1990) for South American tropical moist forest on rolling terrain may only partly help reduce damage.

The stand volume after logging ranged from 165 to 221 m^3 ha^{-1} (av. 200 m^3 ha^{-1}). Assuming a stand volume of 280 m^3 ha^{-1} for primary forest as standard and volume taken as 10 - 20 m^3 ha^{-1} then felling and skidding damage accounted for a further (very high) 60 m^3 ha^{-1}.

Felling damage occurred in 33% of the forest area and a 13% loss of potential regeneration surface to skid-tracks, loading bays and logging roads had to be accepted according to Weingart (1990).

The number of PCTs were found to range from 17 to 22 trees per ha (av. 19 per ha). This is only slightly below Wöll's (1986) minimum of 20 per ha. The PCTs were mainly *Heritiera utilis* and *Gilbertiodendron preussii*. The annual diameter increment for PCTs ranged from 0.3 to 0.7 cm (av. 0.5 cm) for logged but silviculturally untreated plots and from 0.7 to 0.8 cm (av. 0.7 cm) for logged and treated plots. This confirms the data for Gola found by Finke (1989). Treatments were confined to liberation thinning. The average diameter for PCTs was found to be 19 cm drh, and the average annual increment rate calculated for PCTs was 0.42 m^3 ha^{-1} for treated and 0.36 m^3 ha^{-1} for untreated plots. In the authors' opinion the resulting extra increment is not worth the effort put into the silvicultural treatments.

The concession of Gola and Kpelle National Forest was sold afterwards to Sierra Leone and exploitation was continued in a way similar to salvage felling, rendering the management plans so far formulated rather pointless.

Civil war and its consequences. Information acquired by operating the pilot projects in Liberia has never been applied on a large scale. The authors are not aware whether plans similar to those presently being worked out in the Côte d'Ivoire (see Yapo project) existed in Liberia during the late 1980s.

The civil war which began in December 1989 was still going on at the time of writing this book. The war is bound to have serious consequences for forestry in the country for many years to come, as it has been confirmed that several Liberian foresters have been killed in this national tragedy. Mr. Charles Taylor's National Patriotic Front of Liberia (NPLF) gained control of most of the country outside the capital Monrovia. European and American companies resumed trade or renewed lucrative concessions with the NPLF.

According to Block (1992) France, Germany, the U.K., Italy, The Netherlands, Spain and Greece imported 142,900 m^3 roundwood equivalents from the part of Liberia commonly referred to as ‘Taylorland’. At the moment two FDA organisations exist, one in Monrovia which is not effective and one in ‘Taylorland’, and both were formed by old FDA employees. Exports take place from the harbours of Buchanan, Harper, Greenville and sometimes from San Pedro (the Côte d'Ivoire). Over 200,000 m^3 roundwood equivalents were exported between November 1991 and October 1992 according to figures from the African Economic and Intelligence Unit in London. France is the main destination for roughly 68% of all Liberian timber exports. All these operations fuel the civil war and allow an uncontrolled creaming of the forest to take place with all its disastrous consequences.

After the end of the civil war the FDA will have to be reorganized and it is to be hoped that past mistakes will not be repeated. A serious drawback will be the fact that FDA headquarters were burnt down, including the archives. Essential reports have been lost forever and, when the authors tried to retrieve some of the German reports in Germany, they were no longer to be found.

4.4.2 Different refinement regimes: options chosen in the Côte d'Ivoire

When the authorities in the Côte d'Ivoire were confronted by the alarming deforestation figures for the early 1970s and the inadequate reforestation efforts made to counter this trend they had to do something at short notice. The necessity of managing the permanent forest estate in the future adequately in future made them realize that it was vital to understand the dynamics of the natural forest. The outcome was the establishing of three experimental sites where forest dynamics were to be followed after silvicultural treatments.

These natural regeneration trials were initiated in 1976 and inspired by a planned, but never executed, FAO-project (Cailliez 1974) in the moist forest of Peninsular Malaysia in 1974 (Bertault 1986, Maître 1986b, Maître 1991, Aïdara 1992). Whitmore (1984) gives some brief information about the circumstances and developments in Peninsular Malaysia as does Schmidt (1991). Suffice it to say that the ecology of the Dipterocarp forests in South-East Asia is quite different from the ecology and therefore, the silviculture in West Africa. Nevertheless, some influence has been felt.

Previously, a large number of experimental and trial plots had been set up in the Côte d'Ivoire, but these were, as Maître underlined in 1991, almost invariably too small in area and had no links between them in the absence of a basic methodology and agreed research design. Consequently there were few practical possibilities for either the interpretation of or a comparison of the data collected.

Since the early 1970s new research work had begun in a number of tropical forest regions which concentrated their efforts on experimental areas with large size plots, and with the greatest possible number of replications in spatial terms, measurements of simple parameters (e.g. diameter and position of trees) and computer data processing. This had been, for example, the case in Suriname since 1967 (de Graaf 1986), in Ghana (this book) and in Liberia (this book). The experiments in the Côte d'Ivoire here described were designed in their own way.

The Irobo, Mopri and La Téné experiments It was in view of the above that three series of silvicultural pilot projects were initiated to study forest dynamics in the Côte d'Ivoire in 1976 by SODEFOR in cooperation with French research workers. The overall design and the initial results of these trials were presented by Mielot & Bertault (1980), Maître & Hermeline (1985), Bertault (1986), Maître (1986a, 1986b, 1991) and Aïdara (1992) on whose work the following is based.

The management principles aimed at inducing a more homogeneous structure to the stand by the manipulation of natural regeneration. A study of the proposal for the FAO-project on Peninsular Malaysia and the experience gained with APN during the 1950s induced steps to be taken as described below.

According to Bertault (1986) the failure of APN was attributed to inadequate intervention in the canopy. The intervention proposed was, therefore, far more radical than that of APN. The study focused on stems ≥ 10 cm drh. The principal aim was to elucidate stand dynamics as affected by relatively simple, low-cost treatments -as opposed to those the APN system offered- that could be undertaken on a large scale. As regrowth at ground level was known to be difficult to manipulate and control, no particular treatment was envisaged for improving seedling regeneration. Favourable or unfavourable regeneration growth was thought to be determined by the intensity and type of silvicultural treatment at a higher level in the vertical strata.

Description of the research sites. The project covers 1200 ha and comprises three separate sites each consisting of a block of 400 ha, subdivided into 25 plots, each of 16 ha, surrounded by a 500 m wide bufferzone. In each plot only the central 4 ha were monitored (see Fig 4.6). The three sites are characteristic of the principal ecological zones of the rain forest: Irobo in wet evergreen forest, Mopri in the transitional zone of moist evergreen and moist semi-deciduous forest formations and La Téné in moist semi-deciduous forest.

To enable comparison to be made with a forest in which the structure and composition were still intact, four 4-ha plots were established in the Divo botanical reserve in 1977. No logging activities could be traced back in this reserve which is located some 30 km north-west of Mopri. The stand figures are described by Mielot & Bertault (1980) and incorporated in Table 4.9. It is surprising that of the later authors dealing with these three pilot projects only Catinot (FAO 1989) presented some of the Divo figures. The extent of the impact of the treatments on the forest structure has to be determined using data from unlogged forest such as found in Divo.

Commercial exploitation had taken place before site selection. Van der Hout & Oesterholt (1985) stated that FC Mopri had previously been selectively logged at least three times. This exploitation reflected standard logging practice as applied to forests all over the Côte d'Ivoire. Only in La Téné were ten plots considered to be over-stocked, and here additional logging of all commercial species ≥ 80 cm drh took place. The average extraction of 53 m^3 ha^{-1} over these 160 ha was considered to be heavy, so no additional treatments were applied to these 10 plots (Bertault 1986).

Table 4.9 The basal area and stock of trees ≥ 10 cm drh after logging for Irobo, Mopri and La Téné (La Téné before additional logging) and the Divo botanical reserve never previously logged. Modified from Mielot & Bertault (1980).

	Irobo	Mopri	La Téné	Divo
Total basal area	24.6 m^2/ha	22.6 m^2/ha	27.9 m^2/ha	29.6 m^2/ha
Basal area commercials	9.0 m^2/ha	13.5 m^2/ha	20.5 m^2/ha	24.3 m^2/ha
Total volume	251 m^3/ha	225 m^3/ha	301 m^3/ha	348 m^3/ha
Volume commercials	98 m^3/ha	162 m^3/ha	257 m^3/ha	294 m^3/ha
Total stems all species	397/ha	277/ha	306/ha	454/ha
Commercial stems	96/ha	146/ha	204/ha	308/ha

If we compare the figures for commercials with those found in Liberia (Tables 4.6 and 4.7) then the relatively high share of these species is striking. This is because of the fact that, for this study, the commercial species were those rated merchantable, i.e. either those actually in commercial use or some lesser-used species considered to be technically viable. The number of such species is in excess of 70 in the Côte d'Ivoire, and some 42 were present within the various study areas (see Appendix IV). This is radically different from the approach described for Liberia.

Silvicultural treatment on the three sites was confined to refining (poison girdling and some additional climber cutting). Three intensities were chosen which resulted in an additional basal area reduction of either 20%, 30% or 40%. Refinement started with the largest non-commercial trees (where necessary some less interesting commercial species were included) until the desired percentage of elimination had been reached. These operations started in December 1977 and lasted until May 1979. Initial refinement operations proved to have an efficiency of ± 75% of the foreseen basal area reductions, and an after-treatment was given in 1979 to reach the goal set (Mielot & Bertault 1980). The trees died off in from 6 months to two years and decomposition could take up to 15 years, as some 'candles' (i.e. dead trees without crowns) could still be seen during a field visit by the first author in March 1992.

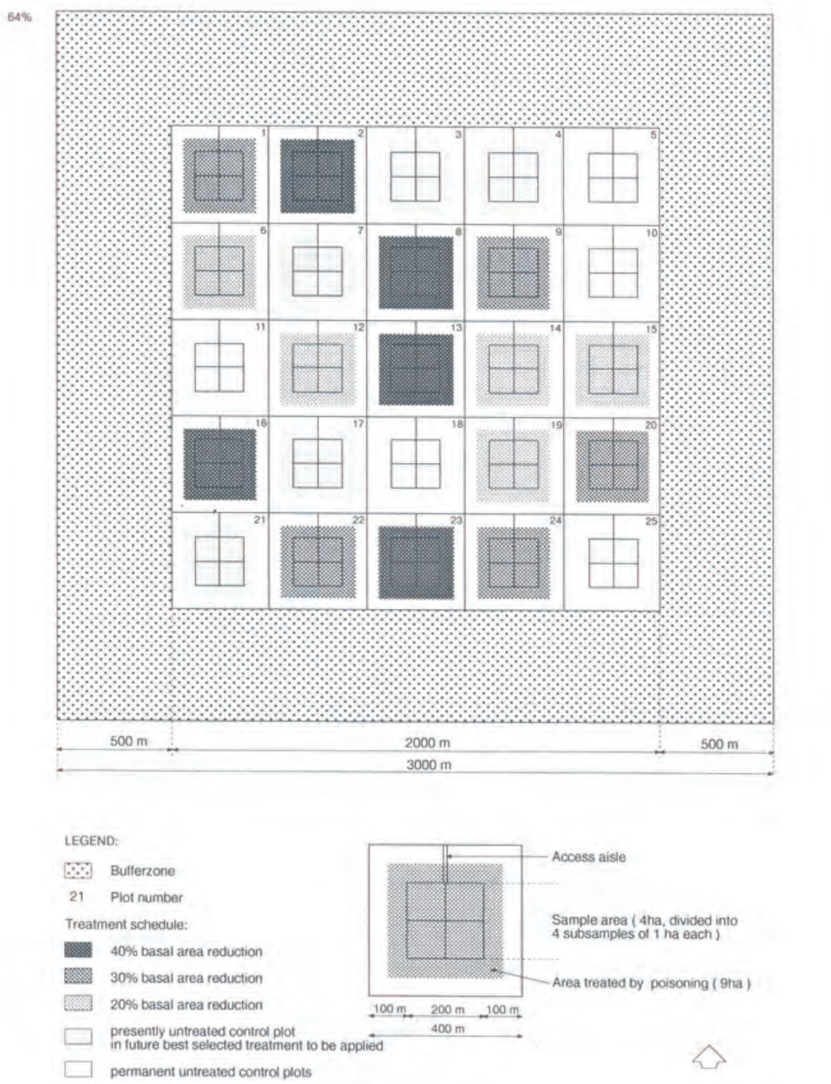

Figure 4.6 Layout of experimental plots and treatments in Mopri, Côte d'Ivoire, as executed in 1976. Source: SODEFOR records.

The final outcome of first treatment evaluation was that it proved to be difficult to distinguish and group the resulting basal area reductions. Instead of forming groups of plots with equal basal area reductions, the remaining basal areas were put into groups within certain ranges, which does indeed make more sense, as the main concern of a forester should be the condition of the remaining stand and not what has been removed.

- 35 plots were refined. In Mopri and Irobo 7 plots each were heavily refined, with the following remaining basal areas (10 cm drh lower limit): Mopri 11 -14 m² ha^{-1}; Irobo 15 - 17 m² ha^{-1}. Moderate refinement took place at 8 plots in Mopri with remaining basal areas of 16 - 18 m² ha^{-1}, in 8 plots in Irobo with remaining basal areas of 17 - 22 m² ha^{-1} and in 5 plots in La Téné with remaining basal areas of 15 - 21 m² ha^{-1}.
- 30 control plots remained untreated (10 on each research site).
- 10 plots in La Téné were logged-over.

Measurement of 50 trees/4 ha (one compartment) took place every 6 months with permanent dendrometer ribbons. Initially, trees were selected at random only from the commercial species in the 10 - 60 cm drh class. In total 3,750 trees were (and still are being) measured representing 14 tree species with over 100 sampled trees each, 12 tree species with between 50 - 100 sampled trees each and 10 tree species with less than 10 trees represented. The 18th enumeration was conducted during the visit of the first author in 1992.

Every two years all trees ≥ 10 cm drh were measured, but these measurements were not completely reliable because of inaccuracy. The results presented in the next chapter are those that became available 4 years after silvicultural treatment for trees over 10 cm drh and 7 years after the silvicultural treatment of 40 0.1-ha sub-plots in which regeneration assessment was carried out on saplings and poles of 2 - 10 cm drh (10% diagnostic sampling).

Main results and remarks. Some of the more striking results are presented here according to Maître (1986a), but the views of the authors, where these differ, will also be expressed:

- All commercial species responded favourably to the treatments.
- Logged-over plots showed better performance than control plots, but less good than the one provoked by the moderate refinement. The chablis (canopy gaps) were less evenly distributed within the forest stands where additional logging had been carried out than were the canopy gaps in refined stands.
- The opening of the canopy had most effect on small and medium-sized trees, which compete fiercely for light.
- Commercial species responded more favourably than did non-commercial species to treatments, even on an individual level. It should be noted that most non-commercial species had been removed from the stand, so hardly anything could be reliably reduced as to the dynamics of those species.

- Volume increments for stems of commercial species over 10 cm drh were:
  0.7 - 1.8 m^3/ha/yr for control plots about 2.5 m^3/ha/yr
  for logged-over plots (La Téné only)
  2.9 - 3.6 m^3/ha/yr for plots with moderate refinement
  2.2 - 2.9 m^3/ha/yr for plots with heavy refinement

Moderate refinement here is rated as reductions to 16-22 m^2 ha^{-1} basal area remaining, and heavy refinement as reductions to 11-17 m^2 ha^{-1} basal area remaining. Maître (1986a) did not distinguish the two refinement regimes as those used in the listing given above but, from Maître & Hermeline (1985), we were able to reconstruct the difference. From the volume increments presented it is clear that the moderate refinement regimes responded more favourably. This is because the mortality rates of the compartments with heavy refinement regimes increased dramatically, especially for trees over 25 cm drh, while recruitment and growth rates were almost equal for both treatments. The cause of the heavy mortality on heavily refined plots is not given by Maître, but could well lie in the considerable change in the microclimate after extensive opening of the canopy.

The experimental design has some weaknesses. For instance, the data gathered says little about the dynamics of individual species, treated or untreated, as the sampling intensity would seem to be insufficient for this.

The intervals between the 20%, 30% and 40% refinement regimes were quite narrow. A differentiation into 20% and 50% refinement regimes would have been more valuable for the experiment. The conclusion that hardly any difference exists between the heavy and moderate refinement regimes is therefore not surprising.

Intervention in the forests can be characterized as severe, both in terms of treatments and of additional logging. To demonstrate this the Mopri forest reserve figures will be compared with those of Divo botanical reserve (see Table 4.10). These two reserves are only some 30 km apart.

Table 4.10 Basal area and volume stock of trees ≥ 10 cm drh after treatments for Mopri and unlogged Divo. Data for Divo modified after Mielot & Bertault (1980), and for Mopri modified from Maître & Hermeline (1985).

	Mopri A_0				Mopri A_4				Divo			
	G	Gc	V	Vc	G	Gc	V	Vc	G	Gc	V	Vc
Control	21.7	14.2	220	149	22.4	14.8	228	156	29.6	24.3	348	294
Moderate refining	16.6	15.1	172	159	18.0	16.4	185	172				
Heavy refining	12.4	11.3	125	116	13.2	12.2	133	125				

A_0 = year of treatment; A_4 = 4 years after treatment
G = basal area (m^2ha^{-1}); V = volume (m^3ha^{-1}); c = commercials

The basal area of 29.6 m^2ha^{-1} for the unlogged Divo botanical reserve falls well within Dawkins' (1959) classic range of 23 - 37 m^2ha^{-1} for African lowland moist forest.

During various visits to Mopri forest reserve by the authors, in 1987 and early 1992, the heavily refined compartments showed a very open upper-storey and hardly any regeneration. Few trees in the 10-20 cm drh class were seen and a blanket of herbs (e.g. Marantaceae) with some lianas covered large areas and appeared to be hard for seedlings to penetrate. The stand density of 12.4 m^2ha^{-1} after the heavy refinement -a more than 50% reduction of basal area as compared with stand data from Divo botanical reserve- seems to be too low for the tree strata to fully dominate the ecosystem. Plot records indicate that rather than natural regeneration being hampered by the interventions, it would be slightly assisted. It nevertheless remains to be seen as to whether the recruitment will guarantee sustained yield in the future, considering the high level of mortality. The data about mortality do not allow firm conclusions to be made.

The semi-permanently open structure seen in the Mopri plots, with the return to a normal closed forest structure obviously blocked by some internal cause, may be seen as a warning against heavy refining in this type of forest. It could be that low rainfall in this zone (about 1500 mm/yr) makes trees compete less successfully with herbs.

In the far wetter forests of Suriname (South America) the second author has observed a vigorous and rapid return to closed forest after a single heavy refinement, even down to a minimum basal area of 5 m^2ha^{-1} or less (de Graaf 1986, see also Fig 5 in Schulz 1967). In that biome an important role was played by the ubiquitous pioneer tree species which require strong light for germination and, moreover, the forest had only been logged once and then only lightly. Problems with climbers and herbal weeds arose only after repeated and very severe interferences which ultimately broke the dominance of the trees. In the plantations with *Pinus caribaea* in Suriname, however, weed and climber problems were endless, the (exotic) pine trees not being able to shade out herbs, shrubs and climbers or to otherwise fully dominate the undergrowth after crown closure had been achieved.

Traditionally, opening the canopy of tropical moist forest provokes problems with climber growth but in this case in the Côte d'Ivoire it seemed that the shade-tolerant character of most of the climbers encountered and the additional cutting of climbers did not lead to climber growth smothering the regeneration. One of the few more detailed studies on African lianas by Jongkind & Lemmens (1989) describes how, in the undergrowth of moist forest in Gabon, small shrubs of several common Connaraceae species often show hardly any growth for many years. When the canopy of the forest opens these shrubs rapidly produce long shoots and appear to be lianas. The same phenomenon is reported for other lianescent species. These shrubs would not be removed in silvicultural operations since they show their lianescent properties only afterwards. Too drastic opening of the canopy may lead to flowering instead of producing shoots.

The abundance of lianas seems to have nothing to do with the existence of gaps. Caballé (1986) found that increasing gap surfaces showed decreasing numbers of lianas. This might lead to the conclusion that the preferred small gap sizes for the regeneration of climax tree species could lead to increasing problems with lianas. But according to Caballé (1986), the lower numbers of lianas in large gaps could be attributed to a lack of support trees rather than to the light regime.

In all these discussions about liana behaviour a clear distinction has to be made between the various stages in the development of lianas. As previously stated the seedlings of lianas may appear to be 'normal' tree seedlings, waiting in shade for a chance to grow, and when in this form they may not easily be recognized as liana species. More studies will have to be conducted in which the character (strategy; temperament) of the liana species is investigated, as well as their abundance and composition before and after treatment and their ecological role for wildlife.

Maître (1991) describes the experimental plots in 1980, four years after treatment as having a more normal appearance with the 'candles' (dead trees) mostly having disappeared and the stand consisting of sound trees without climbers or drooping crowns. The upper-storey simply became more open with an abundance of valuable species, particularly after refinement. This probably applies only to the compartments with a moderate refinement regime as discussed above.

In the lightly refined stands the shrub *Scaphopetalum amoenum* can form a dense, almost monospecific, under-storey by means of vegetative layering which blocks the regeneration of other species. This shrub which looks similar to the cocoa shrub forms an under-storey that resembles to a cocoa plantation. This problem was noticed by Van der Hout & Oesterholt (1985) in the initial stages of the silvicultural experiments and later also by the present first author in the Mopri forest reserve in 1992 and in the Tano Nimri forest reserve, Ghana, in 1990. The same phenomenon was reported by Hall & Swaine (1981, p. 55) in Ghana and de Rouw (1991, p. 185) in the Taï region, east Côte d'Ivoire. According to Guillaumet (1967, p. 80) the plant community is related to soils derived from schists. Removal of this dominant under-storey species might be necessary to allow for the regeneration of other species.

In the Irobo experimental plots the regeneration counts for the 2-10 cm drh class showed that in comparison with the control plots, silvicultural intervention had scarcely modified the floristic composition of the understorey. This has to be attributed to the effects of the seed- and seedling bank. In the treated plots the number of poles and saplings was 17% higher than in the control plots.

The commercial species represented only 7% of the 2-10 cm drh class in Irobo. One third of them consisted of only two species, namely *Heritiera utilis* and *Scottelia klaineana*. This is consistent with the floristic composition of the upper-storey. If we take only the number of extra recruited commercial species this works out at 23 stems. The more valued species were poorly represented in this low stratum however, only 16% of individuals belonging to species capable of growing to a diameter of 40 cm or more.

In the under-storey the treated plots in Irobo showed a light, (only 14%) reduction of climbers (diameter ≥ 2 cm) compared with the control plots. The regeneration class of 2 - 10 cm drh showed one climber per 5.3 stems in control plots as against one climber per 7.2 stems in treated plots.

Eight years after silvicultural intervention Bertault (1986) found only a few climbers per ha in trees of over 10 cm drh in the control plots and almost none in treated plots, due to systematic climber cutting at the moment of intervention. He also noted that most climbers had a shade-tolerant character, as opposed to the general belief that light-demanding climbers would dominate and smother natural regeneration.

A management system based on the described practice of interventions was economically justified. Schmidt (1987) presents the estimated cost ratio over 30 years for this system as compared with tree plantations:

- natural forest management produced 25 m^3 per ha at a cost of 140 US$, which is about 1 m^3 produced for 5.6 US$.
- tree plantations produced 250 m^3 per ha at a cost of 1,860 US$, which is about 1 m^3 produced for 7.4 US$.

Differences in revenue will be even larger, as the technical properties and corresponding prices of the timber produced by tree species in natural forest management are usually better than those of timber produced by most species in tree plantations. If a wider range of species from the natural forest can be introduced in local markets, the economics of the operation will improve.

This outlook is certainly realistic for the Côte d'Ivoire. In 1987 the government reduced the annual cut of 4 - 5 million m^3 which had been permitted since the early 1970s, to 3 million m^3 roundwood equivalent. Local consumption stands at 1.9 million m^3 and can be satisfied completely. The West African situation with its high population densities will offer a good opportunity for the introduction of lesser-used (‘secondary’) species on the local market. According to Aïdara (1992) the general government policy should be to promote a combination of intensified exploitation and refinement, as this combination would best optimize the production potential of the natural stands (see also Fig. 4.7). Such silvicultural intervention is now envisaged for some of the control plots of the three research sites.

Conclusion. It is the moderately refined compartments which are most promising since their productivity was doubled when compared with untreated compartments. Research efforts in future should be concentrated on stand densities to remain instead of on basal area reductions.

Productivity of natural stands can be raised considerably by silvicultural treatment, even when compared with forest plantations in the Côte d'Ivoire where production level stands at 4-5 m^3ha^{-1} per year for *Tectona grandis* and at 7-8 m^3ha^{-1} per year for *Terminalia ivorensis.*

Schmidt's (1987, 1991) description of the projects here discussed deviates from the data presented here. Averages and increment data in his report seem exaggerated.

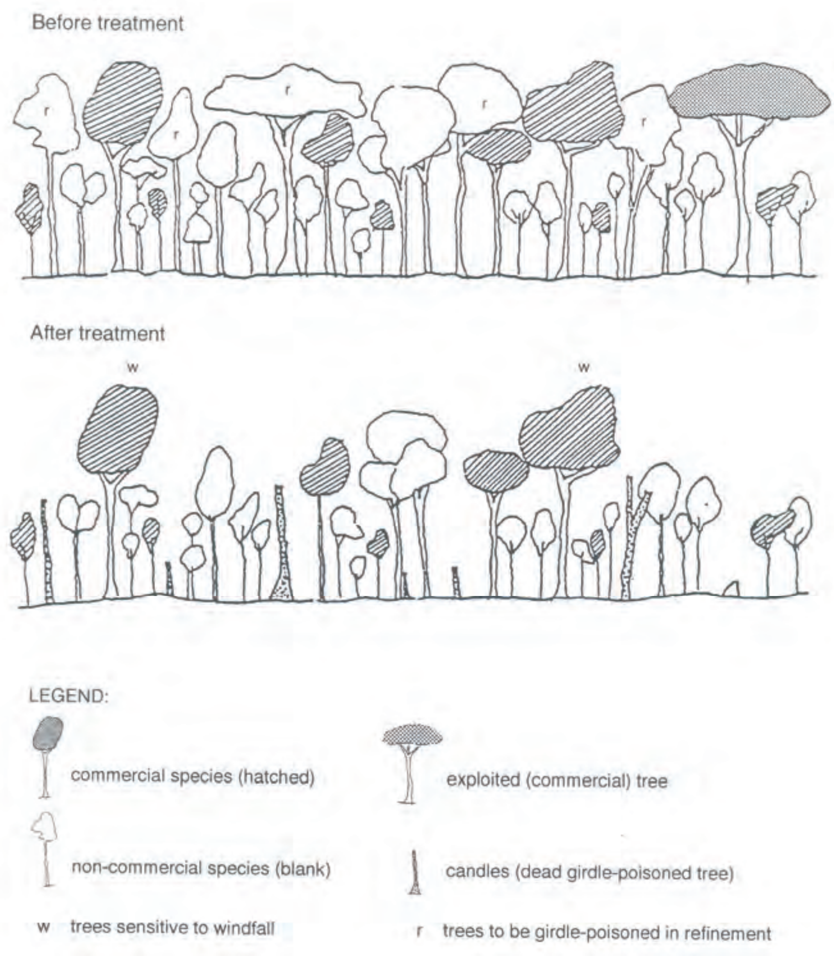

Figure 4.7 Profile of forest before and after treatment. Treatment consists of exploitation and refinement. The optimal situation is depicted here. Modified from Maître (1987, 1990).

4.4.3 The Yapo project

The promising results achieved in the three pilot projects prompted the European Community to finance a project in the 10,000 ha of evergreen forest in the Yapo forest reserve between 1983 and 1988. Similar ecological and environmental conditions as in Irobo are found here. The last exploitation series was in 1982, before treatments commenced (Cabrera Gaillard 1988).

The total forest area available at Yapo was subdivided into compartments (Unités Primaires) each measuring 250 ha. 27 compartments (UP1 to UP27) with a total of about 7000 ha forming the experimental site. Between 1984-87 a forest inventory and a grouping of the compartments according to site conditions into similar exploitation r-egimes was undertaken (see Fig. 4.8 and Table 4.11). In addition, refinement consisting of climber cutting and poison girdling as practised in the earlier experiments was done to reach a uniform basal area reduction of 30% by felling and refinement combined. A 30% basal area reduction could be reached by uniform refining killing all trees of non-commercial species ≥ 30 cm drh, as confirmed by the figures in Table 4.11.

Table 4.11 Yapo exploitation regimes and stock of commercial species. Modified from Cabrera Gaillard (1988)

Groups (compartments)		Commercial species				nc species	All species
	Vc ≥ 50 cm	Nc ≥ 50 cm	30-50 cm	10-30 cm	Gc	Gnc ≥30 cm	G
Group 1 (4)	13.2 - 20.0	3.8	4.7	9.7	2.4	9.7	26.7
Group 2 (8)	11.2 - 13.5	2.8	5.3	10.9	2.0	8.7	27.0
Group 3 (7)	11.9 - 14.6	2.6	3.5	7.6	1.7	9.1	28.1
Group 4 (8)	10.5 - 13.4	2.2	2.8	5.6	1.5	8.6	27.7

V = volume (m^3ha^{-1}); N = tree numbers per ha; G = basal area (m^2ha^{-1}); c =commercials; nc = non-commercial (secondary) species

It was found that UP4, 8, 22, 27 of group 1 were well stocked and exploitation took place within the timespan of one year in 1989-90. The stems were sold at the highest bid ‘à pied’. Sixteen sample plots of 4-ha each were selected to give a sampling intensity of approximately 1%.

In 1986 16 permanent sample plots were selected for a detailed study with 4 untreated control plots and 12 treated plots. Each sample plot covered 4 ha in which biannual recording of all trees ≥ 10 cm drh took place. In each group one untreated control plot and three treated plots were established. This resulted in a 1% sampling intensity. Cabrera Gaillard (1988) presented some 7 of these plots and one of them cannot even be found on the map in Fig 4.8, as its place could not be traced on the original maps. The remaining 9 plots had to be measured during 1989, but we were not able to trace the results.

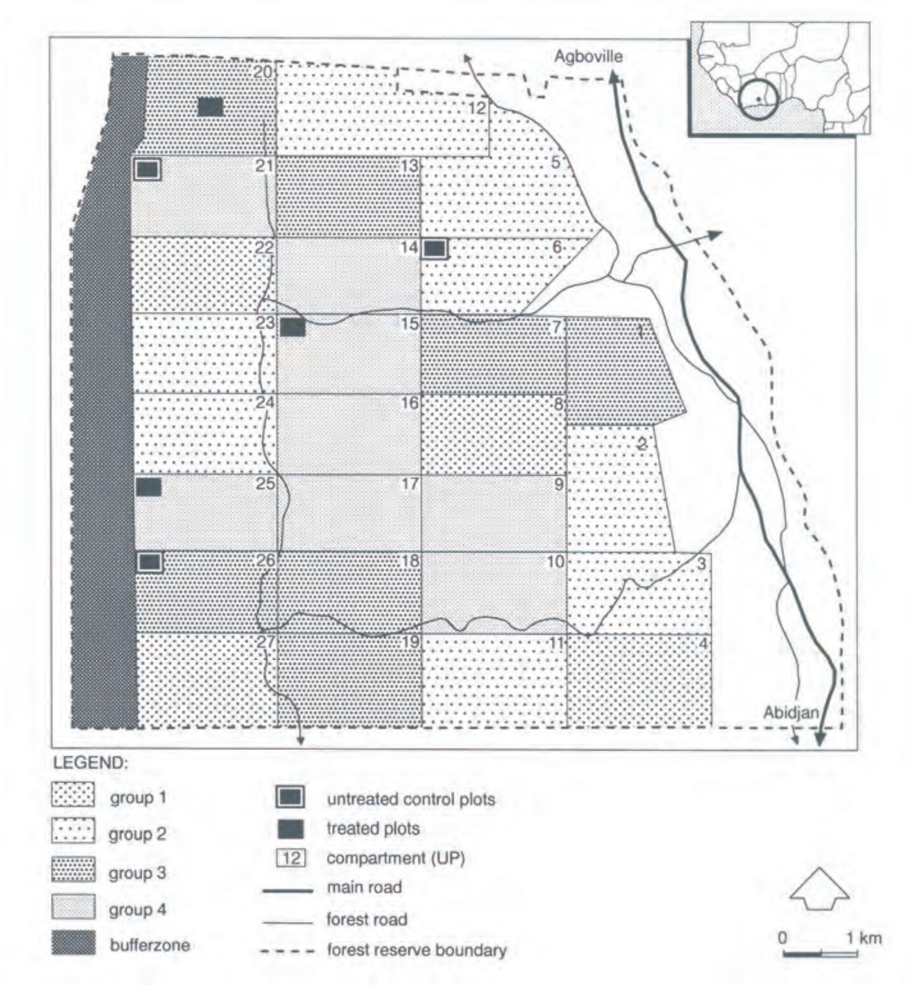

Figure 4.8 Layout of experiments at Yapo forest reserve, Côte d'Ivoire. After Cabrera Gaillard (1988), with additional information from a map by SODEFOR made in 1986.

The exploitable volume at Yapo was well below the average extraction of 53 m^3ha^{-1} as found at La Téné. It is not certain that the stock of commercial species is sufficient to guarantee sustained yield in future for this group as defined for the Yapo project. If we take the maximum annual diameter increment in the 30 - 60 cm drh class which averaged 0.5 cm in Grebo (Liberia) to be also realistic for the Yapo situation, then the felling series would be 40 years to pass the 30 - 50 cm drh class. For a yield of 20 m^3 some 5 stems would be required and mortality should be nil. From the figures of Table 4.11 and 4.12 these assumptions do not seem realistic.

Table 4.12 FC Yapo: standing volume (m^3ha^{-1}), development of volume determined by increment, ingrowth, mortality and net increment ($m^3ha^{-1}yr^{-1}$) of trees $\geq$ 10 cm drh of commercial tree species in 4 treated and 3 control plots. Modified from Cabrera Gaillard (1988).

	Volume	Increment	Ingrowth	Mortality	Net increment
Treated	131.9	2.0	0.1	1.6	0.5
Control	132.1	2.1	0.2	0.6	1.7

The operational costs were 200 US$/ha in 4 years, which is estimated to be higher than for routine management in the future. A new system of selling standing trees was introduced which resulted in an average price of 11 US$/$m^3$, making a yield of 12 m^3/ha to give a return of 132 US$/ha. This price is very low when compared with the price of sawn timber and does not reflect the actual value of the raw material for industry. In developed economies, timber logs of locally grown species of such or even lower quality fetch at least ten times this price. Pricing in Yapo was most probably heavily influenced by the give-away prices common to concession contracts.

Next to timber sales, substantial financial returns came from the sale of firewood, from sale of small and medium-sized trees of *Funtumia africana* and *Discoglypremna caloneura* for match sticks and of *Garcinia kola* wood for native toothpicks. Stems of *Funtumia africana* and *Discoglypremna caloneura* were exploited with a lower felling limit of 35 cm drh. The 1989 production amounted to some 900 m^3 and gave a return of 20 US$/$m^3$.

Optimistic ideas about future successes with this type of management should recognise the hard fact that such a system of selling timber on stump, to be harvested by the buyer, requires sound control of the operations for instance by the forest service. This proved to be difficult in the Yapo project. During operations a number of valuable *Khaya* mother trees were taken by the logger without permit. Control has its price and, what is more, needs preparation to provide the trained personnel needed.

4.5 Evaluation of ongoing pilot projects

4.5.1 Potential Crop Trees

The projects in Liberia concentrated on the numbers of Potential Crop Trees and on exploitation damage which proved excessive, probably because of untrained fellers and machine operators on difficult, steep terrain. The frequently too low numbers of Potential Crop Trees in Liberian studies may be ascribed to the quite restricted number of species accepted as being commercially valuable.

Pilot projects in the Côte d'Ivoire were occupied more with improving the increment of the very few Potential Crop Trees left after the repeated logging activities that are usual in the Côte d'Ivoire forest reserves. Results from both series of projects are helpful in finding better ways for improving management results.

Working with PCTs may indeed be the best method for safeguarding continuity in the representation of commercial species in the ecosystem, rather than relying on small size regeneration in systems that apply clear felling. The high mortality rates expected for small regeneration make it risky to invest much in such systems. Furthermore it has been proven in the Côte d'Ivoire and Liberian experiments that increment per tree can be considerably raised by silvicultural treatment.

4.5.2 Sustained yield or sustainable management

The very technical approach to finding solutions for silvicultural and forest management problems as demonstrated in the pilot projects discussed above, seeks mainly to improve productivity and to cause less harvesting damage in the forest. Such an approach may result in better solutions being overlooked. For instance, one of the first problems seemed to us that sustained management in these forests was often formulated as obtaining just plain sustained yield which then was and is often crudely defined as periodically harvesting the same quantity and quality of timber.

From the commonly accepted definition of sustainable forest management by ITTO (1992), we can see the complexity in its entirety: ‘Sustainable forest management is the process of managing permanent forest land to achieve one or more clearly specified objectives of management with regard to the production of a continuous flow of desired forest products and services without undue reduction of its inherent values and future productivity and without undue undesirable effects on the physical and social environment.’

Such a definition gives much scope. What the authors here find most important in the silvicultural approach is that the forest ecosystem can, in the long run, survive everything that is done to it. Managers have to restrict their interference in the forest to what the ecosystem can with credibility be assumed to bear. Reduced yields in following felling cycles are not to be dismissed out of hand if they were better for the ecological functioning of the forest.

In sustained management the simple assumption that the first yield of logs -i.e. trees- taken from the forest was ‘reasonable’ might just be wrong. It may have been too much in terms of keeping the ecosystem functioning well within the limits set by the manager. To then fix that first yield as a measure for the next yield in an attempt at sustained management, then requires the impossible of the ecosystem.

The cautious and conservative approach as followed in the permanent forest estate of Ghana appears to be a better one with many silvicultural opportunities left open for the future. Sound timber trees left standing should not be seen as being a waste or an economic loss, but more as an opportunity left for a further step in forest management and as a future harvest for later generations. More experimenting with silvicultural treatments would be advisable for Ghana in order to help improve future productivity.

4.5.3 Increment calculations

Clear information should be sought from studies on forest dynamics about the potential productivity of domesticated forest, not a plundered and semi-destroyed forest (nor an unlogged forest) and the limits found should be applied in forest policy and individual forest area management plans. Attempts to domesticate the forests in West Africa should take account of the differences in site conditions such as those along the soil catenas (the soil 'gradient' along the slopes) that have such a large influence on species composition and potential productivity. The usual simplistic planning of secondary roads and skidtrails for log transport preferably on the easiest terrain and often on just the most productive parts of the catena, should also be re-thought. The study of van Rompaey (1993) goes into the catena effects on vegetation.

Calculations on possible sustained yield in the past were too often made using unreliable average values for diameter increment and mortality rates of species or even groups of species. Such usually results in junk 'data' about forest dynamics. Averages may be used for comparing results in a field experiment seeking for the best treatment, but not for defining volumes to be harvested and grown in a large forest estate with variable terrain conditions.

Such average values as mentioned above have often been the result of a lumping together of extreme values resulting from the highly variable conditions in the forest. Differences in results can also be caused by setting different limits, for example, for diameter classes. Young and thin immature trees have a diameter growth pattern that may differ greatly from the diameter growth pattern of aged and large trees of the same species, on the same site. Increment results from the Côte d'Ivoire found with populations of mainly young trees are not directly comparable with increment data from Ghana calculated from data from stands with mainly large old trees. For instance, de Graaf (1986) found that, even for the relatively small total diameter range of trees in the Surinam dryland forest, the differences in increment were considerable between trees grouped in different diameter classes only 10 or 15 cm wide. The main reason for this was of course the position of small and large trees in the canopy as regards exposure to light, but rooting depth may also play a role, especially in forest opened up by human interference in a seasonal climate where drought stress occurs.

4.5.4 List of commercial species

Clearly the list of commercial species is of eminent importance for silviculture and for sustained yield. Increasing the number of species that are economically as well as ecologically interesting to keep and manage in the forest stands will be very beneficial to forest management work. This extending of the list of timber species will occur anyhow, but the usual pedestrian reason is that the more expensive timbers have become very scarce. If we wait for this to happen, these commercially most interesting species may become locally extinct which would be a small disaster for the forest in question. In Ghana this danger has been spotted, and measures are being taken to avoid it.

Such an extension of the list of exploitable tree species should not be interpreted as being a permit to fell even more trees for timber harvesting. The yield prescribed, which is the quotum to be taken, should remain restricted to what the forest can stand as far as the loss of mother trees and harvesting damage, probably not more than some 30-40 m^3ha^{-1} in each felling series over a period of 20 to 40 years. This can only happen when the absurdly wasteful exploitation methods of today have been declared outdated and have been replaced by efficient but careful working -with care for the forest and not only for the wallet-.

4.5.5 Silvicultural treatments

Furthermore, the positive effects on the increment of commercial timber trees effected by silvicultural interferences such as refining or liberation, demonstrated in the Liberian and Ivorian experiments should be exploited to improve the results of regular forest management as already executed in Ghana. Experimenting with the liberation of PCTs of medium size (e.g. 30-50 cm drh) might be very fruitful where these PCTs are present in good numbers per ha, unlike the situation in forests which have been repeatedly plundered. Such stands have to be created in the domestication process by investing in nursing activities in the forest. The Bossematié project discussed in Chapter V is an example of this.

To provoke an unequivocal response to interferences in increment experiments there should be a range from very heavy reduction of overall (or individual) competition through medium reduction to slight reduction. To the authors it would seem that experiences in the Ghana Selection System in the past have been obtained in the slight and medium reduction range only. Forest management itself should be cautious but experiments should be bold.

Results have to be applied with expertise. Blanket refining operations may result in local over-reduction of non-commercial forest components, plant species as well as animal species, and should not be prescribed without being aware of the ecological consequences to the stability of the ecosystem. In brief, the wealth of the forest should be maintained in contrast to the poverty of over-domesticated ecosystems such as tree plantations and annual crops, which still tend to replace natural forest in West Africa because of population pressure on the land.

One of the few trials to integrate non-timber forest products in management has been the Yapo project in the Côte d'Ivoire. Yapo exploitation results show the importance of non-timber forest products in forest reserves in West Africa, but their incorporation could be on a more structural basis. More about non-timber forest products will be found in the next chapter.

The social functioning of the forest is an under-exposed field. This goes for research and management alike. Traditional cultures in West Africa are intertwined with their forest, and the interdependency which still exists is worth studying.

5. FUTURE

Several new ideas and developments in forestry can now be seen in West Africa and a selection of them as given below, make the possibility of positive changes occurring in the near future quite hopeful. In Ghana sustained forest management has already made significant progress. However, new dangers loom.

In the Côte d'Ivoire, an exemplary project is being executed, the FC Bossematié project, where totally ruined forest complexes are having flora and fauna nursed back into good condition. In research work in Taï National Park a new idea on selection harvesting is being developed which could be used in bufferzone management, it being a specifically 'near-nature' method.

In Liberia, the current situation is not clear. Frequently, forests and forest management are severely damaged in periods of chaos and of failing governmental controls. Lack of hard currency will keep the need to log for export alive, whilst controls will probably be either ineffective or even totally absent.

Altogether, a concerted effort has to be made by West African countries and the timber importing countries, which are largely in Western Europe, to turn the good examples shown here into a management reality for forests in the entire region.

5.1 Reorganisation of the forest sector in Ghana

5.1.1 The move towards sustainable timber production

The Ghana Government takes the move towards sustainable timber production seriously. A reorganisation of the entire forest sector of Ghana has been under way since 1979, when the Government banned the export of green logs of 14 species in order to boost the local processing of logs.

In order for forestry methods to improve the first step is to gain information about the state of the forests. From 1980 on the Forestry Department executed a national forest inventory of just over 150,000 ha of forest reserves with the assistance of FAO/UNDP. The declining state of the economy brought this inventory to a standstill in the early 1980s (François 1989).

Since 1985 a national forest inventory to cover all the forest reserves within the rain forest zone has been instigated with assistance from the British Overseas Development Administration (ODA) and it is to be completed in 1993. At the end of 1988 some 546,000 ha had been examined. This national forest inventory and a network of 500-1000 permanent sample plots should lay the foundations of sound and sustainable forest management. A total of 350 permanent sample plots have already been selected and monitored, while some 250 are still to be selected in order to make up a total of 600 plots which are needed for growth modelling and yield prediction. The recording of the results in these plots will take place every five years and the first results are already coming.

A new species classification (see Appendix V) was introduced in order to replace the former one which dated back to the 1950s and which had been based on the economic value and growth rates of that time and is now regarded as outdated.

- Class 1: species exported from Ghana over the period 1973-88.
- Class 2: species attaining 70 cm diameter and a frequency of greater than 1 tree per km^2.
- Class 3: species not attaining 70 cm diameter or with a frequency of less than 1 tree per km^2.

Class 1 and 2 constitute the timber production potential of the Ghanaian moist forest zone.

Gross standing volume of well formed trees ≥ 30 cm drh is estimated at 188 million m^3, of which 101 million m^3 in trees over 70 cm drh. Only 11% of the total volume of trees that attain sizes over 70 cm drh belong to the class 2 species and the remaining percentage consists of class 1 species. This shows a lack of potential in class 2 species. Efforts should be concentrated on the class 1 species (Ghartey 1989).

After comparing the present stock volume, the annual growth and the annual yield of the class 1 species (Alder 1989), the following conclusions can be drawn:

- The resource of the traditionally desirable species is likely to be exhausted within 2-3 decades at the present rates of felling.
- *Triplochiton scleroxylon*, *Piptadeniastrum africanum*, *Antiaris toxicaria* and *Turraeanthus africanus* are some of the significant class 1 species, which are presently being felled at a sustained level or are even under-utilised.
- A shift to the utilisation of species not at present highly demanded will be necessary.

To regulate the yield a modification was needed to the silvicultural systems that had been tried and developed in Ghana (Nolan 1989). The annual allowable yield should be approximately 1.2 million m^3 since the production-working circle area totals 1.16 million ha, and it was found that 1 m^3/ha/yr could be felled on a sustained base. The felling cycle should be approximately 80 years, given a total standing volume of 101 million m^3 of class 1 and 2 species over 70 cm drh and an annual allowable yield of 1.2 million m^3 (Alder 1989). Probably an annual allowable yield of 200,000 to 300,000 m^3 might be nearer to reality, given the fact that the condition of many production forests is poor (condition 5 + 6 of Fig. 5.1) or confined to slopes with an incline of over 30% (Hawthorne pers. comm.).

According to Nolan (1989) the timber extracted for 1987 was 1.2 million m^3 and for 1988 1.3 million m^3. This corresponds with the annual allowable yield for all class 1 and 2 species but, in reality, the harvest is taken from a limited number of species as we saw before. Obligatory exploitation of all trees of the allowed yield should be enforced to reduce the pressure on the too few preferred species.

A similar prescription already exists in Liberia where the forestry administration has listed obligatory and future obligatory species for exploitation by concessionaires. The problem is the lack of adequate enforcement and this can be seen all over the African continent. The financial returns of the forest sector are not sufficiently redirected to this sector for a financially sound implementation and the execution of forest policy. Forestry revenues are regarded as being a quick way to obtain foreign exchange earnings to benefit the national treasury.

The following measures have so far been taken to avert the overexploitation of the forests which was the general practice in the 1970s. A ban on the export of logs of an additional four species was imposed in 1988. As from late 1989, new minimum diameter limits were imposed and a special felling permit was required for a number of species (see Appendix VI). In the first half of 1990 the overall yield was reduced by 30%, which mainly affected the high diameter classes and the felling cycle was fixed at 40 years instead of 15 years. A period of 80 years was thought more appropriate

(Alder 1989), but was rejected as being too long by the Forestry Department. In future the permanent sample plots will be a good instrument to help assess more appropriate felling cycle periods for each forest.

A total ban on the exploitation of *Hallea ciliata* and *Hallea stipulosa* for both export and domestic use was announced. These two Rubiaceae species are found along streams and are regarded as essential for watershed management. As from 1994, the export of logs and green rough timber will no longer be allowed. Nowadays these kinds of measures change frequently and new ones are constantly being announced.

The forest reserves have been grouped into Forest Management Units with an area of approximately 500 km^2 each. The Forest Management Units are found within one forest district and forest type to form the basic unit in which sustained yield management can be practised according to prescribed working plans (Nolan & Ghartey 1992). It is not yet clear to what extent ecological and site specific limitations are cared for in the Forest Management Unit concept, but some protection aspects will be indicated below.

Because of the reorganisation of the forest sector no new concession grants are being handed out. This situation has existed since 1988 when the National Investigation Committee (a kind of internal security organisation) started an investigation on malversations in the forest sector over the last decade. The Forestry Department wants to match the calculated annual allowable yield of 1.2 million m^3 and the total sawmill capacity, which at present shows overcapacity. Only some 30 sawmills will be allowed to operate in future and the closing down of several inefficient sawmills will be unavoidable. Privatization of all state owned sawmills by way of joint ventures takes off in 1993, to enable them to operate efficiently and competitively in the future. Added-value processing will be promoted in order to create more jobs and higher revenues for the state. Concession rights are to be withdrawn from all persons who possess a felling license but who do not possess processing facilities.

Finally a re-allocation of concession areas, totalling 1.16 million ha of forests under a production-working cycle has been envisaged. The process has been delayed due to political matters beyond the authority of the Forestry Department, but will constitute the line to be followed. At present temporary felling permits are handed out under pressure of some timber companies and this causes the re-entering of compartments at too short intervals and even of illegal felling activities. The Chief Conservator of Forests, Mr. J.H. François (pers. comm.), says that this situation is only temporary and that the reallocation of timber concessions will take place in the near future.

The Chief Conservator of Forests strives at producing legislation in which the same minimum diameter limits will be applicable in all forest land outside forest reserves, the ‘unreserved forests’. Special permits are required to fell undersized trees in those areas. These forests outside the forest reserves should fall under the jurisdiction of the Forestry Department, but a power struggle within the Ministry of Lands and Natural Resources is preventing this.

5.1.2 Conservation values and forest reserve condition

As discussed before, most of the permanent forest estate was destined for timber production after World War II, but some parts were set aside for protection under a 'protection working cycle'. In practice this meant that either no management plan existed at all or that the plan was delineated so vaguely that logging could continue. The strictly protected areas were often inaccessible, and it proved necessary to redefine the protection forests. We will describe the steps taken in brief.

The state of the forest condition was determined to reveal the degree of disturbance and the stage in the succession phases and the extent of these, as described earlier in this book. The parameter used was forest (canopy) disturbance.

The following condition score for the forest reserves was used (after Hawthorne & Juam Musah 1993):

1) **Excellent** (primary or late secondary) with few signs (<2%) of human disturbance, fire damage, farms or logging anywhere in the defined area, and a good canopy throughout, except in areas of natural treefall.
2) **Good throughout**, area less than 10% heavily disturbed. Logging damage only light or well-dispersed throughout the forest, or if excessive and heavy only in small patches (<10% of area). Fire damage none, or peripheral (<10% of area), or slightly more extensive but light.
3) **Slightly degraded**, obviously disturbed or invaded, and usually patchy, but still with good forest predominant. Maximum 50% of area with broken upper canopy, and < 255 of area with serious scars of poor regeneration (e.g. unofficial farms, log loading yards, roads).
4) **Mostly degraded**, poor condition throughout. More than 50% with heavily disrupted canopy, or 25-75% scarred. Forests light to moderately burnt throughout included here.
5) **Very poor condition**. Almost all heavily burnt or >75% deforested (i.e savanna, plantation or farm). Much of the canopy-less area with regeneration dominated by Chromolaena and pioneers.
6) **No significant natural forest left** (<5% left, even that not perfect). Including reserves where any surviving forest has little chance of surviving 10 more years.

Slightly more than half of the reserved forests proved to be in reasonable condition, but these forest areas were mainly confined to the perhumid and moist evergreen forest type. A worsening forest condition gradient was seen from wet towards drier areas (Hawthorne & Juam Musah 1993). This is not without reason, since it is the semi-deciduous forest which shows the highest share of commercial species and which has accordingly suffered excessively from both logging and the following fires.

Hawthorne & Juam Musah recommend a multi-scale approach to the protection of forests. This includes **fine-grained protection** which is site specific, and is necessary to prevent erosion, to maintain sufficient seed-bearers to assure adequate regeneration and which will also provide good niches for flora and fauna elements. Small forest patches (e.g. sacred groves), pockets or individuals of rare tree species and restricted forest use for certain areas and/or species (including non-timber forest products) are designated to be protected under this type of protection.

Figure 5.1 Permanent forest estate conditions in Ghana. After Hawthorne & Juam Musah (1993)

Medium to large-grained protection is needed in specially protected areas. These areas are selected as genetic stock reserves, to assure minimum viable areas and/or minimum viable populations of flora and fauna elements (see also Shafer 1990). One can think of larger forest animals (like elephants and monkeys) which need large tracts of forest in a biostatic phase (closed canopy) without which these animals will disappear or be an easy target for hunters. Forests which require special attention are those with a high biodiversity and rare species and are mainly confined to the per-humid forests both lowland and upland and some outliers of dry semi-deciduous forests. Hawthorne has worked out a species classification according to a scale of endemism to enable the selection of the above mentioned protection areas. The programme on floppy disk with handbook is available from the Overseas Development Administration, U.K.

These are some of the measures which have been taken and will be taken in the course of the coming years to obtain a sound forest sector with the main goal of working on a sustained base. For the moment the silvicultural system with natural regeneration is still mainly based on the pre-1970 selection system, and this will have to be brought to a state-of-the-art level by additional research in the coming years.

A serious threat to the forest -even that within the permanent forest estate- is formed by the mining industry. An ever-expanding, open cast goldmining industry began in since 1990. The Ghanaian moist forest zone forms one of the world's richest gold belts, as the former name of Ghana -the Gold Coast- already indicates. It has proven attractive to explore these minerals at very shallow depth.

Recently Neung Forest Reserve status was partly changed in favour of open cast goldmining and the forest reserve boundary line has been redrawn. A similar forest of the same area has been selected from unreserved forest as compensation but, as the Chief Conservator of Forests states, this forest will never be the same and this new trend should be strongly opposed. Short term interests still seem to prevail over long term interests in the political arena.

5.2 The situation in the Côte d'Ivoire

5.2.1 National forest development objectives

In the 1970s the export of first quality hardwoods from the Côte d'Ivoire had already fallen drastically due to the increasing scarcity of marketable trees in the forest, but it was not until 1987 that the annual allowable yield to 3 million m^3 roundwood equivalents from an annual yield of 4 to 5 million m^3 since the early 1970s (see also Fig. 3.7). The 1988-2015 National Forestry Plan outlines a long term strategy of forest resource protection and management, within the framework of the FAO's Tropical Forestry Action Plan. An immediate action plan for the rehabilitation of the forest sector up to 1995 in cooperation with the private sector has been worked out (Ministère des Eaux et Forêts 1988).

In essence the aim is to preserve and wisely use the 1.3 million ha of the remaining natural moist forest and maintain 1.8 million ha of savanna forest. In 1982 a ban on logging activities for the entire savanna region was decreed to protect this environment. The Côte d'Ivoire forest service envisages being able to rehabilitate the production potential of the forests to its 1980 level of 4 million m^3 roundwood equivalents.

For the time being the forest service has a national production level of 2 to 3 million m^3 in mind. However, annual production of less than 1 million m^3 would seem to be more realistic today as the Côte d'Ivoire forest reserve area (productive and unproductive) covers only 1.6 million ha in the moist forest zone. The value of 1 million m^3 is justified by the national forest inventory data for Ghana for which the annual allowable yield was estimated at 1.2 million m^3 over a productive forest reserve area of 1.16 million ha. This is an average harvesting level of 1 m^3 per ha. The Ghanaian forest estate on average is far healthier and more richly stocked than the Ivorian forest estate.

In the Côte d'Ivoire it is the demarcation and surveillance of the permanent forest estate which had priority since most of the reserves had been seriously infiltrated by farmers. The physical presence of the forest service was required and concentrating executive powers in one body was found to be necessary, while the logical next step was to decentralise it. Since the beginning of 1992 SODEFOR (Société de Développement des Plantations Forestières) has become the sole organisation responsible for both natural and artificial forest management. At present some five district forest offices (Centres Gestion Forestière) exist in Abengourou, Agboville, Bouaké, Daloa and Guiglo, to work out management plans. Such an organisational structure has existed in Ghana for decades.

Recently minimum diameter limits were introduced in the Côte d'Ivoire, mostly 50 or 60 cm drh (see Appendix VII), as a simple tool to avoid overexploitation. Still, it should be remembered that at this time Ghana works with minimum diameter limits as high as 110 cm drh (see Appendix VI). Van Rompaey (1993) lists potential maximum diameters and shows that most species have much higher potential. Higher diameters are to be preferred both from an economic and an ecological point of view.

Concessionaires are still allowed to re-enter compartments for periods up to 3 years, which is too long. SODEFOR experimented with an exploitation period of 1 year in FC Yapo, where standing stems were also sold experimentally to the highest bidder. These experiences should be evaluated and, if found positive, be introduced on a national level to improve the revenue to the state. Formerly chantiers (compartments of 2,500 ha) could be obtained at low costs such as CFA 45,000 (CFA 50 = Ffr 1) with very few conditions and no limitations as to exploitation. A decision chart for silviculture (see Appendix XII) is in preparation (Aïdara in prep.).

The main activities of the forest service so far are the demarcation and surveillance of forest reserves and a general inventory at a sample intensity of 1 to 2% of all trees > 20 cm drh, which will provide basic data on forest flora and commercial timber. Further detailed inventories, at 10% sample intensity, will then be carried out to define the detailed management plans including the maximum annual allowable yield for forests under a production cycle (World Bank 1990). The total area under a production cycle is envisaged as encompassing 70% of total forest reserve area. The local demand for firewood and charcoal (8.2 million m^3yr^{-1}) and lumber (1.9 million m^3yr^{-1}) should be completely satisfied (1987 figures). Annual firewood and charcoal consumption is estimated to reach 14 million m^3 by 1995 (Ministère des Eaux et Forêts 1988). If no action were taken a total deforestation of the forest reserves would be achieved before 1995.

5.3 Case study of forest reserve management: the example of FC Bossematié, Côte d'Ivoire

5.3.1 Management for restoration

To reverse the deforestation trend several reserves have been designated as to be rehabilitated in cooperation with the private sector and international institutions. Two demonstration projects were selected for rehabilitation at an intensive level: the FC Haut-Sassandra in west Côte d'Ivoire and the FC Bossematié in east Côte d'Ivoire. The latter forms part of a German-sponsored research and management project to rehabilitate 7 forest reserves within the jurisdiction of the Abengourou district forest office.

Today, forest covers only 5 to 10% of the total surface of Abengourou district. Closed forests are still present in the forest reserves but these are heavily overexploited and degraded. Wöll (1992) estimated that 50% of the forest reserve area is being illegally occupied by farmers, growing food and cash crops such as cocoa and coffee. Some reserves such as FC Diambarakro were completely occupied by farmers, others like FC Mabi, FC Songan, FC Tamin and FC Yaya were still in a fairly good condition in the early 1980s (Cuny 1986). Laumans *et al.* (1991) stated that at that time only FC Mabi and FC Yaya are relatively little degraded. The condition of the forest reserves was downgrading at an accelerating pass in less than a decade. The rehabilitation project has been underway since 1990.

The FC Bossematié, of the semi-deciduous forest formation covers 22,400 ha. Like most other forest reserves in the region, FC Bossematié has been selectively logged 5 to 6 times from the early 1960s until 1990. Exploitation has been halted since 1990 in FC Bossematié but, unfortunately, the mining of the forests continues in the other reserves of the district. Studies of SPOT images confirmed that the vegetation in FC Bossematié was overexploited and, in part, seriously damaged. Detailed 10% inventories on 2 to 3 plots of 50 ha each were conducted in the northern section to check the SPOT images. These studies revealed that the Bossematié forest had an abundance of regeneration of commercial species. This enabled the manager to implement silviculture with natural regeneration.

The work conducted relies considerably on the experiences gained in Liberia during the late 1970s and 1980s, as described in the previous chapter. The essential difference with the Liberian experience is that, in the Bossematié project, recent important ecological knowledge has been collected and incorporated into the management plan. Complete harmony between ecology and economics is considered to be utopian and workable compromises between the two actors in this field are sought. The key words of this forestry project are silviculture, ecology and conservation, which implies a break with the past that had been so concentrated on timber production.

A management plan is worked out by zoning the reserve area according to stock and ecological information. The first assessment tool was the 10% inventory data as described above. The condition of the reserve can be described in the following total surfaces for vegetation and land use types: 500 ha cash crops, 1,200 ha subsistance farming, 700 ha covered by *Chromolaena odorata*, 5,800 ha seriously degraded forest, 6,200 ha degraded forest and 7,900 ha slightly degraded forest. Accordingly some 14,200 ha or 64% of the area were designated for silviculture with natural regeneration since adequate stocks of regeneration were encountered while areas with inadequate stock, like abandoned farm land, are designated for enrichment planting (see Fig. 5.2).

The original 200 farmers (see Fig. 5.3), of which some 3 large authorized farms (2 people, one of whom was a minister), were ordered to abandon their mostly extended farm on which they did not entirely depend. Such reclaiming of authorized or unauthorized enclaves is also seen as a political signal. The preservation of the forest reserve depends largely on the participation of the local population. An ethnobotanical survey has been conducted to find out local priorities in the use of non-timber forest products. In future the controlled harvest of these products within the reserve will be allowed and the cultivation of certain products outside the reserve will be propagated. The giant snail (*Achatina spp.*) was over-exploited in the past and a re-introduction programme is planned.

More labour intensive and permanent agricultural systems surrounding the reserve are to be introduced. Sustainable food farming systems in densely populated West Africa are scarce and need more attention from research. It is obvious that silvicultural and ecological components are easier to effect than the participation of the local population. Nevertheless, the success of this project depends entirely on the positive engagement of local authorities and the motivation of personnel to work in the forest and for the local population.

5.3.2 Biological reserves within forest reserves

Ecological research focuses on faunal key species to determine areas within the reserve with the highest priority for conservation. It is of interest to note that in Ghana the same process is underway but here, instead of fauna elements, floristic components are being studied to determine conservation areas (Hawthorne & Juam Musah 1993). The fauna of FC Bossematié is impoverished since an extensive closed canopy structure with high trees is no longer available. Certain guenon monkeys (*Cercopithecus spp.*) and bird species are missing. Poaching has brought some species within FC Bossematié to the brink of extinction and only strict controls have so far prevented this extinction to be total (Waitkuwait 1992). Fauna elements are essential links in the regeneration process and animals may even be key species as far as seed dispersal and predation is concerned.

Some 70 to 95% of all tree species are thought to be animal dispersed. To assess this link, footprints around natural waterholes which were made additionally attractive by artificial saltlicks (see Fig. 5.4) were monitored (Waitkuwait 1992). Dung piles of forest elephants and chimpanzees were analyzed for seeds and germination trials were undertaken. Important faunal indicators in the regeneration process studied in Bossematié are: chimpanzees (*Pan troglodytes*), royal antelope (*Neotragus pygmaeus*), maxwell duiker (*Cephalophus monticola*), black dorsal duiker (*Cephalophus dorsalis*), black duiker (*Cephalophus niger*), bongo (*Booceros euryceros*) and forest elephant (*Loxodonta africana cyclotis*). Observation of waterholes at intervals of 500m and 2 km from the reserve boundary, as well as at the centre of the reserve, are taking place to find out the frequency of animal visits (see Fig. 5.4).

Some three biological reserves were selected within the forest reserve as areas to conserve the genetic tree stock and as a resting-place for animals. Figure 5.5 demonstrates that these zones were also the preferred habitat for forest elephants. FC

Bossematié's biological reserves measure at least 2,000 ha, with all catena positions and vertical strata present.

To conserve the tree genetic resources *in situ,* according to theoretical calculations by Kemp *et al.* (1976), 200 to possibly 10,000 individuals are required. An arbitrary minimum population number per species of 200 sexually mature trees could be recommended as a working rule. Ashton (1976) estimated in Borneo that 1,000 ha of forest should be preserved if 60% of the species were to be conserved and that 2,000 ha might be sufficient to conserve all but the rarest species. Forest inventory data should be able to reveal such minimum required areas for conserving tree genetic resources for other rain forest areas.

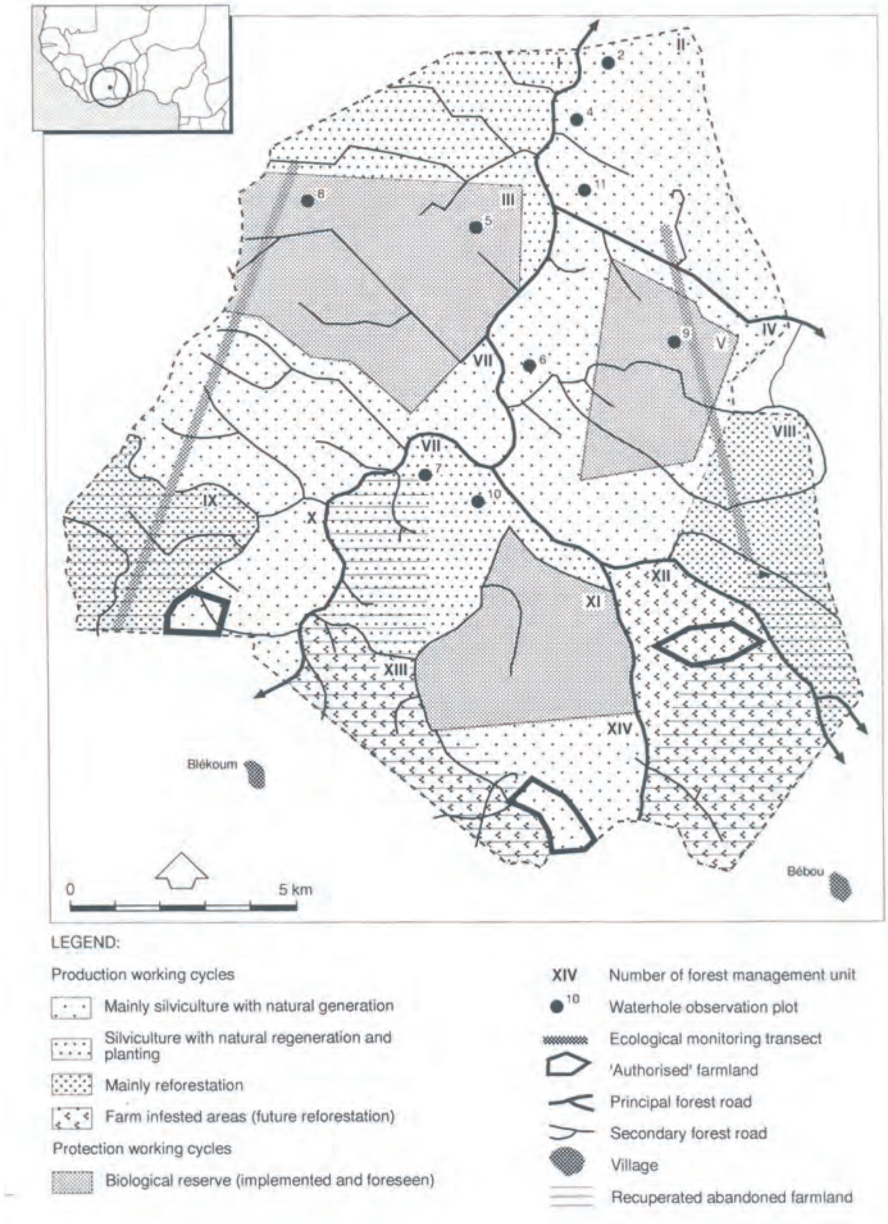

Figure 5.2 Map of management plan of Bossematié Forêt Classée, Côte d'Ivoire. Source: records H.J. Wöll.

Figure 5.3 Detail of map of FC Bossematié, Côte d'Ivoire, showing intrusion of farmers into the reserve (hatched and dotted areas). Source: records H.J. Wöll.

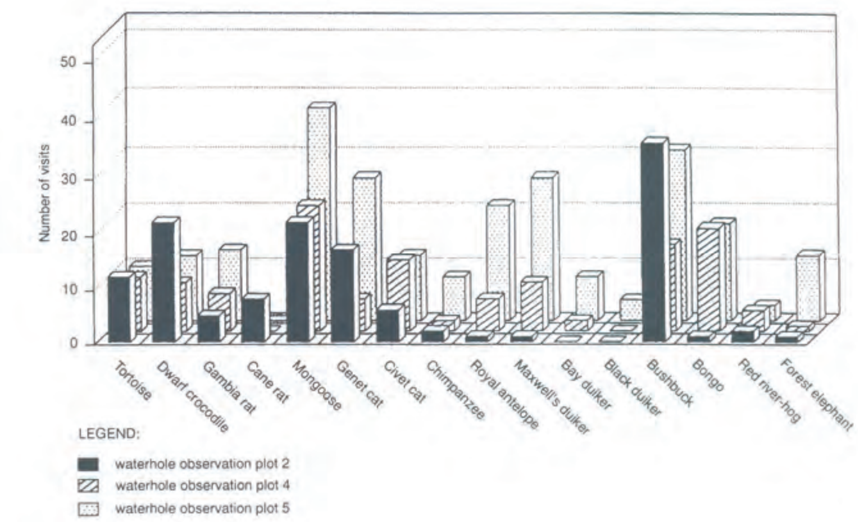

Figure 5.4 Numbers of waterhole visits of various game species. Such statistics were used to select areas for biological reserves in the FC Bossematié, Côte d'Ivoire. Source: records W.E. Waitkuwait.

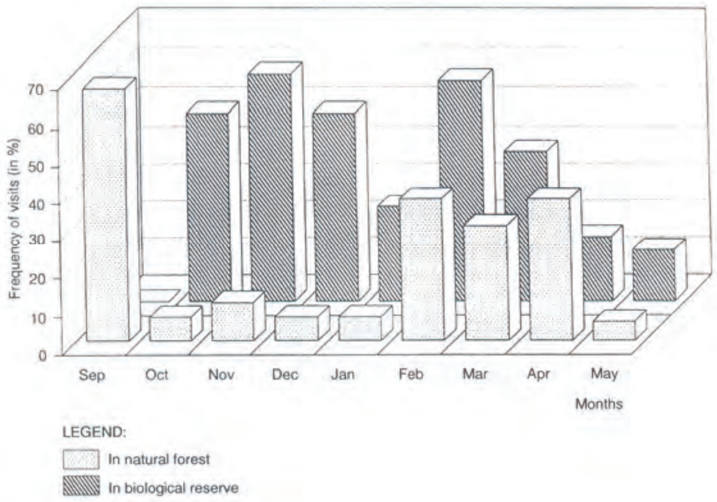

Figure 5.5 Time spent by forest elephants in two forest management units. The biological reserve is clearly more attractive. Source: records W.E. Waitkuwait.

5.3.3 Silvicultural treatments.

In 1990 a detailed study was made in the northern sector B, group II, with a total surface of 1,982 ha (see Fig. 5.6). This area was designated for the application of silviculture with natural regeneration. Figure 5.7 shows the detailed management plan for 6 compartments in group II. A total of 280 ha were surveyed, line sampling at a 10% intensity took place in all 6 compartments, except for the once farmed compartment 2. All tree species, both commercial (class I-III) and non-commercial, were included in the survey, and all trees above 5 cm drh were measured and recorded as well as all saplings above 1.2 m height, to assess the regeneration. According to Wöll (1991, 1992) the minimum number of potential crop trees (PCTs) should be 60 trees per ha in the 5 - 40 cm drh class. Of the original 60-70 PCTs it is expected that in 50-60 years 30 PCTs will die at a presumed 1% mortality rate. A felling cycle of approximately 25 years is envisaged in which 5 trees can be felled. Ecological limitations are being incorporated and important fruiting trees, like *Parinari excelsa*, can be more important than PCTs are.

Some 150 to 160 woody species above 5 cm drh were found and of these 53 belong to a group of commercial species. Of the 20 most frequent species which make up some 60% of all stems encountered, *Nesogordonia papaverifera*, *Scottelia klaineana*, *Aningeria robusta*, *Triplochiton scleroxylon*, *Mansonia altissima* and *Pterygota macrocarpa* belong to the class I commercial species. The class II commercial species *Celtis mildbraedii*, *Funtumia elastica*, *Celtis adolfi-friderici*, *Sterculia oblonga* and the class III species *Celtis zenkeri* belong to the same group of 20 species.

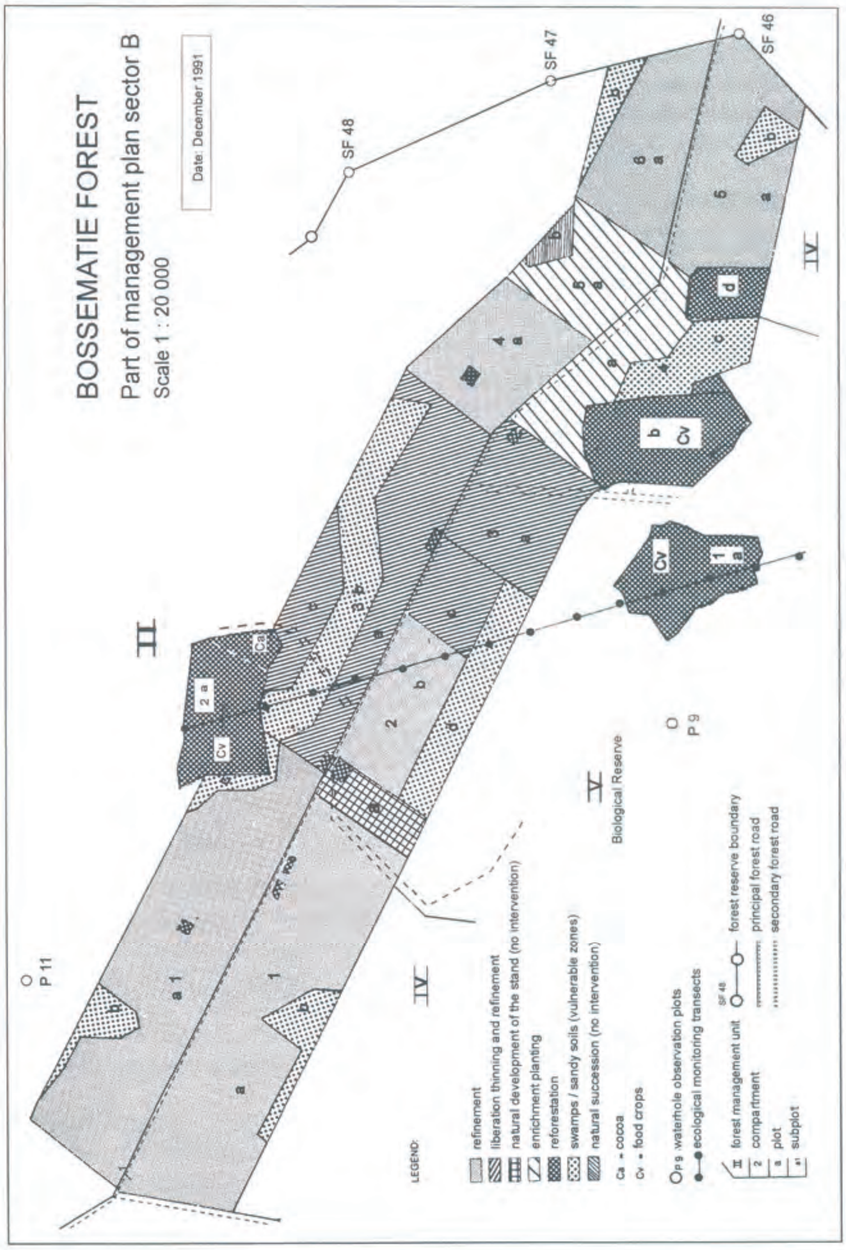

Figure 5.6 Detail of Forest Management Unit B showing actual condition of vegetation and treatment advised for the smallest units. In practice the whole sector falls within natural regeneration management. Source: records H.J. Wöll.

The natural regeneration count for commercial species in the 1.2 m height - 5 cm drh class showed abundant regeneration: out of a total of 736 (100%) trees per ha the following number of trees per ha were encountered: class I, 608 (83%), class II, 99 (13%), class III, 29 (4%). *Nesogordonia papaverifera* and *Mansonia altissima* together form 58% of the total number of saplings. This implies that *Mansonia altissima* is especially over-represented when compared with the composition of higher diameter classes in the forest.

Treatments are confined to liberation thinning since adequate stock was found. Commercial species formed some 57% of all trees over 10 cm drh (see Table 5.1). The basal area showed that this part of FC Bossematié was well stocked, even after the creaming operations of past decades. The overall stock of PCTs was also sufficient according to Wöll's standard of 60. The study revealed that 90% of the PCTs were either suppressed by surrounding trees or had been infested by climbers. The upper-storey of this forest could be characterized as being very open since often less than 8 stems over 60 cm drh were encountered per ha. Less than 20 to 30% of the surface was covered by the crown projection of these big trees.

When assessing the crown positions according to the classes introduced by Dawkins (1958) it was surprising to find out that only one fifth of the PCTs in this overexploited forest were not suppressed and could be catalogued in Dawkins class 5 (full exposure). Even of these PCTs some two-third were infested by lianas. The latter is not so surprising, since a liana tangle was also encountered in the Ghanaian Tropical Shelterwood System, characterized as being drastically opened up forest.

Table 5.1 The basal area and stock of trees ≥ 10 cm drh before treatment at 280 ha in sector B, group II, compartments 1,3,4,5,6 in FC Bossematié. Based on Wöll (1991).

Total basal area	16.5 m²/ha
Basal area commercials	10.7 m²/ha
Total stems all species	320/ha
Total commercial stems per ha	182/ha
Total commercial stems > 50 cm	21/ha
PCT 5 - 40 cm drh class	66/ha
PCT standard according to Wöll	+

Enrichment planting is planned for impoverished areas (poor stock of PCTs and/or former farmland) especially at the farm-infested boundary sites of the reserve. Wherever these sites are surrounded by areas rich in natural regeneration the best option may be natural succession.

A mild liberation operation, killing on an average 1.5 m^2ha^{-1} or approximately 10% of the total basal area, comprising mainly trees of the pioneer species *Musanga cecropioides* combined with climber cutting, had been done from 1991 on. This operation will not bring the total basal area below 50% of the original primary forest condition which might be the critical limit for African lowland moist forest. The remaining basal area of ± 15 m²/ha is close to the presumed limit, but the forest will probably respond favourably to these conditions.

5.3.4 Conclusion

A management plan as made for FC Bossematié seems to be best suited for seriously degraded forest reserves, a situation prevailing in most of the forests of the Côte d'Ivoire. The concept of biological reserves within forest reserves is not new, but should be incorporated in all management plans to ensure ecological niches for flora & fauna elements. A restoration of biomass and crown cover will be essential for the well-being of all Ivorian closed moist forests. National production targets should be set at a minimum and not at a maximum as they are at present. A production stop such as that in FC Bossematié is probably a necessity to restore the forest ecosystem, and a conservative production target for the next felling cycle may be the best option. Continued annual creaming of 5,000 ha (2 compartments) of seriously degraded forest such as those envisaged in SODEFOR's other pilot project in FC Haut-Sassandra would appear to be the wrong approach.

5.4 Harvesting system based on the life phases of trees

5.4.1 The advantages of growing large trees

Natural ecosystem-analogue methods for the sustainable exploitation of the tropical moist forest is a concept recently launched by forest ecologists of the Agricultural University of Wageningen (The Netherlands) working in the Côte d'Ivoire. Over the past ten years the sylvigenesis and forest eco-unit concept (Oldeman 1978, 1990) have formed the basis for research targeted to finding a sustainable silvicultural system which is ecologically acceptable. This research work has been conducted in Taï National Park in the south-west of the Côte d'Ivoire.

The principle is that the evident biological reason for the consistent failure to achieve sustainability in forest management is not based on the incapacities of the natural forest ecosystem. The failure is rather based on the rigour of the attempts to substantially modify forest characteristics in order to maximize rather than optimize timber outputs. The natural forest ecosystem had arrived at the highest state of efficient substrate use for timber production. The moist forest ecosystem is vulnerable to large scale perturbations (e.g. heavy silvicultural interventions), but small scale disturbances (e.g. treefall of a forest giant) can be overcome quite well. Gap regrowth processes will ensure that, within 30 to 100 years, a new forest giant will occupy this gap (Vooren 1992).

Imitating small scale natural renewal processes in forest ecosystems should therefore constitute the most attractive basis in energy terms for taking advantage of the reproductive potential of the forest. Imitating treefall gap formation in size and frequency by the timely harvesting of over-mature and close-to-senescent-trees, that have passed the major part of their timespan of sexual maturity, is essential to the regeneration process and is the basic concept (Vooren 1992).

Exploitation should concentrate on cabinet timbers, particularly the traditionally highly demanded Meliaceae species. The Meliaceae species fruit plentifully and, every year, the establishing of numerous seedlings is assured (Taylor 1954). The seedlings are efficient colonizers of small gaps, sufficiently resistant to dry periods and shade, they do show longevity and fast height growth when exposed to light (Alexandre 1988). A 2.3% strip sampling exercise over 11,000 km^2 in the forest reserves of Ghana revealed a normal stem number diameter class distribution for the Meliaceae (Foggie 1960). This is confirmed by the latest forest inventory in Ghana (see Table 5.2).

Table 5.2. Mean stem numbers per km^2 for Meliaceae species by cm diameter classes for Ghana (Ghana Forestry Department 1989)

	5-9	10-29	30-49	50-69	70-89	90-109	110-129	>130	Total
Entandrophragma angolense	131	214	30	10	7	3	1	1	396
Entandrophragma candollei	17	33	3	1	1	1		<1	55
Entandrophragma cylindricum	66	83	12	6	5	4	2	1	179
Entandrophragma utile	32	44	5	3	2	1	1	1	89
Khaya ivorensis	101	65	11	10	8	4	3	1	203

The data from the Taï National Park is, however, less promising. Recently, de Klerk (1991) assessed the natural regeneration of five Meliaceae species over a total area of 8.5 ha in the Taï National Park. While high densities of mature trees of those species occur in the recorded plots, no seedlings and no young trees were found of *Entandrophragma candollei* and *Entandrophragma cylindricum*, and very few young trees were found of *Entandrophragma angolense*, *Entandrophragma utile* and *Khaya anthotheca*.

Vooren (1992) suggests that no further intervention is necessary to stimulate or favour regeneration of cabinet timbers because adequate regeneration is provided by natural gap replacement processes. Even if this were to be correct, the harvesting criteria suggested by Vooren (1992) would have major implications for future exploitation and for the timber market.

Preliminary harvest quotas were estimated at one tree per five hectares per year. The main difference with traditional harvesting systems will be that these trees will be very widely scattered over the forest. The optimum harvest stage will normally approach a tree's maximum age which cannot be interpreted by the growth rings as it could be in temperate zones. Instead, morphological indications of loss of vigour in crowns of canopy trees were used. This was done by interpreting large scale aerial photographs and corresponding terrestrial observations of a large number of specimens of the Mimosaceae *Piptadeniastrum africanum* (see Vooren & Offermans 1985). It is assumed that, in future, the 'ripeness' of timber trees can be expressed in a characteristic and measurable foliage-interspace or sub-crown interspace ratio for each species.

Harvesting will mean entering compartments at wide time intervals to harvest a single tree and this will result in a fairly intensive network of semi-permanent skid tracks. The idea to use helicopters to take out the logs is technically feasible but also expensive. It would, however, save much damage to the terrain by the heavy machines that are normally used for skidding. Concessions should cover a huge area to guarantee a steady roundwood supply and the sawmill should be able to handle logs of dimensions of over 150 cm drh. Another problem that will arise is the high frequency of heartrot encountered in over-mature trees of the cabinet timbers. This will reduce sawing efficiency considerably and also the financial output. So a prediction has to be made for each marketable species about what time (i.e. diameter) heartrot begins to occur.

It seems doubtful as to whether a high price/volume ratio of cabinet timber species will cover all the expenditure. Is there time to experiment with such a financially uncertain harvesting system? And is there, anywhere in the world, the political stability needed to stand firm to keep so much valuable timber in the accessible forest and to reserve large stretches of land for such forest when the overall output is so low and the claims of agriculture so strong? The system is meant by Vooren (1992) to be applied in buffer zones around absolute nature reserves, but even those will have to produce for the national economy even when focussing mainly on locally used, non-timber forest products.

There is, however, much to say in favour of keeping large trees in the forest. In the Taï forest, Côte d'Ivoire, a remarkable low dynamism in gap formation was found, nearly twice as low as that reported for South American and Central African rain forest. Jans *et al*. (1993) found an average, relatively small, gap size of 55 m² and an extended turnover time of aproximately 240 years. This reveals that we are dealing with a forest of low dynamics since the turnover time of the South American and Central African rain forest is approximately 100 years. A dominance gain of shade bearing canopy species can be seen. Although the research results of Jans *et al*. (1993) remain rather weak because of the methods used to estimate gap age, the area covered by the survey was about 20 ha, making the study one of the few that have taken such a large sample.

It may be worthwhile concentrating on growing large trees, such as in the approach described above, but some limitations have to be considered. Recent research on increment borings to estimate average diameter increment in the unlogged Taï forest, by Kuppen *et al.* (1992) revealed the vigour of individual trees of large dimensions. Some 195 specimens of 6 tree species were analyzed. The trees with an average diameter of over 100 cm drh of *Entandrophragma angolense*, *Entandrophragma utile* and *Piptadeniastrum africanum* showed an annual diameter increment rate of some 0.7 cm. Tree species possessing an average diameter of over 65 cm drh, like *Heritiera utilis* showed a rather slow increment of 0.4 $cm.yr^{-1}$, comparable with the value for *Terminalia superba* with an increment of 0.5 $cm.yr^{-1}$. *Petersianthus macrocarpus* had fast growth with an average increment rate of 0.9 $cm.yr^{-1}$.

This shows clearly that even in an untouched forest like the one of the Taï where competition must be fierce, there exists a great deal of potential for increment in the highest diameter classes. Even a relatively slow diameter increment rate as seen in individual trees of *Terminalia superba* will, in trees of large dimensions, give a substantial volume increment each year. As demonstrated above however, we can expect moderate to fast increment rates at these dimensions! This is a good reason for conserving the largest trees in a selection felling system.

Such a system, though possibly suffering financial drawbacks because of the large standing stock of timber, could produce better than systems concentrating on the juvenile stages, as these last have to bear long investment periods to obtain trees that reach mature timber stages. The selected trees will have fulfilled their ecological functions for several decades and, if harvesting is done before heartrot takes hold, the timber market will be able to supply high standard cabinet timbers with low processing losses. The high diameter limits as applied presently in Ghana (see Appendix IV) are a good step in this direction.

5.5 Promotion of lesser used species

5.5.1 An example of what to do

Silvicultural systems with natural regeneration are easier to implement when a wider range of species in the forest is commercially acceptable. Most systems described earlier in this book had to work with a restricted list of species, often not more than 20 out of a potential number of over 100. Many complex manoevres had to take place in order to ensure an equally large yield in the next felling series. The traditionally favoured species come mainly from a group of species not requiring open conditions for germination, but where the seedlings later do require light at a later stage (see also Table II.1). By repeatedly removing mature trees of this limited list of highly demanded species, a gradual shift in the composition of the forest in favour of non-desired species takes place in the course of time.

To avoid this shift and to achieve the aim of sustainable forest management more easily, more West African timber species have to be accepted on the market. This has happened in South-East Asia where many of the wide range of species of Dipterocarpaceae are now accepted by the market. Here silviculture and overall management is much eased by the wider choice of species to be maintained in the stand. In the Neotropics (Latin America) the local market accepts a large range of species, again easing problems for silviculture. Export here is very restricted as yet.

What has to be done to introduce lesser-known species to the market? The process involved will be discussed with reference to the Mimosaceae *Albizia ferruginea* presently classified by the market as a 'lesser-used species'. This species finds its optimum in the dry semi-deciduous forest.

Before the trade will accept a lesser-used species it wants to ensure itself of the following:
(a) regular and adequate supply
(b) availability of heavy dimensions

(c) suitable physical and technical properties
(d) known preferred end-use applications
(e) relatively low cost when compared to traditionally accepted species

The possibilities of a guaranteed and regular supply has to be drawn from reliable national forest inventories. A national forest inventory like the one executed recently in Ghana will reveal the availability of volumes in all diameter classes and, accordingly, the annual allowable yield per species can be calculated. Permanent sample plots will reveal the dynamics of the species over a long period in order to be able to regulate the annual allowable yield in a sustained way. In Ghana it was found that only those species that had an abundancy of at least one stem ≥ 70 cm drh per square km and which were exported at least once since 1973 have an export potential. This is a clear indication of their market potential, although at present, such species may be classified as belonging to a group of lesser-used species.

In order to warrant sustained forest management, concessionaires will have to take the total allowed yield of the compartments they are allowed to work at the moment. These allowed yields are prescribed by the forest service after the enumeration of the compartment and compilation of stock and yield maps. Removing the entire allowed yield in one operation is best for sustainable forest management as the forest ecosystem can then be left in peace to recover. Returning several times over a period of some years to pick out another load of a new species for the market is far more destructive than harvesting the same volume in a single operation. Using the forest as a 'living log yard' collecting what you need when you need it is not a 'green' alternative, but rather a sign of a lack of the capacity to make good plans or to cooperate with neighbours.

The log yard of the concessionaire, who normally also operates a sawmill to supply the domestic and export markets, does not always have enough stock of a required species, even a common species, to meet orders. As far as lesser-used species are concerned, the low stocks available at the log yard often prove problematical. It will therefore be necessary for suppliers to cooperate and to establish a kind of common timber exchange market. This is already being put into practice, but often only on a limited scale between companies. A national log/timber bank regulated by a federation of producers would solve many of these current problems.

The wood processing industry and the end-users need information about the physical, mechanical and chemical properties of potentially new timber species. For each species comparable data must be available through a databank. Such a databank holding information about lesser-used species for specific end-uses is currently being established by the Department of Forestry in Wageningen on behalf of the International Tropical Timber Organization (ITTO). The program is available on floppy disc (Zijp 1990, Polman & Zijp 1992).

As long as a steady flow of traditionally accepted species are available at relatively low prices, the lesser-used species will find it hard to be accepted by the market. The sawmills and building companies strongly affect the choice of a timber species and architects also influence this choice. It will be important to convince them that accepting a wider range of species, cq. lesser-used species, would be a good way to help achieve sustainable forest management for certain moist forests. Consumers themselves have clearly responsibilities in this area, not only the foresters.

Reasonable pricing of lesser used species should guarantee that the cost of intensive sustainable forest management, as described above, is covered and that timber can compete with other construction materials.

Example of the Mimosaceae Albizia ferruginea. The national forest inventory of Ghana species abundance revealed that 7 stems per square km for stems over 70 cm drh of *Albizia ferruginea* were to be found. Nevertheless this species is considered to be a 'lesser-used' species. The volume per km² of stems over 30 cm drh averages 82 m^3, while the volume of stems over 70 cm drh averages 59 m^3 per km² (Ghana FD 1989). These volumes are indicative of guaranteed regular supply in volumes from Ghana. *Albizia ferruginea* occurs widely in tropical Africa from Senegal to Angola and Uganda (Hall & Swaine 1981). A regular supply should pose no problems. In Ghana *Albizia ferruginea* was grouped with traditional commercial species like *Guarea cedrata*, *Tieghemella heckelii* and *Turraeanthus africanus* in the category 'abundance of stem frequency of trees greater than 70 cm drh'.

Technical information. The commercial international name of *Albizia ferruginea* is Iatandza. This Iatandza is a light wood (av. 600 kg/m^3 air dry), soft to moderately hard, with slight linear shrinkage. The wood is satisfactorily resistant to fungi and termites. Iatandza is easily sawn and contains hardly any silica. It is considered to behave satisfactorily as far as the fastening of nails, screws and staples, and glueing, machining and finishing are concerned.

Iatandza is suitable for exterior and interior joinery (without treatment), parquet flooring, furniture and structural frames. It can be sliced and peeled very easily to produce plywood and peeled veneers. Iatandza of slightly inferior quality can be used for making formwork and crates (Zijp 1990, Polman & Zijp 1992).

5.6 Potential of non-timber forest products

5.6.1 Introduction

Non-timber forest products are a very heterogeneous group of commodities, which include all the animals, plants and other materials a forest area supplies apart from timber. Millions of people exploit these non-timber products in one way or another for their daily subsistence; food products such as fruits, nuts, seeds, mushrooms, herbs, game and fish, but also construction materials and commodities for medicine and cultural ceremonies.

Apart from this there is a group of non-timber forest products that are produced naturally by plants and emerge from injured tissues, such as exudates, viscous liquid compounds or others, and which are mainly for industrial use. These include essential oils, tannins and dyes which are often obtainable only with the aid of chemical solvents or steam distillation. To give an idea of their wide application here is impossible as the list would be unending.

The original Brazilian word 'extractivismo' will be used to denote the harvesting or extraction of these non-timber products. It is quite an important part of the rural economy in some parts of the Amazon region (e.g. Richards 1993).

What all these non-timber products have in common is that it is hard to quantify them in terms of volume and economic value. This might also explain why they are often referred to as being minor forest products, a term expressing a certain degree of denigration, and denies the huge impact this production makes on the lives of millions of people all over the world. The products are collected in such variety and quantities, both for commercial and individual household purposes that, in terms of economic value, they may locally even outweigh that of timber (Parren 1992). This can be demonstrated by two products with an entirely different impact in the West African region. On a daily subsistence level the role of wild animals in the nutritional package will be presented, while the derivate of the *Thaumatococcus daniellii* fruits completely depends on an international market.

5.6.2 West African bushmeat

It is questionable as to what extent non-timber forest products play a role in West African economies but, as mentioned above, their importance should not be underestimated. For West Africa Asibey (1974) estimates that 75% of the protein sources consumed consists of the meat of wild animals: 'bushmeat' or 'viande de brousse'. For the Côte d'Ivoire alone annual bushmeat consumption has been estimated at over 50,000 tons (MEF 1988). All this meat finds its way onto the markets, even to the capital. A total ban on hunting has existed in the Côte d'Ivoire since 1974 (IUCN 1986) except for traditional hunting (small scale) but, as can be expected, this does not prevent a thriving market from existing. Each day in the late afternoon 'illegal' bushmeat markets sprout up at street corners all over Abidjan.

Martin (1989b) states that, at the end of the 1970s, the Nigerian bushmeat market was estimated to range between 150 and 3,600 million Naira (1 Naira = 1 US$). These estimates indicate that several percent of the Gross National Product are spent on bushmeat. Recently Falconer (1992) confirmed the popularity of bushmeat in Ghana. The Central market of Kumasi is controlled by 50 full-time traders who sell smoked meat originating from the savannah regions north of Kumasi and another is at Atwemonom where a further 15 wholesalers sell fresh meat.

The smoked and fresh meat markets are specialized, each with its own structure and network. The fresh meat consists mostly of Black and Maxwell duikers, grasscutters and bushbuck and comes almost entirely from within a 75 km radius of Kumasi. Smoked meat originates from as far as Bolgatanga, 450 km north of Kumasi, and is generally from grasscutters, warthogs, red river hogs, kobs, oribi duikers and roan antelopes. Hunters claim that most animals are captured on farmland (76%) and less (24%) in the forest. A lean period for bushmeat sales falls during the early rainy season when fish, an alternative source of protein, is plentiful and cheap. A hunting ban exists in Ghana during the short rainy season from August onwards, and this explains why the market is flooded in the two previous months.

Falconer (1992) estimated the bushmeat trade in Kumasi at 17,600 kg of meat, worth 12.7 million Cedis (£ 23,090) over a four week period whereas the estimated annual bushmeat consumption in this town is estimated at 160,000 kg. It should be noted that the vast majority (83%) of the hunters interviewed never took their catch to Kumasi or to other urban markets. This meat finds its way entirely onto the domestic market. Not surprisingly most people interviewed regarded bushmeat as for them the most important forest product. But does it really come from the forest?

A distinction has to be made between the ubiquitous fallow land, covered with bush, and the residual high forest whether in forest reserves or not. Most bush meat indeed seems to come from the farmland bush, or 'brousse' in the Côte d'Ivoire, and this is quite logical when so much closed canopy forest has been replaced by farmland. Bushmeat might be regarded as a farm product rather than as a forest product, just as is the case with the hares in Europe.

Although 95% of the interviewed Ghanaians and Nigerians confirmed that they eat bushmeat either regularly or once in a while, it cannot be found registered in any statistics. This confirms the lack of an organized market authority which was able to attach economic values to these rural products.

On the other hand, since the first half of this century, the non-timber forest products for industrial use that have found their way onto official markets have often been ousted from this market by mineral or synthetic substitutes. This is due to the nature of forest products. The regular supply and the constant quality required are the first problems that have to be solved by the forester when he wants to pay attention to the extractivismo of non-timber forest products in his management plans. The local market could well offer better opportunities to ensure a market than the competitive international market.

5.6.3 A natural sweetener

Botanical. The first known reference to the natural sweetener *Thaumatococcus daniellii* was made by the British surgeon W.F. Daniell, who reported tasting the fruit in Sierra Leone in 1855. He subsequently sent samples to Kew Gardens and was rewarded by having his name immortalised. *Thaumatococcus daniellii* is confined to West and Central Africa from Sierra Leone to Gabon.

Thaumatococcus daniellii belongs to the Marantaceae, a family of herbs that expands vegetatively by means of rhizomes from which arise erect, short-lived leafy and flowering shoots. The white to violet coloured flowers are, in general, pollinated by bees and produce a fruit which is red to bright red when mature (see Fig. 5.7). The winged fruit contains one to three seeds. The jelly-like arils surrounding the seeds contain a sweet substance which has been called thaumatin (Sijtsma 1993).

Domestic application. The fruit is very sweet and the local people like to suck the sweet aril out of the fruit. It is traditionally used to sweeten the sour taste of old palmwine and other fruits. Women rub the aril on their nipples to stimulate their children to drink. Amongst some tribes the plant is a symbol of female fertility. Its presence is held to indicate good soil. The leaves are used as disposable plates or as wrapping material.

Industrial application. The sweetening characteristics of the substance thaumatin, consisting of two proteins (Stephens 1983), has attracted the interest of a British firm. In three regions of the Côte d'Ivoire the fruits of *Thaumatococcus daniellii* are collected in the forest, mainly by women. They are then transported to one of three distribution centres in Bangolo, Lakota and Alepe, and here the aril is separated from the fruit and frozen before being transported to Abidjan for shipment to the U.K.

An aqueous extraction then yields the purified TALIN^{R} protein to be applied as a sweetener. The weight of the aril is some 7% of the total fruit weight and after extraction yields some 2% of TALIN^{R}, so tremendous amounts of fruits are required to yield a few kilogrammes of TALIN^{R}. The advantage of this sweetener above others are described in Table 5.3.

The TALIN^{R} powder is water soluble and typical products of application as a sweetener are in chewing gum, coffee, soft drinks, tobacco products, flavours, savory flavours and pharmaceutical products.

Table 5.3 Characteristics of thaumatin (TALIN^{R} proteins) of *Thaumatococcus daniellii* after extraction. Source: Sijtsma (1993).

(1) Safe natural sweetener for human consumption
(2) Very low level of calories
(3) Potential admixture with other sweeteners to reduce their consumption
(4) Improvement in product flavour, quality and perception
(5) Useful to diabetics

Extractivismo. The production of TALIN^{R} depends entirely on extractivismo in West Africa and, so far, is confined to the Côte d'Ivoire and, to a lesser extent, to Ghana. Increasing world demand for this sweetener requires an increased supply which is difficult to meet at the moment. At present extractivismo is taking place in evermore remote areas, away from the distribution centres mentioned. Fruit extractivismo, when not destroying the plant itself, is not harmful for the population since the plant will reproduce vegetatively by producing new shoots from the rhizome.

From the above it is apparent that the extractivismo operations ought to be regulated to ensure the regular supply of the fruits. More ecological research should provide information about the autecology of the plant and the present ways of collecting it. Measures based on such knowledge should then ensure that the extractivismo is not going to be indiscriminate. For example, the extractivismo-period and the quantity of the produce should be determined. Sijtsma (1993) has already indicated that there could be a correlation between rainfall and yield levels. This will help the forest service to work out control measures in cooperation with local authorities for extractivismo within forest reserves.

The rising demand for thaumatin and its derivate TALIN^R implies that the possible cultivation of *Thaumatococcus daniellii* has to be studied and that research into selecting high-yielding individuals should continue. Experiments carried out in Nigeria in the 1970s faced the problem of producing enough seedlings (Onwueme *et al.* 1979). Germination is prolific on the waste mounds at the distribution centres and starting nurseries at these centres would be an option. Vegetative propagation is another option. The selection of high-yielding cultivars and cultivation as a soil cover crop under perennials would seem to be most suitable. A shade-tolerant crop as *Thaumatococcus daniellii* seems to fit well into an agroforestry system including perennials such as rubber, cocoa and coffee.

5.6.4 Overall conclusion

Non-timber forest products have much potential to benefit local populations, and a wide range of approaches has to be studied in order to optimize their potential. This should be done without harming the environment. More research is needed and the results should be incorporated in forest management plans. Amazingly enough, at the present time, most of the non-timber forest products do not originate in the high forest but rather from farmland and secondary forest not belonging to the permanent forest estate. This underlines its potential to be incorporated in agroforestry systems. For forest management it implies an additional value with timber remaining the principal product. If it were found necessary to take some pressure off the natural environment, the *ex situ* propagation - preferably in agroforestry systems - should be chosen.

To convince policy makers that the contribution to the economy of non-timber forest products is far from negligible, their value should be assessed with priority. Research to find new applications, for example by modifying the raw material as in the case of *Thaumatococcus daniellii*, has hardly begun. High expenditure biochemical research laboratories in West Africa, sponsored by international donors, might help to strengthen the industrial base to compete on the world market. Local processing instead of exporting the raw materials could also boost the added economic value of these forest products. The challenge for the foresters will be how to incorporate some of these objectives into forest management.

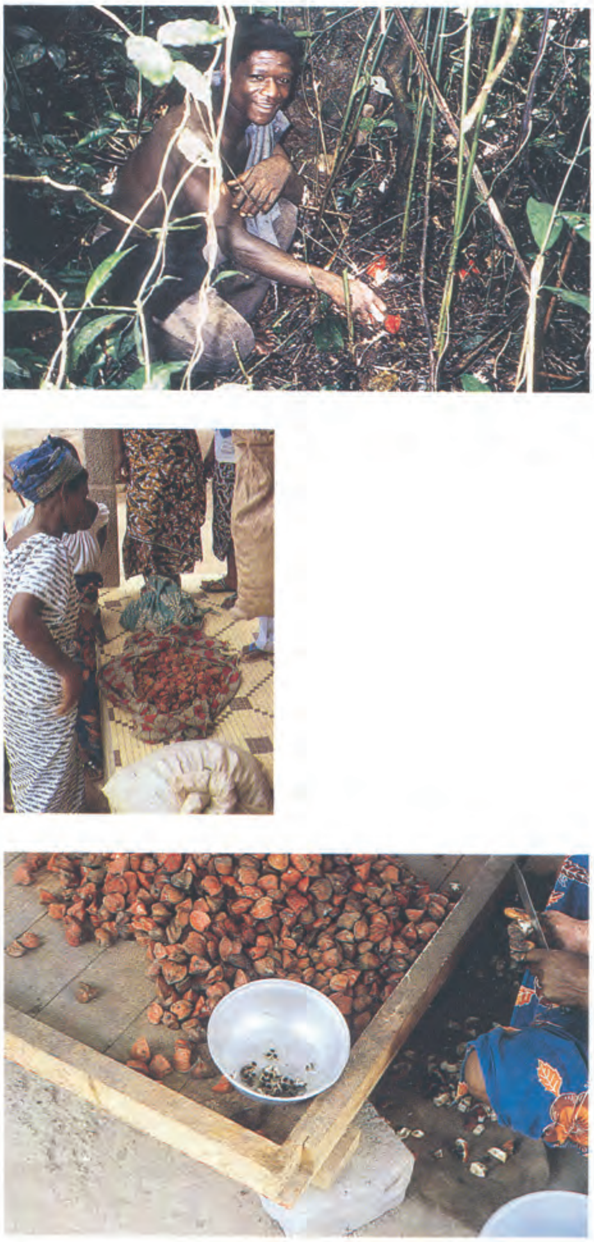

Figure 5.7 A,B,C. *Thaumatococcus daniellii*, a natural sweetener.
A: Picking fruits of *Thaumatococcus daniellii* near Kpandu, Volta Region (Ghana). Photo D. Sijtsma, 1992.
B: Fruits of *Thaumatococcus daniellii* offered for sale at distribution centre Bangolo, Côte d'Ivoire. Photo M.P.E. Parren, 1992.
C: Separation of aril of the fruits of *Thaumatococcus daniellii* at distribution centre Bangolo, Côte d'Ivoire. Photo M.P.E. Parren, 1992.

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LIST OF ACRONYMS

APN	Amélioration des Peuplements Naturels
CELOS	Centrum voor Landbouwkundig Onderzoek in Suriname [Centre for Agricultural Research in Suriname]
CIRAD	Centre de Coopération Internationale en Recherche Agronomique pour le Développement
CTFT	Centre Technique Forestier Tropicale (nowadays CIRAD-Forêt)
drh	diameter at reference height, i.e. at breast height (1.30 m) or 30 cm above buttresses
FAO	Food and Agriculture Organization
FC	Forêt Classée
FD	Forestry Department
FDA	Forestry Development Authority
FORIG	FORestry Institute of Ghana
FPRI	Forest Products Research Institute (nowadays FORIG)
FR	Forest Reserve
GFML	German Forestry Mission to Liberia
GPR	Game Production Reserve
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH
ICBP	International Council for Bird Preservation
IDEFOR	Institut des Forêts (formerly CTFT-CI)
ITCF	Inter-Tropical Convergence Front
ITTO	International Tropical Timber Organization
IUCN	International Union for the Conservation of Nature
MEF	Ministère des Eaux et Forêts
MUS	Malayan Uniform System
NF	National Forest
NP	National Park
NPLF	National Patriotic Front of Liberia
ODA	Overseas Development Administration
PCT	Potential Crop Tree
PES	Post-Exploitation System
PSP	Permanent Sample Plot
RF	Réserve de Faune
RIF	Regeneration Improvement Fellings
SODEFOR	Société de Développement des Plantations Forestières
TSS	Tropical Shelterwood System
UNDP	United Nations Development Programme
UP	Unité Primaire
WCMC	World Conservation Monitoring Centre

APPENDIX I

GHANA minimum diameter limits till late 1940s. Based on Logan (1947).

87 cm drh	
Leguminosae	
Piptadenia gabunensis (Harms) Roberty	Okan, Denya
(= *Cylicodiscus g.*)	
Meliaceae	
Entandrophragma angolense (Welw.) C. DC.	Tiama, Edinam
Entandrophragma cylindricum (Sprague) Sprague	Sapelli
Entandrophragma utile (Dawe & Sprague) Sprague	Sipo
Guarea cedrata (A. Chev.) Pellegr.	Bossé
Guarea thompsonii Sprague & Hutch.	Black Guarea
Khaya ivorensis A. Chev.	African Mahogany
Moraceae	
Milicia excelsa (Welw.) C.C. Berg	Iroko, Odum
(= *Chlorophora e.*)	
Ochnaceae	
Lophira alata Banks ex Gaertn.	Azobé
Rhizophoraceae	
Anopyxis klaineana (Pierre) Engl.	Bodioa, Kokoti
Rubiaceae	
Nauclea diderrichii (De Wild.) Merrill	Bilinga
Sapotaceae	
Tieghemella heckelii Pierre ex. A. Chev.	Makoré, Douka
Sterculiaceae	
Heritiera utilis (Sprague) Sprague	Niangon
(= *Tarrietia u.*)	
68cm drh	
Combretaceae	
Terminalia ivorensis A. Chev.	Framire
Terminalia superba Engl. & Diels	Limba
Leguminosae	
Piptadeniastrum africanum (Hook. f.) Brenan	Dabéma
Meliaceae	
Lovoa trichilioides Harms	Dibétou,African walnut
(= *L. klaineana*)	
Turraeanthus africanus (Welw. ex DC) Pellegr.	Avodiré
Sterculiaceae	
Mansonia altissima (A. Chev.) J.R. Drumm.	Bété
Nesogordonia papaverifera (A. Chev.) R. Capur.	Kotibé
Triplochiton scleroxylon K. Schum.	Obeche, Samba, Wawa
Ulmaceae	
Celtis adolfi-friderici Engl.	Ohia
Celtis mildbraedii Engl.	Ohia
Celtis zenkeri Engl.	Ohia
58 cm drh	
Rubiaceae	
Hallea stipulosa (DC.) Leroy	Abura, Bahia
(= *Nauclea s.)*	

APPENDIX II

Economic classification of Ghana timber species. Based on Osafo (1970)

Class I: especially valuable timber species

Class Ia:

Meliaceae

Entandrophragma angolense (Welw.) C. DC.
Entandrophragma cylindricum (Sprague) Sprague
Entandrophragma utile (Dawe & Sprague) Sprague
Khaya anthotheca (Welw.) C. DC.
Khaya grandifoliola C. DC.
Khaya ivorensis A. Chev.

Moraceae

Milicia excelsa (Welw.) C.C. Berg (= *Chlorophora e.*)

Rubiaceae

Nauclea diderrichii (De Wild.) Merrill

Sapotaceae

Tieghemella heckelii Pierre ex. A. Chev.

Class Ib:

Combretaceae

Terminalia ivorensis A. Chev.

Leguminosae

Pericopsis elata (Harms) van Meeuwen (= *Afrormosia e.*)

Meliaceae

Lovoa trichilioides Harms (= *L. klaineana*)

Sterculiaceae

Triplochiton scleroxylon K. Schum.

Class Ic:

Sterculiaceae

Heritiera utilis (Sprague) Sprague (= *Tarrietia u.*)

Class II: tree species of general utility

Class IIa:

Leguminosae

Piptadeniastrum africanum (Hook. f.) Brenan

Meliaceae

Entandrophragma candollei Harms
Guarea cedrata (A. Chev.) Pellegr.
Guarea thompsonii Sprague & Hutch.

Ochnaceae

Lophira alata Banks ex Gaertn.

Class IIb:

Leguminosae

Guibourtia ehie (A. Chev.) J. Léonard

Meliaceae

Turraeanthus africanus (Welw. ex DC) Pellegr.

Moraceae

Antiaris toxicaria Lesch. (= *A. africana, A. welwitschii*)

Rubiaceae

Hallea ciliata (Aubr. & Pell.) Leroy (= *Mitragyna c.*)
Hallea stipulosa (DC.) Leroy (= *Mitragyna s.*)
Sterculiaceae
Mansonia altissima (A. Chev.) J.R. Drumm.
Nesogordonia papaverifera (A. Chev.) R. Capur.

Class III: tree species of possible future economic importance

Burseraceae
Canarium schweinfurthii Engl.
Combretaceae
Terminalia superba Engl. & Diels
Ebenaceae
Diospyros sanza-minika A. Chev.
Flacourtiaceae
Scottellia klaineana Pierre (Incl. *S. chevalieri, S. coriacea*)
Guttiferae
Mammea africana Sabine
Lecythidaceae
Petersianthus macrocarpus (P. Beauv.) Liben
(= *Combretodendron macrocarpum, C. africanum*)
Leguminosae
Afzelia africana Sm.
Albizia adianthifolia (Schumach.) W.F. Wight
Albizia ferruginea (Guill. & Perr.) Benth.
Albizia zygia (DC.) j.F. Macbr.
Cynometra ananta Hutch. & Dalz.
Distemonanathus benthamianus Baill.
Erythrophleum suaveolens (Guill. & Perr.) Brenan
(= *E. guineense)*
Piptadenia gabunensis (Harms) Roberty (= *Cylicodiscus g.*)
Myristicaceae
Pycnanthus angolensis (Welw.) Warb. (= *Myristica a.*)
Olacaceae
Strombosia glaucescens Engl. (= *S. pustulata*)
Rhizophoraceae
Anopyxis klaineana (Pierre) Engl.
Sterculiaceae
Sterculia rhinopetala K. Schum.
Ulmaceae
Celtis adolfi-friderici Engl.
Celtis zenkeri Engl.
Holoptelea grandis (Hutch.) Mildbr.

Class IV: all other tree species

APPENDIX III

LIBERIA minimum diameter limits since about 1976

Original source appendix I, II and III of the Forestry Development Authority standard Forest Management Plan-form introduced around 1976 and still applicable. Appendix I minimum diameter limits; appendix II obligatory species (*); appendix III future obligatory species (+).

100 cm drh			
Meliaceae			
	Entandrophragma utile (Dawe & Sprague) Sprague	Sipo	*
Sapotaceae			
	Tieghemella heckelii Pierre ex. A. Chev.	Makoré, Douka	*
90 cm drh			
Bombacaceae			
	Ceiba pentandra (L.) Gaertn.	Fromager	+
Leguminosae			
	Brachystegia leonensis Hutch. & B. Davy	Naga	+
Meliaceae			
	Entandrophragma angolense (Welw.) C. DC.	Tiama, Edinam	*
	Entandrophragma candollei Harms	Kosipo	*
	Entandrophragma cylindricum (Sprague) Sprague	Sapelli	*
Sterculiaceae			
	Triplochiton scleroxylon K. Schum.	Obeche, Samba	*
80 cm drh			
Burseraceae			
	Canarium schweinfurthii Engl.	Aiélé	+
Leguminosae			
	Erythrophleum ivorense A. Chev.	Tali, sasswood	+
	Erythrophleum suaveolens (Guill. & Perr.) Brenan (= *E. guineense*)	Tali	+
	Piptadeniastrum africanum (Hook. f.) Brenan	Dabéma, Dahoma	+
Meliaceae			
	Guarea cedrata (A. Chev.) Pellegr.	Bossé	*
	Guarea thompsonii Sprague & Hutch.	Black Guarea	*
	Turraeanthus africanus (Welw. ex DC) Pellegr.	Avodiré	*
Moraceae			
	Milicia excelsa (Welw.) C.C. Berg (= *Chlorophora e.*)	Iroko, Odum	*
Ochnaceae			
	Lophira alata Banks ex Gaertn.	Azobé	+
Rubiaceae			
	Hallea ciliata (Aubr. & Pell.) Leroy (= *Mitragyna c.*)	Abura, Bahia	*
	Hallea stipulosa (DC.) Leroy (= *Nauclea s.*)	Abura, Bahia	*
	Nauclea diderrichii (De Wild.) Merrill	Bilinga, Kusia	+
70 cm drh			
Apocynaceae			
	Alstonia boonei de Wild.	Emien	+
Bombacaceae			
	Bombax buonopozense Beauv.	Kapokier	+

Combretaceae		
Terminalia ivorensis A. Chev.	Framire	*
Terminalia superba Engl. & Diels	Limba	*
Humiriaceae		
Sacoglottis gabonensis (Baill.) Urb.	Ozouga	+
Leguminosae		
Afzelia bracteata T. Vogel ex Benth.	Doussié	*
Afzelia bella Harms var. *gracilior* Keay		*
Daniellia ogea (Harms) Rolfe ex Holl.	Faro	+
Daniellia thurifera Benn.	Faro, Sopi	+
Meliaceae		
Khaya anthotheca (Welw.) C. DC.	Acajou-blanc	*
Lovoa trichilioides Harms	Dibétou	*
Myristicaceae		
Pycnanthus angolensis (Welw.) Warb. (= *Myristica a.*)	Ilomba	*
60 cm drh all other species including the following * and +		
Guttiferae		
Mammea africana Sabine	Oboto	+
Symphonia globulifera L. f.	Ossol	+
Leguminosae		
Guibourtia ehie (A. Chev.) J. Léonard	Amazakoué	*
Tetraberlinia tubmaniana J. Léonard	Sikon	*
Moraceae		
Antiaris toxicaria Lesch. (= *A. africana*, *A. welwitschii*)	Ako	+
Sterculiaceae		
Heritiera utilis (Sprague) Sprague (= *Tarrietia u.*)	Niangon	*
Mansonia altissima (A. Chev.) J.R. Drumm.	Bété	*
Nesogordonia papaverifera (A. Chev.) R. Capur.	Kotibé	*
Pterygota macrocarpa K. Schum.	Koto	+

APPENDIX IV

Principal tree species (average stem number per ha) of the three studied forest-types: Irobo Evergreen forest-type, Mopri transition of Evergreen and Moist Semi-deciduous forest-type, La Téné Moist Semi-deciduous forest-type. Original source Bertault (1986).

The 42 principal tree species		La Téné	Mopri	Irobo
Guibourtia ehie	Amazakoue (1)	3.1		
Alstonia boonei	Emien (2)	1.1	+	
Terminalia superba	Fraké (1)	2.3	+	
Morus mesozygia	Difou (1)	4.0	+	
Mansonia altissima	Bété (1)	4.6	+	
Ceiba pentandra	Fromager (1)	1.9	1.1	
Khaya anthotheca	Acajou (1)	2.1	5.0	
Aningeria robusta	Aningueri (1)	2.7	7.6	
Entandrophragma cylindricum	Aboudikro (1)	2.8	1.1	
Celtis zenkeri	Asan (3)	7.2	1.9	
Celtis adolfi-friderici	Lohonfe (2)	12.0	6.6	
Gambeya delevoyi	Akatio (1)	12.0	11.1	
Triplochiton scleroxylon	Samba (1)	16.6	2.4	
Nesogordonia papaverifera	Kotibé (1)	21.2	7.3	
Sterculia rhinopetala	Lotofa (2)	24.6	13.9	
Celtis mildbraedii	Ba (2)	60.8	68.4	
Ricinodendron africanum	Eho (2)	5.5	+	+
Lannea welwitschii	Loloti (3)	2.0	1.6	+
Guarea cedrata	Bosse (1)	2.0	9.6	+
Funtumia latifolia	Pouo (2)	8.4	2.4	+
Eribroma oblonga	Bi (2)	9.1	2.4	+
Scottelia spp.	Akossika (1)	7.8	8.5	6.9
Trichilia tessmanii	Aribanda (3)	+	1.2	+
Sterculia tragacantha	Pore-Pore (3)	+	1.4	+
Pycnanthus angolensis	Ilomba (1)	+	2.2	+
Entandrophragma angolense	Tiama (1)	+	2.7	+

Piptadeniastrum africanum	Dabema (2)	+	3.8	+
Daniellia thurifera	Faro (1)	+	+	1.4
Amphimas pterocarpoides	Lati (3)	+	+	2.3
Dacryodes klaineana	Adjouaba (3)	+	3.7	31.9
Petersianthus macrocarpus	Abale (2)		2.7	+
Berlinia spp.	Melegba (2)		2.8	+
Thieghemella heckelii	Makoré (1)		+	1.4
Parinari spp.	Sougue (3)		+	1.8
Gilbertiodendron preussii	Vaa (2)			1.0
Hallea ciliata	Bahia (1)			1.0
Anthonotha fragans	Adomonteu (3)			1.1
Anopyxis klaineana	Bodioa (2)			1.1
Rodognaphalon brevicuspe	Kondroti (1)			1.4
Parkia bicolor	Lo (3)			3.5
Uapaca spp.	Rikio (3)			15.9
Heritiera utilis	Niangon (1)			33.2

- Stem number is given starting from an average stem number of ³ 1 stem/ha
- The + sign indicates the presence of a tree species at a frequency of 0.1 - 1 stem/ha
- If nothing is stated the tree species frequency is < 0.1 stem/ha
- The number stated after the local trade name indicates the technical quality: class 1, especially valuable timber species; class 2, species of general utility; class 3, species of possible future economic importance.

APPENDIX V

Forest Inventory Project classification of Ghana high forest tree species. Source: Wong (1989)

CLASS 1 (Species registered as having been exported from Ghana 1973-1988)

Afzelia bella/ africana
Albizia ferruginea
Albizia zygia
Alstonia boonei
Amphimas pterocarpoides
Aningeria spp.
Anopyxis klaineana
Antiaris toxicaria
Antrocaryon micraster
Berlinia spp.
Bombax brevicuspe
Bombax buonopozense
Canarium schweinfurthii
Ceiba pentandra
Celtis mildbraedii/ zenkeri
Chrysophyllum giganteum/ subnudum/ albidum
Copaifera salikounda
Cordia milenii/ platythyrsa
Cyclodiscus gabunensis
Cynometra ananta
Daniellia ogea/ thurifera
Dialium aubrevillei
Diospyros sanza-minika
Distemonanthus benthamianus
Entandrophragma angolense
Entandrophragma cylindricum
Entandrophragma utile
Entandrophragma candollei
Erythrophleum spp.
Guarea cedrata
Guarea thompsonii
Guibourtia ehie
Heritiera utilis
Khaya antotheca/ grandifoliola
Khaya ivorensis
Klainedoxa gabonensis
Lophira alata
Lovoa trichiloides
Mammea africanum
Mansonia altissima
Milicia excelsa/ regia
Mitragyna ciliata/ stipulosa (= Hallea c., Hallea s.)
Nauclea diderrichii
Nesogordonia papaverifera
Parkia bicolor
Pericopsis elata
Petersianthus macrocarpus

Piptadeniastrum africanum
Pterygota macrocarpa
Pycnanthus angolensis
Sterculia rhinopetala
Strombosia glaucescens
Tereminalia ivorensis
Terminalia superba
Tieghemella heckelii
Triplochiton scleroxylon
Turraeanthus africanus

CLASS 2 (Species attaining 70 cm dbh and occurring at a frequency of more than 1 km^{-1} in the overall inventory results and not presently exported)

Afrosersalisia afzelii
Albizia adianthifolia
Albizia glaberrima
Aningeria spp.
Balanites wilsoniana
Blighia spp.
Bussea occidentalis
Calpocalyx brevibracteatus
Celtis adolphi-friderici
Celtis wightii
Chidlowia sanguinea
Chrysophyllum perpulchrum
Chrysophyllum pruniforme
Cleistopholis patens
Cola gigantea
Corynanthe pachyceras
Coula edulis
Dacryodes klaineana
Duboscia viridiflora
Erythroxylon mannii
Ficus spp. (non-stranglers)
Gilbertiodendron spp.
Hannoa klaineana
Hexalobus crispiflorus
Holoptelea grandis
Homalium letestui
Homalium stipulaceum
Irvingia gabonensis
Lannea welwitschii
Lonchocarpus sericeus
Maranthes spp.
Margaritaria discoidea
Morus mesozygia
Monodora myristica
Ongokea gore
Pachypodanthium staudtii
Panda oleosa
Parinari excelsa
Parkia filicoidea
Pentaclethra macrophylla
Phyllocosmus africanus
Protomegabaria stapfiana
Pseudospondias microcarpa
Pteleopsis hylodendron
Ricinodendron heudelotii
Scottellia klaineana
Sterculia oblonga
Sterculia tragacantha
Stereospermum acuminatissimum
Tabernaemontana spp.
Talbotiella gentii
Treculia africana
Trichilia prieuriana
Trichilia tesmannii
Trilepsium madagascariense

Uapaca guineensis
Xylia evansii
Zanthoxylum spp.

CLASS 3

(All other species)

APPENDIX VI

Minimum felling limits of 1989 in Ghana

Chief Conservator of Forest's Office
Forestry Department,
P.O.Box 527,
Accra

7th November 1989

MINIMUM FELLING LIMITS

1. Until further notice the following minimum felling limits will apply and should be strictly enforced as a prescription for all Forest Reserves.

2. Yield selection and approval should conform with this directive and officers will be personally held responsible for any difficulty.

3. Copies of approved yields should be sent promptly to the Planning Branch who are to monitor this exercise.

CLASS 1 SPECIES
Felling limit 110 cm d.b.h.

Alstonia boonei (Sinuro)
Aningeria spp. (Asanfena)
Ceiba pentandra (Onyina)
Entandrophragma angolense (Edinam)
Entandrophragma cylindricum (Penkwa)
Entandrophragma utile (Enfobrodedwo)
Entandrophragma candollei (Penkwa-akoa)
Khaya anthoteca (Krumben)
Khaya grandifoliola (Krumben)
Khaya ivorensis (Dubini)
Milicia excelsa (Odum)
Milicia regia (Odum)
Nauclea Diderrichii (Kusia)
Parkia bicolor (Asoma)
Piptadeniastrum africanum (Dahoma)
Pterygota macrocarpa (Kyereye)
Triplochiton scleroxylon (Wawa)

Felling limit 90 cm d.b.h.

Amphimas pterocarpioides (Yaya)
Chrysophyllum spp (Akasaa)
Daniella spp. (Hyedua)
Klainedoxa gabonensis (Krona)

Felling limit 70 cm d.b.h.

Afzelia bella (Papao)
Afzelia africana (Papao)
Albizzia ferruginea (Awiemfosamina)
Albizia zygia (Okoro)
Anopyxis klaineana (Kokote)
Antiaris toxicaria (Kyenkyen)
Berlinia spp. (Kwatafompaboa)
Bombax brevicuspe (Onyinakoben)
Bombax buonopozonense (Akata)
Canarium schweinfurthii (Bediwonua)
Celtis mildbraedii (Esa)
Celtis zenkeri (Esakoko)
Cordia spp. (Weneboa)
Cylicodiscus gabunensis (Denya)
Cynometra ananta (Ananta)
Dialium aubrevillei (Duabankye)
Distemonanthus benthamianus (Bonsamdua)
Erythrophleum spp. (Potrodom)
Guarea cedrata (Kwabohoro)
Guarea thompsonii (Kwadwuma)
Guibourtia ehie (Anokye-hyedua)
Heritiera utilis (Nyankom)
Lophira alata (Kaku)
Lovoa trichilioides (Dubinibiri)
Mammea africana (Bompagya)
Mansonia altissima (Oprono)
Mitragyna spp. (Subaha)
Nesogordonia papaverifera (Danta)
Petersianthus macrocarpus (Esia)
Pycnanthus angolensis (Otie)
Sterculia rhinopetala (Wawabima)
Terminalia ivorensis (Emire)
Terminalia superba (Ofram)
Turraeanthus africanus (Apapaye)

Felling Limit 50 cm d.b.h.

Antrocaryon micraster (Aprokuma)
Strombosia glaucescens (Afena)

Felling Limit - Special Permit Required

Copaifera salikounda (Entedua)
Diospyros sanza-minika (Sanza-mulika/Okusibiri)
Pericopsis elata (Kokrodua)
Tiegehemella heckelii (Baku)

CLASS II SPECIES

Felling Limit 110 cm d.b.h.

Ricinodendron heudelotii (Wama)

Felling Limit 90 cm d.b.h.

Blighia spp. (Akye)
Celtis adolfi-friderici (Esakosua)
Cola gigantea (Watapuo)
Hannoa klaineana (Fotie)
Parinari excelsa (Afam)
Pentaclethra macrophylla (Ataa)

Felling Limit 70 cm d.b.h.

Bussea occidentalis (Kotoprepre)
Celtis wigthii (Frempresa)
Chrysophyllum perpulchrum (Atabene)
Gilbertiodendron spp. (Tetekon)
Hexalobus crispiflorus (Duabaha)
Holoptelea grandis (Nakwa)
Lannea welwitschii (Kumanini)
Maranthes spp. (Afram)
Scotellia klaineana (Tiabutuo)
Sterculia oblonga (Ohaa)
Talbotiella gentii (Takorowanua)
Treculia africana (Brebretim)
Trilepisium madagascariense (Okuro)
Xylia evansii (Abobena)
Zanthoxylum spp. (Oyaa/Okuo)

Felling Limit 50 cm d.b.h.

Albizia adianthifolia (Pampena)
Calpocalyx brevibracteatus (Atrotre)
Chidlowia sanguinea (Ababima)
Cleistopholis patens (Ngonenkyene)
Corynanthe pachyceras (Pampenama)
Coula edulis (Bodwue)
Dacryodes klaineana (Adwea)
Duboscia viridiflora (Akokoragyehini)
Erythroxylum mannii (Benkyi-nini)
Ficus spp. (Domini)
Homalium letestui (Esononakoroma)
Homalium stipulaceum (Owebiribi)
Lovingia gabonensis (Abesebuo)
Lonchocarpus sericeus (Sante)
Margaritaria discoidea (Pepea)
Morus mesozygia (Wonton)
Monodora myristica (Wedeaba)
Ongokea gore (Bodwe)
Pachypodantium staudtii (Kumdwie)
Panda oleosa (Kokroboba)
Phyllocosmus africanus (Akokorabeditoa)
Protomegabaria stapfiana (Agyahere)
Pseudospondias microcarpa (Katawani)
Sterculia tragacantha (Sofo)
Stereospermum acuminatissimum (Esono Tokwakofuo)
Trichilia prieuriana (Kakadikuro)
Trichilia tesmannii (Tanunini)
Uapaca guineensis (Kontan)

Felling Limit - Special Permit Required

Afrosersalisia afzelii (Bakunini)
Albizia glaberrima (Okora-akoa)
Balanites wilsoniana (Krobodua)
Chrysophyllum pruniforme (Duatadwe)
Parkia filicoida (Asoma-nua)
Pteleopsis hylodendron (Kwae-kane)
Tabernaemontana spp. (Obonawa)

J.H. FRANÇOIS
CHIEFF CONSERVATOR OF FORESTS

Appendix VII

Côte d'Ivoire economic classification of timber species and minimum diameter limits. SODEFOR since 1990.

Class I: species of high quality (P_1)

Bombacaceae			
	Bombax brevicuspe (= *Rhodognaphalon b.*)	Kondroti	60
	Ceiba pentandra	Fromager	60
Burseraceae			
	Canarium schweinfurthii	Aiélé	60
Combretaceae			
	Terminalia ivorensis	Framiré	60
	Terminalia superba	Fraké	60
Flacourtiaceae			
	Scottelia klaineana (= *S. chevalieri, S. coriacea*)	Akossika	60
Leguminosae			
	Afzelia africana	Lingué	60
	Afzelia bella var. gracilior	Azodau	60
	Daniellia ogea	Faro	60
	Daniellia pynaertii	Faro	60
	Daniellia thurifera	Faro	60
	Distemonanthus benthamianus	Movingui	60
	Erythrophleum ivorense	Tali	60
	Guibourtia ehie	Amazakoué	60
	Pericopsis elata (= *Afrormosia e.*)	Assamela	50
Meliaceae			
	Entandrophragma angolense	Tiama	60
	Entandrophragma candollei	Kosipo	60
	Entandrophragma cylindricum	Aboudikro	60
	Entandrophragma utile	Sipo	60
	Khaya anthotheca	Acajou	60
	Khaya grandifoliola	Acajou	60
	Khaya ivorensis	Acajou	60
	Guarea cedrata	Bossé	60
	Lovoa trichilioides	Dibétou	60
	Turraeanthus africanus	Avodiré	60
Moraceae			
	Antiaris toxicaria (= *A. africana, A. welwitschii*)	Ako	60
	Milicia excelsa (= *Chlorophora excelsa*)	Iroko	60
	Milisia regia (= *Chlorophora regia*)	Iroko	60
	Morus mesozygia	Difou	60
Myristicaceae			
	Pycnanthus angolensis (= *P. kombo*)	Ilomba	60
Ochnaceae			
	Lophira alata	Azobé	60
Rubiaceae			

	Mitragyna ciliata (= *Hallea c.*)	Bahia	60
	Nauclea diderrichii	Badi	60
Sapotaceae			
	Aningeria robusta	Aniégré blanc	50
	Chrysophyllum delevoyi (= *Gambeya d.*)	Akatio	--
	Chrysophyllum giganteum (= *Gambeya gigantea*)	Aniégré rouge	50
	Tieghemella heckelii	Makoré	60
Sterculiaceae			
	Heritiera utilis (= *Tarrietia u.*)	Niangon	50
	Mansonia altissima	Bété	50
	Nesogordonia papaverifera	Kotibé	50
	Pterygota macrocarpa	Koto	60
	Triplochiton scleroxylon	Samba	60

Class II: species of average quality (P_2)

Apocynaceae			
	Alstonia boonei	Emien	60
	Funtumia elastica (= *F. latifolia*)	Pouo	60
Bombacaceae			
	Bombax buonopozense	Oba	--
Euphorbiaceae			
	Ricinodendron heudelotii	Eho	60
Irvingiaceae			
	Klainedoxa gabonensis	Kroma	--
Lecythidaceae			
	Petersianthus macrocarpus	Abalé	--
Leguminosae			
	Albizia ferruginea	Iatandza	60
	Berlinia confusa	Melegba	60
	Berlinia tomentella	Melegba	60
	Copaifera salikounda	Etimoé	--
	Gilbertiodendron preussii	Vaa	60
	Piptadeniastrum africanum	Dabéma	60
Rhizophoraceae			
	Anopyxis klaineana	Bodioa	--
Rutaceae			
	Zanthoxylum gilletti (= *Fagara macrophylla*)	Bahé	--
Sterculiaceae			
	Sterculia oblonga (= *Eribroma o.*)	Bi	60
	Sterculia rhinopetala	Lotofa	60
Ulmaceae			
	Celtis adolfi-friderici	Lohonfe	60
	Celtis mildbraedii	Ba	60

Class III: species of lesser quality (P_3)

Anacardiaceae			
	Lannea welwitschii	Loloti	--
Burseraceae			
	Dacryodes klaineana	Adjouaba	--
Chrysobalanaceae			
	Parinari excelsa	Sougué	--
	Parinari congensis	Sougué	--
Combretaceae			
	Pteleopsis hylodendron	Koframiré	--
Erythroxylaceae			
	Erythroxylum mannii	Dabé	--
Euphorbiaceae			
	Uapaca spp.	Rikio	--
Leguminosae			
	Albizia zygia	Ouochi	--
	Amphimas pterocarpoides	Lati	--
	Anthonotha fragrans	Adomontou	--
	Aubrevillea kerstingii	Kodabéma	--
	Berlinia occidentalis	Pocouli	60
	Detarium senegalense	Bodo	--
	Parkia bicolor	Lo	--
	Xylia evansii	Tchiebuessain	--
Meliaceae			
	Trichilia tessmannii	Aribanda	--
Simaroubaceae			
	Gymnostemon zaizou	Zaïzou	--
Sterculiaceae			
	Sterculia tragacantha	Poré-Poré	--
Ulmaceae			
	Celtis zenkeri	Asan	--
	Holoptelea grandis	Kékélé	60

Class IV: all other tree species

APPENDIX VIII

Elephant poaching activities in Bia National Park, Ghana during one year. Based on Opoku (1988).

Date	Elephants killed	Remarks
06.02.87	two by Ivorian poachers	tusks lost
26.06.87	one	tusks lost
21.08.87	one by Ivorian poachers	tusks confiscated
26.08.87	one	tusks lost
11.10.87	one	tusks lost
25.11.87	one	tusks lost
02.03.88	one	tusks confiscated

APPENDIX IX

National forest elephant culling executed by Game Control Unit - Goaso after farm raiding incidences. Based on Opoku (1988).

Date	Elephants culled	Location		Estimated farm damage
26.01.87	one male	Gyesewobere	Subin FR	Cedi 25,000
28.01.87	one female	Kyemeasua	Ayum FR	Cedi 32,000
18.02.87	one male	Baakoaue	Subin FR	Cedi 46,000
24.06.87	one male	Gyakontabuo	Asin Atandaso FR	Cedi 75,000
25.06.87	one male	Kasim	Asin Atandaso FR	Cedi 55,000
04.07.87	one male	Mantukwa	Draw River FR	Cedi 205,000
28.09.87	one male	Bediako	Bia Tano FR	Cedi 96,000
04.11.87	one male	Nsuta	Asukese FR	Cedi 167,000
01.02.88	one male	Aboabo No.1	Asin Atandaso FR	Cedi 93,000
12.02.88	two males	Arkokwaah	Kakum FR	Cedi 181,000
08.03.88	one male	Adututu	Subin FR	Cedi 75,000
24.06.88	one male	Gyesewobre	Subin FR	Cedi 55,000
11.07.88	one male	Goamu	Asukese FR	Cedi 35,000
16.07.88	one female	Bediako	Bia Tano FR	Cedi 45,000
02.08.88	two females	Bediako	Bia Tano FR	Cedi 17,000
18.08.88	one male	Arkokwaa	Kakum FR	Cedi 105,000
17.10.88	one female	Gambia No.1	Bia Tano FR	Cedi 114,000
16.11.88	one male	Kokofu	Bia Tano FR	Cedi 64,000

In total 20 elephants were culled between December 1986 - December 1988

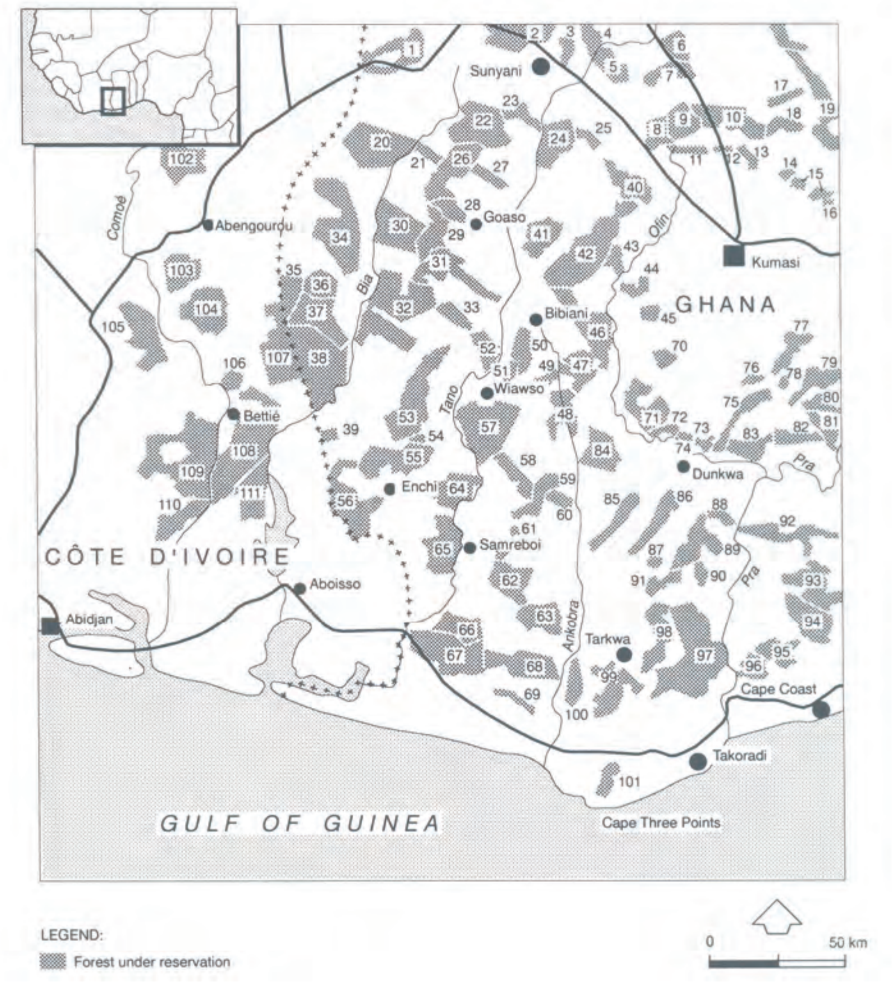
* 13 elephants of the Goaso population
* 6 elephants of the Kakum population
* 1 elephant of the Ankasa population

Exchange rate at the time £1.00 = C 450.00

APPENDIX X

Proposed Transnational Bia-Bossematié network area and status. For Ghana based on Appendix I Hall & Swaine (1981), Mensah (1990), for the Côte d'Ivoire on Laumans *et al.* (1991), Cuny (1986).

Conservation network	Reserve area	Illegal farm area	Date of reservation
Trans Bia South			
Bia NP	7,770 ha		1974
Bia GPR	22,790 ha		1974
Sukusuku FR	14,760 ha	11,000 ha	1972
Bia Tawya FR	55,400 ha	32,000 ha	1965
Trans Bia North			
Bia North FR	35,610 ha		1940
Manzan FR	30,450 ha	18,000 ha	1972
Goaso			
Asukese FR	26,500 ha		1934
Mpameso FR	32,250 ha		1937
Bia Shelterbelt FR	2,950 ha		1940
Bosumkese FR	13,830 ha		1937
Amama Shelterbelt FR	4,400 ha		1940
Bia Tano FR	19,430 ha		1937
Bonkoni FR	7,510 ha		1934
Subin FR	23,830 ha		1956
Ayum FR	11,290 ha		1940
Bonsam Bepo FR	12,430 ha		1934
Krokosua Hills FR	48,170 ha		1935
Muro FR	6,350 ha		1951
Enchi			
Dadiaso FR	17,120 ha		1977
Boin River FR	27,760 ha		1932
Yoyo FR	23,570 ha		1932
Disue River FR	2,360 ha		1943
Tano Ehuro FR	17,610 ha	10,000 ha	1967
Tano Anwia FR	15,310 ha		1935
Santomang FR	2,120 ha		1944
Sui River FR	33,390 ha		1930
Bodi FR	16,700 ha	13,000 ha	1967
Bossematié			
Bossematié FC	22,400 ha	2,500 ha	
Béki FC	16,100 ha	1,800 ha	
Diambarakrou FC	27,350 ha	800 ha	
Besso FC	23,100 ha	300 ha	1976
Manzan FC	4,500 ha	800 ha	1975
Bettié			
Mabi FC	51,000 ha	2,800 ha	1929
Songan FC	35,900 ha	5,400 ha	1952
Tamin FC	26,300 ha	8,800 ha	1952
Yaya FC	22,100 ha	700 ha	1935



An overview of all forest under reservation in the proposed transboundary Bia-Bossematié network area depicted in Figure 2.8.

APPENDIX XI

1 Pamu Berekum
2 Tain II
3 Tain I
4 Yaya
5 Mankrang
6 Asubima
7 Afrensu Brohuma
8 Kwamisa
9 Opro River
10 Afram Headwaters
11 West Asufu
12 East Asufu
13 Gianima
14 Ofin Headwaters
15 Ongwam
16 Kronwam
17 Abrimasu
18 Aboma
19 Awura
20 Mpameso
21 Bia Shelterbelt
22 Asukese
23 Amama Shelterbelt
24 Bosumkese
25 Aparapi Belt
26 Bia Tano
27 Goa Shelterbelt
28 Bonkoni
29 Ayum
30 Subin
31 Bonsam Bepo
32 Krokosua Hills
33 Muro
34 Bia North
35 Sukusuku
36 Bia NP
37 Bia South GPR
38 Bia Tawya
39 Dadiaso
40 Tinte Bepo
41 Desiri
42 Tano Ofin
43 Ofin Shelterbelt
44 Jimira
45 Jeni River
46 Asenanyo
47 Anhwiaso East
48 Upper Wassaw
49 Afao Hills
50 Tano Suraw Ext.
51 Tano Suraw
52 Tano Suhien
53 Sui River
54 Santomang
55 Yoyo River
56 Boin River
57 Suhuma
58 Totua Shelterbelt
59 Bura River
60 Angoben Belt
61 Mamiri
62 Fure Headwaters
63 Fure
64 Tano Anwia
65 Tani Nimri
66 Nini-Suhien NP
67 Ankasa GPR
68 Draw River
69 Ebi River Belt
70 Apamprama
71 Oda River
72 Subin Shelterbelt
73 Denyau Shelterbelt
74 Supuma Shelterbelt
75 Dampia Range
76 Ponro
77 Bosumtwi Range
78 Chiremoasi Bepo
79 Fum Headwaters
80 Nyamibe Bepo
81 Onuem Nyamibe Belt
82 Numia
83 Nkrabia
84 Tonton
85 Bowiye Range
86 Opon Mansi
87 Nkonto Ben
88 Minta
89 Bonsa Ben
90 Ben East
91 Ben West
92 Bimbong
93 Asin Atandanso
94 Kakum
95 Pra Suhien II
96 Pra Suhien I
97 Subri River
98 Bonsa River
99 Neung
100 Ndumfri
101 Cape Three Points
102 Brassué
103 Béki
104 Bossematié
105 Besso
106 Manzan
107 Diambarakro
108 Songan
109 Mabi
110 Yaya
111 Tamin

APPENDIX XII

Decision-chart for silviculture in natural forests in the Côte d'Ivoire as envisaged by SODEFOR. Adapted from Aïdara (in prep).

For tree species categories (economic classification) see Appendix VII

The diagnosis takes into account:
(1) the number of seed trees (> 50 cm drh),
(2) the number of Potential Crop Trees (20-50 cm drh) and
(3) the regeneration (5-20 cm drh), all of Class 1 commercial species.

1) When an exploitable number of seed trees of Class 1 species > 50 cm drh is available per hectare, silvicultural prescriptions will be:

   in case of a 'rich' stand, which means more than 4 such trees ha^{-1} in evergreen forest and more than 8 such trees ha^{-1} in semi-deciduous forest, the following interventions will have to be carried out:

- climber cutting in year n
- tree marking (hammering) for exploitation in year n
- controlled exploitation (in year n+1 up to year n+3) in which seed trees are to be spared and a maximum of 5 trees ha^{-1} to be harvested. Number of seed trees to be spared depends on regeneration counts. In evergreen forest 'rich' regeneration indicates sparing 4 seed trees ha^{-1}, and poor regeneration indicates sparing 5 seed trees ha^{-1}. In semi-deciduous forest 'rich' regeneration indicates sparing of 8 seed trees ha^{-1}, and poor regeneration sparing of 12 seed trees ha^{-1}. In general, of each Class 1 species, at least 10 stems (trees) > 60 cm drh have to be spared per 100 ha.

2) in case of a poor stand as regards seed trees, the Potential Crop Tree population is to be considered (or the regeneration).

   When the stand is 'rich', which implies more than 20 PCTs ha^{-1} in evergreen forest, and more than 30 PCTs ha^{-1} in semi-deciduous forest, the following interventions have to be carried out:

- climber cutting in year n
- PCT marking in year n
- liberation of PCTs in year n

3) When the PCT stand is poor the regeneration counts have to be considered. Regeneration is defined as trees of Class 1 species in the 5-20 cm drh class.

When regeneration is 'rich', which implies more than 75 individuals ha^{-1} in evergreen forest and more than 125 individuals ha^{-1} in semi-deciduous forest, the tasks will be:

- protect and wait
- liberation in a very restricted number of cases (i.e. FC Bossematié)

When regeneration is poor, this may lead to declaring the forest to be ruined.
In a forest declared ruined, the tasks will be:

- protect and wait
- enrichment planting in a very limited number of cases (i.e. FC Yapo).

4) In case of already cleared or even cultivated former forest land the size of the area is decisive for the choice of measures. When smaller than 10 ha, protect and wait; when larger than 10 ha, reforestation should be applied.