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"NATURAL FOREST ON FARMS IN THE NORTHERN ATLANTIC ZONE OF COSTA RICA

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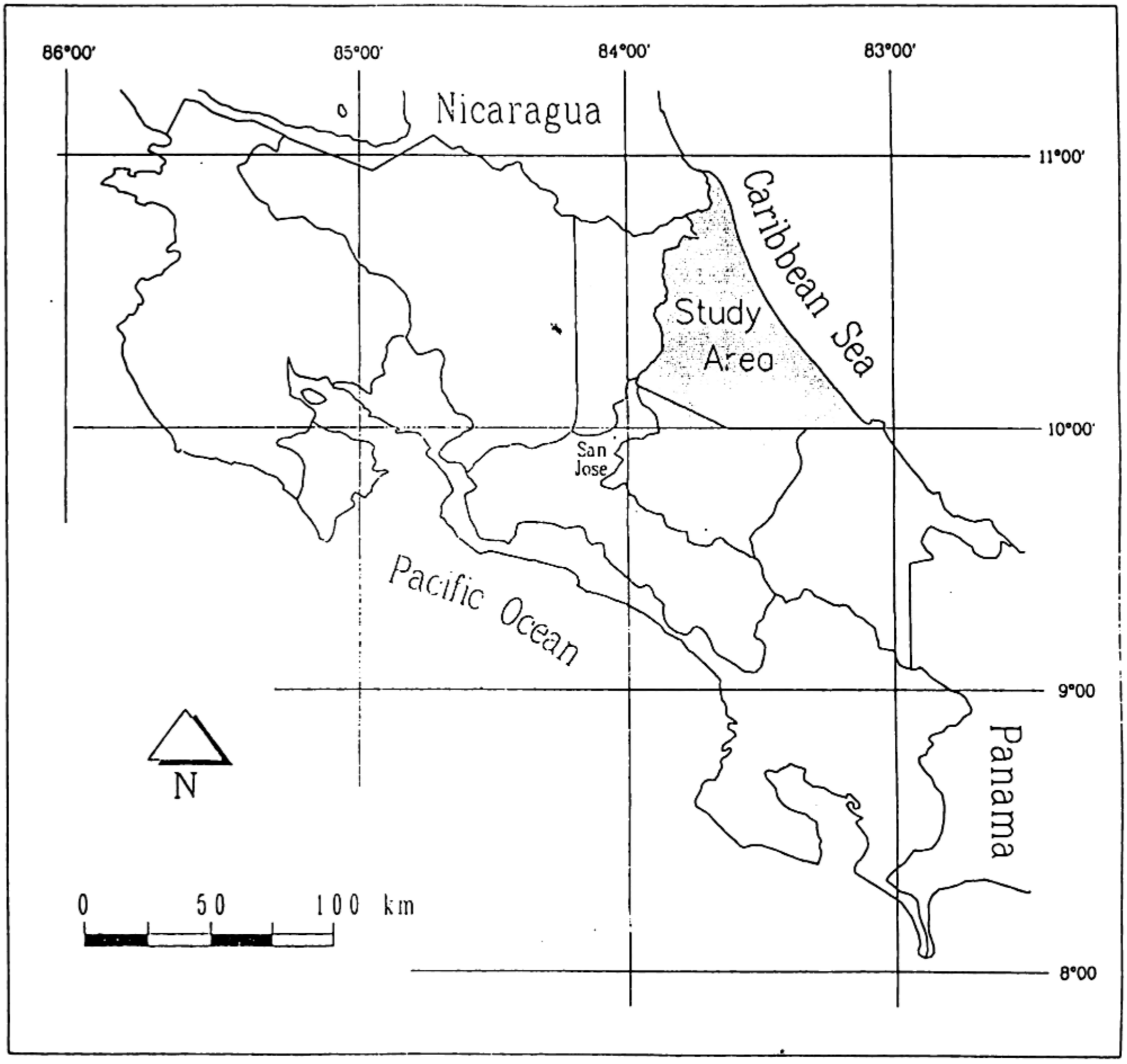

86°00'
85°00'
84°00'
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Nicaragua
11°00'
Caribbean Sea
Study Area
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San Jose
Pacific Ocean
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PREFACE

General description of the research programme on sustainable Landuse.

The research programme is based on the document "elaboration of the VF research programme in Costa Rica" prepared by the Working Group Costa Rica (WCR) in 1990. The document can be summarized as follows:
To develop a methodology to analyze ecologicaly sustainable and economically feasible land use, three hierarchical levels of analysis can be distinguished.
1. The Land Use System (LUS) analyses the relations between soil type and crops as well as technology and yield.
2. The Farm System (FS) analyses the decisions made at the farm household regarding the generation of income and on farm activities.
3. The Regional System (RS) analyses the agroecological and socio-economic boundary conditions and the incentives presented by development oriented activities.

Ecological aspects of the analysis comprise comparison of the effects of different crops and production techniques on the soil as ecological resource. For this comparision the chemical and physical qualities of the soil are examined as well as the polution by agrochemicals. Evaluation of the groundwater condition is included in the ecological approach. Criterions for sustainability have a relative character. The question of what is in time a more sustainable land use will be answered on the three different levels for three major soil groups and nine important land use types.

Combinations of crops and soils

	Maiz	Yuca	Platano	Piña	Palmito	Pasto	Forestal I II III
Soil I	x	x	x		x	x	x
Soil II						x	x
Soil III	x			x	x	x	x

As landuse is realized in the socio-economic context of the farm or region, feasibility criterions at corresponding levels are to be taken in consideration. MGP models on farm scale and regional scale are developed to evaluate the different ecological criterions in economical terms or visa-versa.

Different scenarios will be tested in close cooperation with the counter parts.

The Atlantic Zone Programme (CATIE-AUW-MAG) is the result of an agreement for technical cooperation between the Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), the Agricultural University Wageningen (AUW). The Netherlands and the Ministerio de Agricultura y Ganadería (MAG) of Costa Rica. The Programme, that was started in April 1986, has a long-term objective multidisciplinary research aimed at rational use of the natural resources in the Atlantic Zone of Costa Rica with emphasis on the small landowner.

PREFACE

The present thesis has been written as a contribution to the PhD-forestry research project titled: "Integration of trees and forests in farming systems; an intertemporal LP model on farm level as a tool for land use planning in the Atlantic Zone of Costa Rica". The project is part of the research conducted by the Atlantic Zone programme, a cooperation between the Wageningen Agricultural University, the Centro Agronómico Tropical de Investigación y Enseñanza (CATIE) and the Ministerio de Agricultura y Ganadería (MAG). The Programme has a long term objective to carry out research toward rational natural resources use in the Atlantic Zone of Costa Rica with emphasis on the small land owner.

The general aim of the PhD-forestry research project is to contribute to the process of rural development, based on sustainable land use, in the Atlantic Zone of Costa Rica, by studying the conditions under which trees and forest can be viable components of the farming system. The information gathered from field research will be incorporated in a Linear Programming Model (LPM) for land use planning. The results of the LPM will be used in regional land use planning. The three land use types that are included in the research are: natural forests, plantation forestry and agroforestry.

This study comprises of an analysis of the composition and utilization of natural forest on farms. The research, which conducted the basis of the presented report, has been executed in three research areas in the northern part of the Atlantic Zone. The information which this analysis provides, will be incorporated into the LPM.

The supervisor for this MSc thesis in Costa Rica and The Netherlands was Ir. A.C.J. van Leeuwen, PhD researcher at the Department of Forestry of the Wageningen Agricultural University. Supervision in The Netherlands came, additionally, from Dr.Ir. N.R. de Graaf of the same department. Gratitude goes to both for their critical and useful comments on the research and the manuscript.

Furthermore, I would like to thank Dr. C. Sabogal and MSc F. Carrera of the CATIE/RENARM-project for their advices about and support of the forest inventories and the providence of data analysis software (SED). Furthermore, thanks go the Costarican field assistants Ulises Gómez ('Pipi'), Mario Solano, Carlos Pérez and Enrique Alfaro for their cooperation in the field work and in the socialization.

SUMMARY

This study on the composition and utilization of natural forest on farms was carried out in the northern part of the Atlantic Zone of Costa Rica. In this thesis, the current functions of natural forests in farming systems in the Atlantic Zone are analyzed and possibilities are identified to improve the functions of those forests within farming systems or in land use in general. Research was conducted in three sub-regions of the Atlantic Zone, i.e. Neguev, Río Jiménez, and Cocorí.

The Atlantic Zone is characterized by a humid to very humid climate, with a natural vegetation of tropical rainforest. Due to colonization, and the establishment of cattle ranches and large scale banana plantations, forests are rapidly decreasing. In the Atlantic Zone, forests are not apparent in extensive areas any more, but can still be found in smaller areas on private farms. Forest plots remain where there has been no time or need yet for conversion to crops or pasture. However, forest is at present a supplemental source of income and products for farmers and it could sustain this function when properly managed.

The methodology used in this research to arrive at an analysis of the current and potential utilization of forest on farms in the Atlantic Zone, comprises a combination of two tools for land use planning: Land Evaluation and Farming Systems Analysis. This combination allowed the description of forest use in the technical terms of land utilization types (LUTs) and in the relation between LUTs and farming systems on the one hand, and the description of forest stands in land mapping units on the other hand.

The data for the description and analysis of the forest use were gathered in two phases. First, 40 farmers with forest on their farms were interviewed about their former utilization of the forest, their objectives towards their forest and constraints influencing forest management. In the second phase, seven inventories of forests, selected on basis of their former utilization and hydrology, were carried out.

In this research, two LUTs have been identified, both directed on wood production. In the first type, farmers sell the standing trees to a contactor, who extracts the logs with machines. In the second type, the wood is extracted by hand or animal traction and used for maintenance of the farm or sold to a neighbour. Other silvicultural operations than harvesting were hardly identified, neither was the use of non-timber forest products by farmers. Although most farmers consider commercial and/or consumptive exploitation of their forest in the future, the forest is not regarded as a productive part of the farm with a need of management. The present general trend is that forest is given a romanticized value by farmers, like the protector of humidity, plants and animals. The presence of the forest depends often on other farm components. When labour is available or income fails, the forest will often be converted to pasture. The farmers lack the ability to determine the real economic value of the forest as well as the knowledge to use and improve that value. Furthermore, forest utilization is hindered by legal and bureaucratic obstacles. The relative importance of natural forest for farmers has led in this study to the identification of four types of farming systems, i.e. small farmers making regular use of their forest, pastoralists directed on conversion of their forest to pasture, farmers who need products,

income, nor the land from their forest, and farmers who have forestry, for financial gain, as major activity on the farm.

In the Atlantic Zone, two types of forest have been identified and described, i.e. the well-drained and poorly-drained forest, although the inventories of several well-drained forest stands under different management give the indication that the variety in forest types is larger. In both types of forest, *Pentaclethra macroloba* and *Carapa guianensis* are the most dominant species. The well-drained forest shows a considerably higher production potential than the poorly-drained forest. All exploited stands were in need of silvicultural treatments decreasing competition and increasing the commercial share. The secondary forests appeared very diverse, but show in general a very high commercial production.

At the end of the study, a series of forest management options for the different farming systems are discussed, enclosing techniques for forest mensuration and silvicultural and harvesting operations. Farmers need extension on the possibilities of forest management in order to allow them to make a rational choice between silvicultural and livestock systems as the "best" use of their land. Technical assistance should be provided and constraints related to legislation and the marketing of forest products should be removed to make forest utilization more attractive and to improve the quality of the practices. The introduction of forest management should be supported by appropriate research.

RESUMEN

Este estudio por la composición y aprovechamiento del bosque natural en fincas fue ejecutado en la parte norte de la Zona Atlántica de Costa Rica. En ésta tesis, las funciones actuales de bosques naturales en sistemas agropecuarios en la Zona Atlántica son analizadas y las posibilidades para mejorar las funciones de estos bosques en sistemas agropecuarias y en el use de tierras en general son identificadas. Los estudios fueron realizados en tres sub-regiones de la Zona Atlántica, a.s. Neguev, Río Jiménez y Cocorí.

La Zona Atlántica es caracterizada por un clima húmedo a muy húmedo, con una vegetación natural del bosque tropical húmedo. Por efecto de colonización, y el establecimiento de fincas ganaderas y bananeras de escalas largas, los bosques están disminuyendo rápido. En la Zona Atlántica, los bosques no están ya, mas presentes en áreas extensivas, pero todavía pueden encontrarlos en fincas privadas. Lotes con bosque permanecen donde no habían tiempo o necesidad ya, para la conversión a cultivos o pasto. No obstante, actualmente, bosque es una fuente suplemental de ingresos y productos para agricultores. El bosque podría mantener esa función siempre cuando su manejo sea correcto.

La metodología usada en esta investigación para llegar a un análisis del aprovechamiento actual y potencial de bosques en fincas de la Zona Atlántica, contiene una combinación de dos herramientas para la planificación del uso de tierra: Evaluación de Tierra y Análisis de Sistemas Agropecuarios. Esta combinación permitió la descripción del uso del bosque en términos técnicos de tipos de utilización de la tierra (LUTs) y en la relación entre LUTs y sistemas agropecuarios por un lado, y la descripción de bosques en unidades de tierra proyectada por el otro lado.

Los datos para la descripción y análisis del uso del bosque fueron acumulados en dos fases. Primero, 40 agricultores con bosque en las fincas, fueron entrevistados por el aprovechamiento antiguo del bosque, los objetivos con el bosque y estorbos influyendo el manejo del bosque. En la segundo fase, siete inventarios de bosques, seleccionados en base a la aprovechamiento anterior y hidrología, fueron ejecutados.

En ésta investigación, dos LUTs fueron identificados, los dos dirigidos a producción de madera. En el primer tipo, los agricultores venden árboles en pie a un intermediario, quien saca los troncos con máquina. En el segundo tipo, la madera es sacada por mano o tracción animal y usada para el mantenimiento de la finca o vendida a un vecino. Otras operaciones silviculturales que cosechar, apenas fueron identificadas, tampoco fue el uso por finqueros, de productos forestales no maderables. Aunque, la mayoría de los agricultores lo consideran como explotación comercial y/o consuntiva del bosque, el bosque no es apreciado como una parte productiva de la finca con una necesidad de manejo. La tendencia general actual es que el bosque obtiene un valor romántico de los agricultores como protección de la humedad, plantas y animales. La presencia del bosque depende frecuentemente de otros componentes de la finca. Cuando la mano de obra esta disponible o los ingresos faltan, el bosque a menudo lo convertirán en pasto. A los agricultores les falta la potencia para determinar el valor económico actual del bosque y también el conocimiento para usar y mejorar éste valor. Además, el uso del bosque esta

obstruido por obstáculos burocráticos y legales. La importancia relativa de bosques naturales para agricultores ha llevado en este estudio a la identificación de cuatro tipos de sistemas agropecuarios: agricultores pequeños que usan el bosque a menudo, pastoralistos dirigidos a la conversión de sus bosques a pasto, agricultores que no ocupan los productos, el ingreso, ni la tierra de su bosque, y agricultores que tienen forestería para ganancias financieras, como la mayor actividad de la finca.

En la Zona Atlántica, dos tipos de bosques fueron identificados y descritos: Bosque con buen y con mal drenaje, aunque los inventarios de diferentes bosques, con buen drenaje, pero con manejo diferente, dan la indicación que la variedad en tipos de bosque es más grande. En los dos tipos de bosque, *Pentaclethra macroloba* y *Carapa guianensis* son las especies mas dominantes. El bosque con buen drenaje muestra una producción potencial considerable más alta que el bosque con mal drenaje. Todos los bosques intervenidos necesitaron tratamientos silviculturales para reducir la competencia y aumentar la parte comercial. El bosque secundario pareció muy diverso, pero muestra una producción comercial bastante alta.

Al final del estudio, una serie de opciones del manejo del bosque para los diferentes sistemas agropecuarios están discutidos, incluyendo técnicas para la medición de bosques, operaciones silviculturales y para la corta. Los agricultores necesitan extensión sobre las posibilidades del manejo del bosque para permitirles hacer una elección racional entre sistemas silviculturales y ganaderos como "El mejor" uso de la tierra. Asistencia técnica debería de ser puesta a disposición y obstáculos relacionados a la legislación y comercialización de productos forestales deberían de ser movidos para hacer la utilización del bosque más atractiva y para mejorar la calidad de las prácticas. La introducción del manejo del bosque debería de ser soportado por investigaciones apropiadas.

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Natural forest on farms in the northern Atlantic Zone of Costa Rica

1. INTRODUCTION

1.1 Introduction

The presented study is an attempt to describe the use and composition of "natural forests" in the Atlantic Zone of Costa Rica. It is an analysis of the small scale use of forests on farms in three research areas in the northern part of the Atlantic Zone, i.e. Neguev, Río Jiménez and Cocorí.

The area under forest in Costa Rica has been decreasing rapidly over the past decades. The principal cause of the deforestation is a strong demand for land, rather than for timber (Hartshorn et al., 1982). In the Atlantic Zone of Costa Rica forests and trees are still an important component in land use. Due to the rapid deforestation forests are not apparent in extensive areas any more, but forests can still be found in smaller areas on private farms, and trees are mixed with agricultural crops and pasture in agricultural systems. Trees and forests are an important part of the farm, either as a source of land, a stabilizing element in land use or a source of wood, fruits and money (van Leeuwen, 1992). However, the use of forests and trees is little rationalized. The natural forest precluded agricultural expansion, communication and trade while the abundance of forest has always provided a surplus of forest products, leading to an underestimation of their value (Romeijn et al., 1987). Many trees and forests are cut due to a prevalence of short term benefits over long term benefits (van Leeuwen, 1992). Forest plots remain where there has been no time yet for conversion to crops or pasture. On the pasture trees are left from the original forest, but a gradual reduction of their number occurs with longer colonization (Romeijn et al., 1987). The disappearing of forests and trees can bring along some negative effects. Due to logging and agricultural expansion, areas of lower agricultural potential and those serving ecological stability are claimed (Romeijn et al., 1987). This is not only a development on regional level but takes place within farms as well, where patches of potentially productive forest are removed to make place for agriculture independent of the suitability of the soil for such land uses. Furthermore, there might be lack of timber and non-timber products for sale and on-farm use in the near future (van Leeuwen, 1992) with its consequences for the farmers' economies. The exhaustion of the natural forests available for exploitation will have profound effects on the national economy as well (Hartshorn et al., 1982).

When natural forests on farms are considered, one deals with relative small areas of land, ranging from 0.5 to over 100 hectares. Up till now forestry activities have almost exclusively been limited to harvesting (timber mining). General studies on the forest and tree component on farms in the Atlantic Zone by Verbraeken (1988) and Zambon (1987) and the more economic evaluation of this component by Hulsebosch (1992) give the impression that forest is a supplemental source of income and products and that it could sustain this function when properly managed, but that at present, it is not appreciated as of major importance for the farm or the farm household in a way that farmers choose to maintain it in some forest like state. It is considered as a source of land. Farmers still have forest due to the fact that they did not have the time or the labour to turn it into another land use or they did not need or could not manage more land of another use. Furthermore, preliminary visits of farmers for this study did show that the regulations on forest use are anything but an incentive to change this attitude.

The assumption that forests could contribute with products and income to the farm households is supported by investigations in La Selva, Sarapiqui (Hartshorn et al., 1982) and of CATIE[1] (Finegan and Sabogal, 1988a; Hutchinson, 1988a). They make clear that certainly under the present market conditions, which allow the acceptance of almost every tree species by sawmills, timber production in the heterogeneous tropical forests of Costa Rica can be ecologically possible and economically feasible.

However, most research on forest management for timber production has been realised in experimental plots and little experience is gained with forest management suitable for execution by small farmers with relatively small forests or the requisites for the successful implementation of such practices. Furthermore, there is a lack of information on the composition of forests and of forest dynamics in the plains of the Atlantic Zone.

Considering the foregoing, research will be necessary on the small farmers' perception of forests on their farms and how forest management could be economically viable to make the investment of labour and other inputs in natural forest management interesting for the farmer or farmer groups. The requirements and outputs, financial as well as non-financial, of the existing types of forest utilization have to be described as well as the possibilities to improve those activities.

1.2 Objectives and research questions

The general objective of this study is to contribute to the PhD-forestry research on the viability of tree and forest components in farming systems in the Atlantic Zone; the development of a methodology for the planning of sustainable land use.

Problem statement: What are the functions of natural forests in farming systems in the Atlantic Zone of Costa Rica at the moment and what are the possibilities to increase the (positive) functions of those forests within these farming systems or in land use in general?

Research questions and related sub-questions:

1) What are the natural forest resources on farms?
   - how can different types of natural forest and forest stands be classified so that management needs can be determined?
   - what are the effects of different types of utilization on the composition and exploitable stock of forests?

[1] Centro Agronómico Tropical de Investigación y Enseñanza (Tropical Agricultural Research and Training Centre).

2) What are currently the different types of natural forest management on farms?
   - what is the opinion of the farmers on the functions of their forest?
   - what are the inputs and outputs of forest management by farmers?
   - are there patterns in forest size and use in relation to research area, farm size, etc.?
   - what are the objectives of farmers regarding their forest?

3) What are possible improvements of the actual forest land utilization types on farms?
   - what are the constraints farmers encounter in the utilization of their forest?
   - what are provisional alternative forest management practices for the identified forest types and stands?
   - what alternative practices are feasible according to the possibilities and constraints of the farmers?

1.3 Methodology and organization of the study

The aim of this report is to give a description of the utilization and composition of natural forests on the farms in the northern Atlantic Zone of Costa Rica and to search for possibilities to improve the current use.

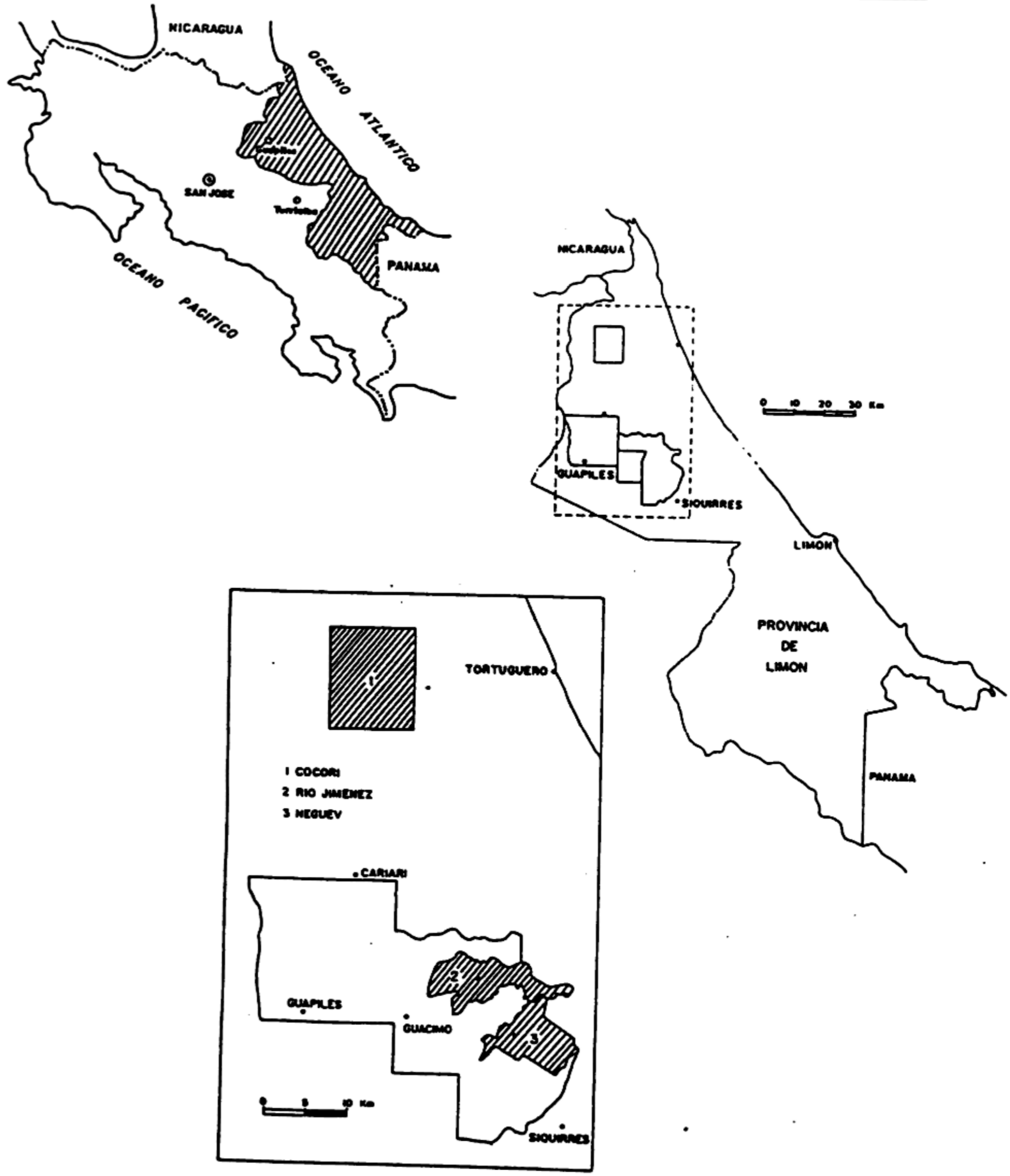
For this purpose, first the context of the present forest use on farms will be given as derived from literature (chapter 2). The three research areas will be shortly described as well as the land use in general and the colonization history of the Atlantic Zone, which is important for an understanding of the current attitude of farmers towards forest.

Farmers' forest utilization will have to be compared in this research with silvicultural practices generally applied in the tropics. In order to make proper use of the complex and diverse tropical rainforest ecosystem it is necessary to be able to identify and valorize the major factors which determine its production potential and to translate this into management needs and possibilities. In chapter 3 important features from literature for the classification of forest stands will be discussed as well as common silvicultural measures and some in Costa Rica applied silvicultural approaches which can be used to improve the production of those entities wished by the forest owner and/or society.

The report should result in the description and diagnosis of types of forest use and forest composition in the three research areas. Few methods are present directed at such an analysis and all are based on FAO's Land Evaluation for Forestry. This method only concentrates on forestry practices and little on forestry as part of land use on farms or on the farmers involved. In order to tackle this problem the Land Evaluation procedure will be described on its useful elements as well as Farming System Analysis, a tool for the study of farming and land use in general (Chapter 4).

The data were gathered in two phases. First, forty interviews were carried out with farmers in the three research areas of whom was known from foregoing studies that they had natural forest on their farm. Use was made of a list of open ended questions about the composition of the forests according to the farmers, their former utilization, the farmers' objectives towards their forest and constraints influencing forest management. The questions of the interview as well as an elaboration of the interviewing technique are stated in Appendix II. In the second phase of the field work seven forest inventories of 0.5-1.5 ha were executed in forests selected on basis of the information of farmers on the former utilization of their forest, soil type and hydrology. The inventories were directed at differences in forest composition and management possibilities and needs of stands due to former utilization. Time restricted the extent of the inventories to a practical outline of forest in the northern Atlantic Zone of Costa Rica. Chapter 5 gives the methods of data gathering. In chapter 6 the results of the interviews will be presented and analyzed, resulting in the classification of farmers on basis of their attitudes and possibilities towards forest use. The forest inventories are presented in chapter 7 as well as management possibilities and needs of the forest stands.

The possibilities of farmer groups will be combined with the management needs and possibilities of their forests in chapter 8. In the last part of the report (Chapter 9) the conclusions on the function of natural forests on farms in the Atlantic Zone will be presented as well as on the potential of the forests for wood production. Finally, in the recommendations suggestions will be given for tackling the problems observed in this study in order to improve the existing utilization of natural forest within farms.



Map 2.1 The Atlantic Zone of Costa Rica and the location of the three research areas Neguev, Río Jiménez and Cocorí (Source: van Leeuwen and Hofstede, forthcoming)

2. GENERAL ASPECTS OF THE ATLANTIC ZONE OF COSTA RICA

2.1 Introduction

The Atlantic Zone is situated in the eastern part of Costa Rica. It can roughly be divided into a large coastal plain in the east and an extremely mountainous area in the west (Romeijn, 1987). The area covers about 10,000 km^2 (Romeijn et al., 1987). The research for this study took place in the northern part of the coastal plain (see map 2.1).

A number of major interrelated processes have shaped and are still shaping the Atlantic Zone. These processes are deforestation, influx and colonization by people from outside the region, (re)distribution of land, construction of new roads, movement of foreign banana companies, changing crop patterns and the tendency towards intensification.
In the northern part of the of the Atlantic Zone, three research areas, Río Jiménez, Neguev and Cocorí, have been selected by the Atlantic Zone Programme, for which the presented study has been executed. Each of the areas is regarded to be a representative of a different stage in the most important agricultural transformation processes in the Zone (Anonymous, 1987). These areas have been the subject of different studies on the tree and forest component on farms for which purpose Hulsebosch (1992) selected 105 farmers. The focus in this study will be on the three research areas and the selected group of farmers. In this chapter the areas will be shortly characterised as well as the land use and the history of the Atlantic Zone in order to indicate the importance of natural forest on farms.

2.2 The research areas

The western half of the Río Jiménez district forms the oldest in development of the three areas; 20 km ENE of Guápiles, covering about 12,000 ha with 150 households (Anonymous, 1987). The research area will be referred to as **Río Jiménez**. It has a relative long settlement history, which started with the production of coffee and the construction of the railway Limon-Guápiles at the end of the nineteenth century, followed by the establishment of banana plantations and large cattle farms (Waaijenberg, 1990). Nowadays, the land is used by small (> 1 ha) and medium scale farmers for milk and beef production and maize, cassava, cocoa and fruit tree growing (Anonymous, 1987). Furthermore are there banana plantations and cattle farms over 200 ha (Waaijenberg, 1990). The banana plantations are an important source of off-farm work for male as well as female workers from smaller farms. The major part of the soils are suitable for agriculture and beef production, with local limitations because of drainage condition and fertility (Waaijenberg, 1990).

The settlement scheme **Neguev**, 25 km ESE of Guápiles, covers about 5,500 ha. It is the result of a land invasion in 1979 by landless farmers and ex-banana plantation workers, organized by the Small Farmers Union of the Atlantic Zone (UPAGRA[1]) in search for some social and economic security. The area was a large abandoned cattle estate and has been divided into 311 farms of 10-17 ha each by the Institute for Agricultural Development (IDA[2]). The majority of the soils are infertile and are not suitable for the production of basic food crops like maize, beans and rice. Only parts of the parcels along the rivers are fertile and are well suitable for different types of agricultural production (Anonymous, 1987; de Oñoro, 1990).

Cocorí and surroundings, 50 km north of Guápiles is an artificially marked area, covering about 12,000 ha with 150 households (Anonymous, 1987). It is a representative area for the most recent phase of colonization. The late reclamation is due to its remoteness. When the first settlers arrived in the late sixties, the area was completely covered with forest. From 1982 onwards commercial forest exploitation took place and roads were constructed which accelerated the colonization and deforestation. Now, the land is being deforested and cultivated by settlers and claimed by urban land lords which makes that the area is characterised by un-even land distribution (the farm size ranges between 10-1,000 ha) and insecure land tenancy. A majority of the soils is of low fertility and/or poorly drained, resulting in a low agricultural suitability. Subsequently, the land is under pasture for cattle ranching or still covered with forest (van Sluys et al., 1992).

2.3 Climate, soil and vegetation

Climate. The average annual rainfall in the northern part of the Atlantic Zone varies between the 3,000-6,000 mm (Neguev: 3,700 mm, Río Jiménez: 3,900 mm, Cocorí: 5,000 mm) and the average potential evapotranspiration ranges between 1,200-1,500 mm. All months are wet, but january-april is usually dryer than the rest of the year. The average annual temperature is about 26°C. On cloudy days daily temperatures vary between 23 and 26°C; on clear days these values are 20 and 32°C respectively. Relative air humidity is seldom below 90% (van Sluys et al., 1992; Boerboom et al., 1986; van Sluys et al., 1987; Wielemaker, 1990; de Oñoro, 1990; Waaijenberg, 1990).

Soils. The soils in the northern part of the Atlantic Zone can be described and classified (according to Soil Survey Staff in Stoorvogel, forthcoming) as:

1) young, well drained volcanic soils with a high soil fertility (Andic Eutropepts, Typic Udivitrands),
2) young, poorly drained volcanic soils with a high soil fertility (Aquandic Tropaquepts),
3) relatively old, well drained soils with a relatively low soil fertility developed on mud flows and Pleistocene alluvial deposits (Oxic and Andic Humitropepts)

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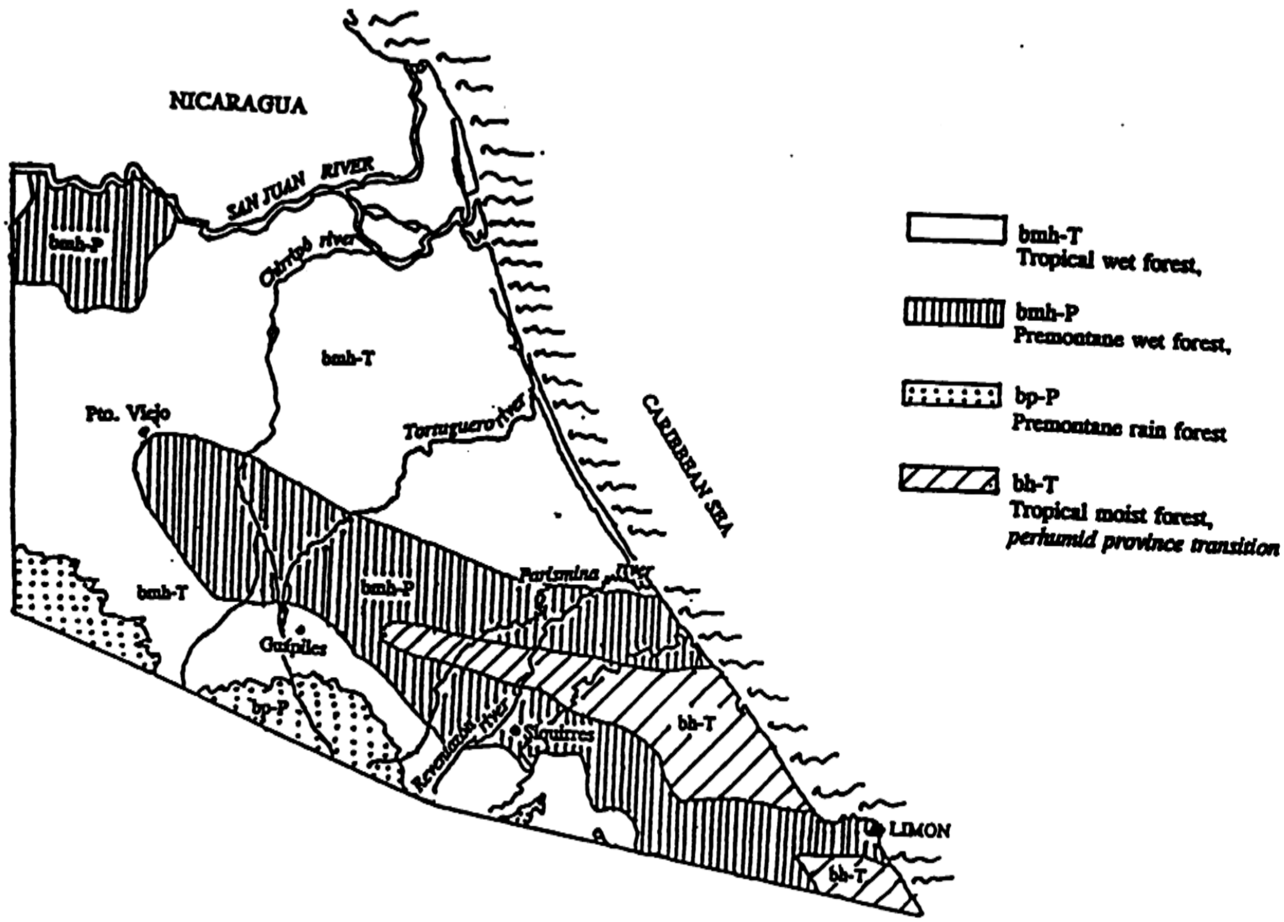
[1] Unión de Pequeños AGRicultores del Atlántico

[2] Instituto para el Desarrollo Agropecuario



Map 2.2 The three life zones of the northern part of the Atlantic Zone (Source: adjusted from Tosi in van Leeuwen and Hofstede, forthcoming)

Vegetation. The natural vegetation of the Atlantic Zone is the tropical rainforest. Regional and local variations in physiognomy and species composition depend in principal on (1): the altitude above sea level and the related average temperatures, temperature extremes, air humidity, precipitation and soil development; (2): the total annual precipitation as ecological northwest-southeast gradient; and (3): the local relief and hydrology, expressed in the drainage pattern and eventually (periodical) inundation (Boerboom et al., 1986).

The first two characteristics are combined by Holdridge (in: van Leeuwen and Hofstede, forthcoming) in his so-called life zones classification. The three life zones distinguished for the northern part of the Atlantic Zone are shown on map 2.2. As can be seen from this map not many differences exist within the Atlantic Zone. Furthermore, "the capacity of natural rain forest to keep its nutrients within the ecosystem makes it possible for natural forests to grow independently of soil fertility on a wide range of very poor to fertile soils" (Koster, 1993).

In the lowlands of the Atlantic Zone, the forest has an irregular canopy and the highest trees with often a broad, umbrella-like crown reach up to 55 m. Underneath the canopy the trees have varying shape, size, age and development stage and belong to a wide range of species (Boerboom et al., 1986). Some important commercial tree species are for instance *Sacoglottis trichogyna*, *Carapa guianensis*, *Cedrela odorata*, *Ceiba pentandra*, *Cordia alliodora*, *Virola spp.*, *Pentaclethra macroloba* and *Hieronyma alchorneoides* (for local names see appendix I).

2.4 Land use in the Atlantic Zone

Cropping patterns

Within the farms in the Atlantic Zone, agriculture is an important activity. The importance of the traditional crops (maize, rice, cassava and beans) is diminishing due to releasing their prices in 1986, but crops are still grown for home consumption (van Leeuwen and Hofstede, forthcoming). Non traditional crops grown are palmheart, fruits and local vegetables, cocoa, ornamental plants and macadamia, which area is expanding (van Leeuwen and Hofstede, forthcoming). Crop production in the Atlantic Zone is characterized by low yield/cost ratios due to problems related to weeds, pests and diseases, drainage, workability and fertility. The problems are aggravated - according to farmers - by high input prices, poor availability of credit and high interest rates (Van Sluys et al., 1987). Banana production is the most important activity in the region and very important for the national economy (van Leeuwen and Hofstede, forthcoming). The banana plantations covered an area of 21,258 ha in 1984 which rapidly expanded to 40,342 ha in 1992 (adjusted from Lok in van Leeuwen and Hofstede, forthcoming). The plantations are mainly in the hands of international and national companies. Due to its high capital investment and technological requirements, banana production on a commercial scale is not possible for small and medium farmers. The only direct relation of the farmers with the banana plantations is the attraction of, but, on the other hand also the competition for, labour and the improved infrastructure (van Leeuwen and Hofstede, forthcoming).

Cattle ranching

The pasture area is rapidly increasing and made up some 35%, i.e. 232,900 ha, of the total farm area in the Atlantic Zone in 1982 (van Leeuwen and Hofstede, forthcoming). The expansion of its area, whether or not actively used, is logical from the farmers' point of view as pasture is often the only and/or easiest option for them in view of transportation and market possibilities, soil characteristics, and/or land attainment rights (see §2.5). Although cattle ranching is economically less important than banana production, its area is ten times larger than the banana plantation area (van Leeuwen and Hofstede, forthcoming). Only a small part of the pastures is for intensive milk production, most is being used for extensive beef production (van Sluys et al., 1987).

Forestry activities

The on-farm forest production is mostly originating from patches of forest or from individual trees. These may be sold to loggers or may be cut gradually for use on the farm.

In the pasture there often is regeneration of *Cordia alliodora*, an appreciated timber species. Permanent pastures are usually fenced with *Erythrina spp.* or *Glyricidia sepium* (van Sluys et al., 1987). When trees are not hindering the main production purpose, the breeding of cattle, trees in the pasture are perceived by the farmers to have the following benefits:

- production of timber and poles by dispersed trees in the pasture for use on the farm or for sale;
- production of fruits for home consumption;
- lowering of costs by using living fences instead of wooden posts.

(Paap, 1993)

A still marginal source of timber production for the future are the forest plantations, which are merely established with subsidies (van Sluys et al., 1987). Current problems with the tree plantations are the lack of knowledge about management of plantations and the relative performance of different species in the Zone. Furthermore, the major part of the farmers plant trees for the subsidy and not for the timber production (van Brouwershaven, 1993).

2.5 Development and deforestation of the Atlantic Zone

Originally, Costa Rica was for 99.8% covered by forests (Hartshorn et al., 1982). Already during the civilizations of the Indians large areas were deforested, but with the arrival in Central America of the Europeans in the 16th century and the consequent disappearance of the Indian cultures, the forest cover returned (van Sluys et al., 1992).

Until the 19th century, the Atlantic Zone was only sparsely populated. The great incentive for the Zone's colonization came in 1871 with the construction of the rail road Siquirres-Limon (Romeijn et al., 1987). The contractor obtained in exchange for the job a large concession of virgin land. At least 100,000 ha of the better soils were turned into banana and cacao plantations by the United Fruit Company (UFC). They attracted labour from elsewhere and an influx of people started, which stimulated deforestation and the establishment of a farmer population. Land conflicts and lack of opportunities for landless people made the government buy land from the UFC to create agrarian settlements like Guápiles (1931), Parismina and La Rita (1934). In 1938 UFC withdrew because of the Panama-disease affecting their banana plantations (Romeijn et al., 1987).

When the banana companies returned in the 1960s, they opened up areas to the north of Guápiles (Río Frio and Cariari). A farming population had already established itself at that time in that region. The construction of infrastructure by the banana companies greatly stimulated colonization of the areas further to the north and west (van Sluys et al., 1992). Attempts by the government failed to direct the spontaneous settlement and invasion of forest areas by creating a new law as well as by the construction of new settlements. The squatting was even legalized by law in 1941; if settlers occupied land uninterruptedly for more than 10 years, showing the occupation by deforesting a part of the land, they then became owners (van Sluys et al., 1992).

Spontaneous settlement still takes place, making use of the possibility to become landowner as submitted by the law of 1941. The actors can be divided into two groups: squatters and settlers (Romeijn, 1987). The first group of squatters reclaims land as profession. They clear the forest and cultivate some crops for subsistence. This way they establish a claim on the land. which they try to sell afterwards (Romeijn, 1987). This group is highly mobile, constantly working on the frontiers of agricultural expansion, opening up new forest areas (Hartshorn et al., 1982). Sometimes they are asked to do the same for large landowners who see this as a way to develop their land with a minimum of investments, since the forest is cleared without costs for the owner. The landowner may turn this land into pasture or try to negotiate with IDA to buy their land, since it is occupied by squatters. The IDA is financed for land distribution under squatters and settlers in Costa Rica. This way the owners sell farmland in stead of forest land, greatly increasing the market value of the land (van Sluys et al., 1992). The group of "real" settlers tries to set up their own little farm, developing hectare after hectare, while or after working for the banana companies for a number of years, investing the revenues in their farm (Romeijn, 1987).

Keeping large tracts of land under forest is considered an invitation to squatters. Owners, therefore, often establish extensive pastures simply to forestall such events. If possible they will try to sell off the timber to loggers beforehand (Romeijn, 1987).

From the 1950's onwards cattle ranching has been strongly stimulated by the Costarican government in order to avoid a too great economic dependence on coffee and banana exports (Romeijn et al., 1987). The development of cattle ranching has increased the domination by large landholders of the agricultural sector. At present, in the north of the Atlantic Zone conversion of forest into pasture, especially by large holders is named as the principal driving force behind the deforestation, i.e. the process of agricultural expansion (Romeijn, 1987). Parallel to those large holders, a great number of new squatters and settlers comes in, following the pattern of new roads (Romeijn et al., 1987).

In newly opened up areas, extensive grazing, although of low return, is a very attractive land use alternative because of the low risk, low labour and input requirements, little dependency on infrastructure for an easy accessability of the market and as an easy way to confirm land claims (van Sluys et al., 1992). A substantial portion of the newly opened up farmland is taken up by large estates of land owners either from the Central Valley around San José or from the United States (Romeijn et al., 1987).

Where the infrastructure is sufficient, commercial exploitation of the forest is possible. The loggers exploit their own holdings or the property of others. For the farmers, selling the wood to loggers can be an important source of income, which helps them to develop their farms. This practice also speeds up the rate of deforestation; the construction of new roads and the maintenance of existing ones by loggers is stimulated, making remote areas more accessible to squatters and settlers (Sluys et al., 1992). This way not only virgin forest is converted but also a decline of the area of farmland under forest takes place. Although this constitutes but a small percentage of the total deforestation it might nevertheless be important, especially for small holders, e.g. via forest products getting scarce in the long run (Romeijn, 1987).

At present the Atlantic Zone still holds the largest forest remains in Costa Rica. The Pococí area, north-east of Guápiles, forms the last extension of forest on level land. With the recently developed roads it provides the most viable region for deforestation (Romeijn et al., 1987). Apart from the plains of the northern Atlantic Zone, large forest areas can still be found in the mountainous ranges of the Cordillera Central and the Talamanca region. These make up the largest part of the 4,600 km^2 of dense forest in the Zone (Romeijn, 1987). The 50% deforested area (figure of 1983), therefore, is concentrated in the coastal plains (Boerboom et al., 1986). Since it is assumed by the Costarican government that the Atlantic Zone, with its more regular rainfall and topography, will prove more suitable for agriculture and pastures than the previous expansion areas of Puriscal and Guanacaste, it is not to be expected that the present expansion in the Zone will come to a sudden halt (Romeijn, 1987).

Costa Rica annually lost between 1.2% and 1.8% of its forest resources from 1970 to 1989, an average of 41 thousand hectares per year (Solórzano et al. in van Leeuwen and Hofstede, forthcoming). However, figures by the ministry of Natural Resources (MIRENEM[3]) indicate a lower deforestation rate for the last five years (1987-1992), some 18 thousand hectares annually (Tico Times in van Leeuwen and Hofstede, forthcoming).

Growing concern about the deforestation has urged the government to impose a new forest law in 1990. It implied the propagation of reforestation and the prohibition of deforestation without a land title and a management plan. According to the forest law all tree cutting should be authorized by the forest service DGF[4] (van Sluys et al., 1992).

[3] Ministerio de Recursos Naturales, Energía y Minas

[4] Dirección General Forestal

3. THE TROPICAL RAIN FOREST: Silvicultural aspects

3.1 Introduction

"The vast climatic and soil variations within the tropics produce an extraordinary diversity of forest types, differing in composition, structure and commercial value. There is no such thing as the "tropical forest" as an uniform form of vegetation" (Lamprecht, 1989: p.34). Climatically conditioned forest types depend mainly on the amount and distribution of the annual precipitation. Precipitation is reflected in the type of tropical forest, especially in the forest's greater or smaller humidity or dryness . The most pronounced characteristic of the influence of precipitation on tropical forest is on the deciduousness of leaves (Borota, 1991). With "rain forest" the evergreen moist forests are meant, which exist in climates with a high to very high, more or less evenly spread rainfall over the year, exceeding 2,000 mm and a relative air humidity of 90-100%, with drops down to 60%. An essential characteristic of the tropical rain forest is that, although during the year some trees loose their leaves for a short period, the forest as a whole maintains its leaf cover. The average annual temperature is 22-27°C with fluctuations during the day of 7-11°C and on yearly basis of 0-3°C (Boerboom, 1982a). The tropical rain forest occurs on various solid, swampy or periodically inundated soils (Borota, 1991). The major part of these forests are found around the equator somewhere between 10° N and S. They cover at the moment still some 4 million km^2 especially in the Amazon-Oriniko basin, around the Golf of Guinea and in the Congo basin, on Ceylon, in West-India, Thailand, Indochina, The Philippines, Indonesia, New Guinea and in a small strip at the east coast of Australia (Lamprecht, 1989).

Tropical rain forests are the most complex and most species-rich ecosystems of this planet (Whitmore in Hoogveld, 1990). The total biomass in tropical forests amounts to 400-660 ton dry weight per hectare, whereas in mature stands in the temperate zone it amounts to about 300 ton per hectare. The tropical rain forest usually consists of a compact closed tall vegetation including a large number of various evergreen tree species (60-100 per hectare with DBH[1] ≥ 10 cm, occasionally even more), shrubs, herbaceous and woody lianas, many epiphytes, herbs, ferns and grasses and an abundance of saprophytic, parasitic and other lower plant species. It also abounds in animals which influence the ecology of the tropical forest; they pollinate flowers, collect, break open and eat the fruits and seeds of trees and by their droppings they distribute seeds over a large area, thereby assisting in the regeneration of various plant species (Borota, 1991).

Different authors like Jacobs, Budowski and Poore have tried to sketch the direct and indirect significance of the tropical rain forest for mankind in the following points (adapted from Jacobs, 1981): a. timber production, b. soil and water conservation, c. climatic stabilisation, d. source of non-timber forest products, e. reservoir of new useful

[1] Diameter of stem at Breast Height (1.3 m)

plants, f. reservoir of useful genetic material, g. living environment for animals, h. medium for education and recreation and other aspects like being the matrix of evolution, source of knowledge and object of respect for the creation. The extraction of goods of direct economic value like timber and non-timber forest products require interventions in the above described ecosystem and imply disturbance of those systems. The complexity and species richness of the tropical rain forest make the application of a standard management to an impossibility. The assessment of parameters is necessary to classify forest stands and their condition for the production of timber and other goods; parameters where upon forestry management can be based.

This chapter assesses and describes the parameters that can simplify the complexity of the tropical rain forest in order to make decisions upon forest management possible. First, a practical classification of forest stands will be discussed (§ 3.2), followed by a characterisation of the parameters which can describe the way in which tropical rain forests are organized (§ 3.3). The organization of a forest is not static but is in a state of a dynamic equilibrium (Finegan, 1991). These dynamics and the regeneration processes they are built upon will be discussed in § 3.4. Forest management has to be based on knowledge of the organization and dynamics of the forest. The management of the tropical rain forest will be discussed by the management objectives and alternative silvicultural measures (§ 3.5). Finally, some silvicultural approaches developed and/or applied in the tropical rain forests of Costa Rica will be discussed (§ 3.6).

The complexity of the forest community, the dominant role trees have in forests and the demand for tree products make that other forest components than trees are often neglected (Hoogveld, 1990). This will also be the case in this research since a profound study of forest ecology is beyond the objectives of this study.

3.2 The classification of natural forest stands

Before discussing several silvicultural aspects of tropical rain forests, it seems convenient to explain the term "natural" as applied in this document. The term "natural" always has been a reason for discussion, since some people consider the presence of human influences always as unnatural. In the course of this paper, the term natural forest will be used for any kind of forest not being a tree plantation, having an essentially different kind of silvicultural context (adapted from Lamprecht, 1989). Only natural forests will be the subject of this study.

The tropical rain forest consists of a wide range of vegetations often characterised by their tree species composition and referred to as forest types, like the Dipterocarp forests in parts of Southeast Asia or the Carapa swamp forests in parts of Costa Rica.

From silvicultural point of view a further classification is possible into forest stands. The specific silvicultural situation of a forest stand is determined principally by the condition of the forest whose management is being planned (adapted from Lamprecht, 1989). Different authors classify these forest conditions in different ways. In this study the following classification for forest stands of Finegan in Manta Nolasco (1988) and Finegan and Sabogal (1988a) will be followed:

- Primary forest: the forest in its natural state, free of known human interventions.
- Exploited (primary) forest: the forest in which the most prominent ecological perturbation has been the selective exploitation of valuable species. The floristic composition and structure of the primary forest remains maintained in a grade which depends on the intensity of the exploitation.
- Secondary forest: a woody vegetation which develops on sites where the original vegetation has been completely removed due to human activities.

As a rule one can hardly distinguish between old exploited stands and primary forest (Lamprecht, 1989). For this reason, the criteria, as given between the different situations, are merely practical ones.

3.3 The organization of tropical rain forests

Whatever stable or evolving, not anarchic, situation of a population or community, in which one detects some type of organization, can be represented by a mathematic model, a statistical law of distribution, a classification or characteristic parameter (Rollet in Manta Nolasco, 1988). Tropical rain forests do have some type of organization that keeps the forest in a dynamic equilibrium. Recognition of this organization and its description by characterising parameters are the basis for an ordained silvicultural planning which is in fact an intervention in the organization.

The organization of the forest is described in terms of the abundance and frequency of species, the basal area, the stem number/diameter distribution and the vertical structure (Lamprecht, 1989). Those parameters will be discussed below. The dynamics of the organization or in other words the fluctuations in its parameters are treated in § 3.4.

Abundance and frequency of species

The tropical rain forest is characterised by a high number of species. But 40-50% of the total of stems belongs to 10-15% of the tree species (Lamprecht, 1989). The most abundant species are those species which have the highest share in the total stem number. Normally, those species also have a high frequency i.e. they will be found throughout a forest stand (Lamprecht, 1989). For specific groups of species there are characteristic combinations of values of abundance and frequency that are important for the silviculture (Lamprecht, 1989):

- high abundance and high frequency are typical for species with a homogeneous spatial distribution. If the dominance or crown projection, is high as well, the species rule in the specific forest type.
- high abundance and low frequency indicates a species inclined to clustering. They form groups at large distances.

- low abundance and high frequency together with a high dominance is typical for solitary standing and spatially even spread ruling trees.
- low abundance, low frequency and low dominance is typical for a "hanger on" which are often neither of ecological nor of economical importance.

Basal area
The basal area (G), expressed in m^2/ha, is the sum of the horizontal cross-sections of the stems at breast height and is easily determined by measuring the DBH. The significance of the basal area is threefold. It is an indicator of the biomass present in a forest (Manta Nolasco, 1988) since both are related to the DBH. Furthermore, the basal area is correlated to the crown projections of trees, thereby an indicator of the dominance of trees and tree species (Lamprecht, 1989); a high share of a species in the total basal area indicates a high dominance. Maybe the most important function of the basal area is that of parameter for the competition within a forest stand, such that the competition is higher when the basal area approaches the value of the primary forest (Dawkins in Finegan, 1991). This way the basal area represents a general measure for the determination of the necessity and grade of a thinning. In order to have an adequate commercial regrowth the basal area should be kept between 40 and 60% of the value of the primary forest. If it is higher than 60% the competition reduces the productivity of the commercial volume. When it is lower than 40 % the forest cover is incomplete and therefore the production below the optimum (Manta Nolasco, 1988). The utility of the basal area for e.g. the grade of thinning is its regional uniformity (Finegan, 1991). For instance in the Atlantic Zone of Costa Rica the basal area of the trees over 10 cm DBH seems to oscillate around an average of 28 m^2/ha (Finegan, 1991).

Stem number/diameter distribution
The importance of the distribution of the stem number per diameter class for the organization of the forest is its function as indicator of the condition of the regeneration of the stand and the individual species (Rollet in Manta Nolasco, 1988). Normally three shapes of the distribution can be found. Often the distribution has the shape of an "inverse J" indicating that there are a lot of individuals in the lower diameter classes. This is considered positive, since it implies that a species has sufficient natural regeneration in order to replace harvested trees. In primary forest this often accounts for the shade-tolerant species. As second, a plain curve is considered neutral; there are sufficient trees over 10 cm DBH that have good chances to reach maturity, but there are few trees in the lower classes and the natural regeneration might fail. This kind of curve often accounts for light-demanding species. Third, in the case of a bell-shaped form, there is a real lack of regeneration. It can represent a light-demanding species in primary forest, but is in fact only present in even-aged stands like secondary forests in the case of light-demanding as well as shade-tolerant species (Finegan, 1991). The underlying mechanisms are further discussed in §3.4.

Vertical structure
The vertical structure of a forest is characterised by the height of different canopy layers and individual trees. Most species and trees are found in the lowest canopy layer. Upwards both the number of species and trees decrease (Lamprecht, 1989). A derivative of the vertical structure is the exposure of the tree crown to the solar light. The exposure of a tree to solar light is related to its growth possibilities, further discussed in §3.4.1.

3.4 The dynamics of tropical rain forests

Silviculture deals with interventions in the organization of the forest. This is done by manipulating the mechanisms that maintain the organization; especially the regeneration process of valuable species. Therefore, it is valuable to know and understand the regeneration process, the elements which affect it and the general ecological context in which the natural regeneration takes place, known as the dynamics of the forest (Manta Nolasco, 1988). In this paragraph first the principles of the natural regeneration process will be treated followed by the forest dynamics it is part of. Both is done for the different forest stand classes.

3.4.1 The natural regeneration process

The potential future composition of a vegetation and the micro-climate are in the first place determined by the surrounding vegetation and the present propagule bank. These factors overrule all other reasons for fluctuations in the regeneration's composition (Hoogveld, 1990). Whether regeneration occurs dependents on a number of prerequisites of which the following are indispensable:
- A sufficient number of viable seeds.
- Appropriate climatic and edaphic conditions for germination and establishment. (Lamprecht, 1989)

As a rule, seed production must be adequate to ensure a more or less continuous availability of viable seeds of several species. The determining environmental factors - of temperature and humidity - are so favourable in the rain forest that optimal conditions for germination and establishment are virtually constant. The exposition of tree crowns to solar light are generally decisive for successful establishment (Lamprecht, 1989). One can distinguish groups of species on basis of their light requirements and in addition their life span; a concept which is closely related to the regeneration cycle in gaps and abandoned agricultural sites (Finegan and Sabogal, 1988a). Two major groups with their subdivisions can be identified[2]:

1) light-demanders (heliófitas): species which require a high grade of illumination in order to survive, grow and develop.
   a) short-lived (efímeras) : of relatively short life span
   b) long-lived (durables) : of relatively long life span
      b1 : of rapid growth
      b2 : of regular growth
2) shade-tolerators (esciófitas): species of relatively long life span which establish, grow and develop in the shadow.
   a) partial (parciales): need a high exposition to light in order to pass for the final stage of development before getting to maturity.
   b) total (totales): without the light requirement of the parciales.

There are few species of big trees which require shadow in their juvenile stage; some tolerate it, but the majority shows a much higher growth rate under relative high exposition to light (Finegan and Sabogal, 1988a).

The short-lived light-demanders correspond with the group of pioneer species (Finegan and Sabogal, 1988a). These trees characterize the first successional stages in large stand gaps or on cleared areas. At an early age they start to produce seeds annually and in considerable abundance. The seeds disperse easy over larger distances and the germination capacity is often preserved for extremely long periods when in the shade of stands (Lamprecht, 1989). The long-lived light-demanders correspond with the "late secondary species" (Finegan and Sabogal, 1988a) or "long-lived pioneers" (Lamprecht, 1989). They establish and grow in early successional stages and can survive for many decades in the upper storey. In later stages they only regenerate under exceptional circumstances (Lamprecht, 1989). Finally, the shade tolerators correspond to the climax species (Lamprecht, 1989).

The classification of pioneers and climax species could give the impression that these species are limited to respectively secondary and primary forests. However, studies in the biological reserve of La Selva in Costa Rica have shown that species of every group are present in the primary forest and that some long-lived light-demanders are very frequent (Finegan and Sabogal, 1989).

3.4.2 The dynamics of the secondary forest

Investigations in the Atlantic Zone of Costa Rica show that the tropical secondary forests in this region frequently present a high abundance of timber species of rapid growth (Finegan and Sabogal, 1988a). Where Lamprecht (1989) notices that there is hardly any market for their light soft wood, Finegan and Sabogal (1988a) state that these species

[2] From the classification in spanish (terms between brackets) of Finegan and Sabogal (1988a); the terms were translated on basis of the terminology of Lamprecht (1989)

produce light wood of little durability with, however, a wide range of uses in Costa Rica.

The succession on abandoned deforested sites shows three waves of development of three ecological groups of plants: pioneer brush-wood, short-lived light-demanding trees and long-lived light-demanding trees, the group which contains the timber species. All the individuals of every ecological group establish in the first 12 to 24 months. None of the species of these three groups regenerates in later stages when the almost absence of solar light prevents the process of regeneration on ground level. The first 1-3 years the brush-wood dominates, thereafter, aggressive, fast-growing short-lived light-demanders take over. After about 7 years the long-lived light-demanders join the short-lived in the upper storey. These two tree groups constitute an even-aged stand, low in heterogeneity; the trees are of the same age, which is the time since the site has been abandoned. The stem number/diameter distribution is bell to plain shaped. After 15-20 year the long-lived light-demanders dominate the stand (Finegan, 1991). However it is possible that the original grass cover on the site slows down the process or that the process does not start at all because of the lack of seed sources of forest trees (Finegan, 1991).

What happens after the third stage depends on factors which affect the dispersion of those species which are not abundant in the first years; in majority they are shade-tolerators, but also some long-lived light-demanders of regular growth which appear to be slow in colonizing abandoned sites (Finegan and Sabogal, 1988a). Some of the factors affecting dispersion are the availability of the seed and the contribution of forest vertebrates which, for a lot of species, constitute a form of natural seeding of the seeds (Lamprecht, 1989). Thus in extensive deforested zones, the succession can come to a stop in the third phase with a vegetation dominated by long-lived light-demanders where normally it should proceed like the process of recuperation in the primary forest (Finegan and Sabogal, 1988) described in § 3.4.3. During the whole process the stem number decreases and the basal area increases towards the values of the primary forest (Finegan, 1991). By measuring these parameters the stage of development of a stand can be determined.

3.4.3 The dynamics of the exploited primary forest

As already mentioned in the definition of "exploited forest", selective exploitation can be compared to an ecological perturbation. The natural fall of a tree of the upper storey is a key element in the regeneration cycle of the primary tropical rain forest. The opening of the canopy and the subsequent increase of the exposure permits the regeneration of light-demanding species and stimulates the growth of the established regeneration of the shade-tolerators; the size of the gap determines what light-demanding species might regenerate. In general terms, one can say that 1% of a primary forest is turned into a gap every year, equal to the fall of one tree of the upper storey/ha/year (Finegan, 1991).

An exploitation increases the scale of the perturbation. In case of a relative light perturbation, a group of saplings and small trees come to development, whose composition does not differ much from undisturbed parts of the forest. In case of larger disturbances the conditions enable the colonization by long-lived light-demanding species and to a lesser degree short-lived light-demanders (in the largest gaps) of genus like *Vismia* and *Cecropia*. The partial shade-tolerant species might regenerate successfully, but in most cases the site will be dominated by the light-demanders due to their higher growth rate (Finegan, 1991; Boerboom, 1982b). Also in the case of an exploitation, like on an abandoned site, the forest ecosystem will try to return to the state of organization of the primary forest, a development that can be followed by measuring the stem number and basal area.

3.5 Silviculture of natural tropical forests

3.5.1 Introduction

Silviculture is defined by Finegan (1991) as the manipulation of the forest in such a way that the extracted trees are replaced by others of good quality in a time span as short as possible and by means of natural regeneration. It is probable that in areas, already colonized by rural population significant areas of forest will only survive when the owners of the land should be able to manage them in an economically attractive way by means of suitable silvicultural systems (Finegan, 1991). The marketing situation for forest products in Costa Rica seems favourable but a silvicultural tradition is not present and has to be introduced. Activities in the forest were always restricted to mining and/or conversion (Hartshorn et al., 1982).

When developing a silvicultural system one cannot simply copy systems from other regions. The diversity in forest types and socio-economic conditions impede such an approach and require an analysis of the local situation as will be discussed in Chapter 4. Furthermore, many silvicultural systems were intended to be applied over extensive areas of state forest, where, like in the case of this study, today one should think in terms of potential and viable systems which are appropriate to relative small forest stands often under pressure from other forms of land use (Hutchinson, 1988b). These may be owned and managed by civic authorities, co-operatives, small industries, or by individual farmers capable of investing little more than their own labour. In such situations it is urgent that silvicultural approaches are within the reach of small landholders (Hutchinson, 1988b).

In the following paragraphs will be discussed how decisions on forest manipulation can be taken (§ 3.5.2) and what silvicultural treatments are available for forestry (§ 3.5.3)

3.5.2 The manipulation of forest ecosystems

Silvicultural systems are based on the manipulation of forest dynamics, species composition and organization (Hoogveld, 1990), in such a way that the forest is converted from its natural equilibrium into a system of nett production (Finegan and Sabogal, 1988a).

The floristic complexity of the tropical rain forest is often presented as a factor which limits the economic viability of the management of this forest type. When the objective is the extraction of only a few very valuable species, this is true (Finegan and Sabogal, 1988a). However, this point of view does not take into account the possibility of simplifying the complexity by means of grouping the species according to their ecological behaviour on basis of light requirements, and their commercial value and the reduction of the floristic complexity by means of silvicultural treatments. Neither does it take into account the market changes which increase significantly the number of commercial species per hectare (Manta Nolasco, 1988).

In northern Costa Rica for instance, almost all tree species growing to saw log size are now commercially acceptable; a situation which can be expected to become increasingly common throughout the tropics. As a result, the thrust of information-gathering before intervening a forest may no longer be to sift the merchantable from the biomass, but becomes instead one of identifying the stage of development of the forest type, identifying the needs and priorities for silviculture throughout a region of interest and estimating the time required to produce the possible future crops of commercially desirable species (Hutchinson, 1988a).

The information for the planning of forest activities can be obtained by measuring the parameters which describe the state of organization of the forest. This is usually done by sampling; a representative minimum area is selected in which the species composition, DBH, stem height, etc. are measured with which the parameters can be quantified. On basis of this information management decisions can be taken. Some sampling methods will be discussed in chapter 5.

3.5.3 Silvicultural treatments

Silvicultural systems are combinations of silvicultural treatments. These are defined as a series of operations, with the purpose of directing the forest towards specific objectives. The operations can be executed individually or simultaneously. Although they may differ in detail, they are common all over the world and therefore can be seen as the basic components of any silvicultural system in the humid tropical forest (Hutchinson, 1993).

The principal objective of management is often the production of timber. The main objectives of the silvicultural treatments are promotion of volume increment of desirable species, regeneration of desirable species, recruitment of saplings into higher diameter classes and balancing of the ecology of the stand to safeguard sustained yield (van Bodegom and de Graaf, 1991). The attention of silviculture is on improving the commercial stock in a stand. This stock consists of trees of desirable species having a good stem form, vigour and well developed crown.

In natural forests not previously managed the "improvement treatment" or domestication represents the first step towards improving the quality and raising the productivity of the resource. Without domestication any other silvicultural measure has only a limited chance of success (Lamprecht, 1989). The operations it consists of should neither be difficult to apply nor should be costly; the return on investment should be considerable (Hutchinson, 1993). According to Lamprecht (1989), after the domestication the forest stands should have the following characteristics:

- being significantly more homogeneous, both floristically as well as with regard to dimensions and age structures, than "untamed" stands;
- furnish raw materials which are in every respect substantially more homogeneous;
- have a large proportion of marketable species and a small proportion of species without value. However, one should not strive to eradicate the non-marketable species;
- produce a larger volume of commercial wood than the original stand;
- have a higher quality of timber ultimately produced.

In some regions the improvement treatments are executed some years before harvesting, but it can also be integrated. The advantage of the latter are a immediate financial returns on the investments.

Domestication and other silvicultural treatments consist of combinations of the operations described below.

A. Canopy opening

The first group of operations are those meant to increase the exposure of the crowns of valuable trees in order to promote their regeneration and growth by opening up the canopy (Manta Nolasco, 1988). In many cases the canopy consists of an upper level of big trees and one or more lower levels, frequently with lianas.

Opening up the canopy, is the most common silvicultural treatment in the humid tropical forest (Baur in Manta Nolasco, 1988; Hutchinson, 1993) and mostly includes the following four operations, whether or not combined:

A.1 Harvesting

Harvesting trees in order to obtain timber can be seen as a form of silvicultural interference as well, since it opens up the forest canopy. Only harvesting is not sufficient to achieve an uniform and positive reaction from advance growth of desirable trees or natural regeneration. Harvesting should be followed by other suitable, previously planned, silvicultural operations as well. Logging damage should be reduced to a minimum in order to obtain maximum productivity (Hutchinson, 1993).

A.2 Cutting of lianas

Cutting of lianas not only serves to open up the canopy and to free tree crowns of the lianas' overshadowing leaf cover. The accessibility of the forest is improved as well. Cutting lianas is often executed one or two years before harvesting in order to separate those trees that are connected by lianas, and by doing so reducing the damage resulting of the exploitation (Hutchinson, 1993). However, the only effective control of the lianas population is by maintaining canopy shade.

A.3 Thinning lower canopy levels
In a lot of silvicultural treatments the inferior canopy levels are thinned in order to promote the natural regeneration before eliminating unwanted trees in the upper canopy level (Lamprecht, 1989).

Because of the dense and wide crowns of the species of the lower levels, their elimination improves the solar illumination at ground level, thus favouring the germination of the regeneration and increasing the growth rate of the young trees. The small stems are eliminated by means of cutting and the larger ones by means of poison-girdling. The advantages of poison-girdling are that logging damage to seedlings and trees is avoided and that the canopy is opened gradually. The latter is positive since it avoids a boom in the lianas population and still favours the advance growth of commercially desirable species (Hutchinson, 1993).

A.4 Thinning the upper canopy layer
Thinning the upper canopy layer serves for increasing the solar light intensity to benefit small desirable trees and for liberating the crowns of the major leading desirables. However, the most important function lies in reducing the basal area in order to decrease the competition within the stand (see §3.3). The killing of the trees is preferably executed by poison-girdling. Except in the case of an improvement treatment, thinning of the upper canopy layer does not take place before the harvesting in order to avoid the presence of standing dead trees during the exploitation (Hutchinson, 1993).

In order to avoid further damage to the regeneration caused by the poisoning of unwanted trees, this operation is only executed during the first treatments. Later on, the development of such trees is not permitted (Lamprecht, 1989).

B Artificial regeneration
Where there is a deficiency in the natural regeneration, supplementary plantings can be applied.

C Cleaning the understorey
This operation increases illumination at ground level in order to induce the germination of desirable trees and to stimulate the development of seedlings and saplings. The operation is costly and may only be applied where necessary and with care such that no saplings of desirables species are cut and the spread of aggressive species is not induced.

D Liberation
Acting by preference based upon the results of sampling, liberation releases young growth from the competition by commercially less-desirable trees. The aim is to assure maximum and constant growth of the young trees of desirable species (Bryan in Hutchinson, 1988b).

Liberation is also valuable to avoid much of the natural mortality of desirable species which would otherwise occur. It stabilizes the population of young trees of the commercially-desirable species at higher levels than possible in untreated forests (Lamprecht, 1989).

Taking advantage of logging's infrastructure after a harvest this operation also is applied to free surviving trees and saplings of desirable species from the competition of woody climbers and trees of species not commercially desirable (Hutchinson, 1993).

E. Refinement
This operation removes trees from the stand exclusively because of their species in order to reduce the competition for valuable species and to decrease the complexity of the stand (Hutchinson, 1993).

3.6 Silvicultural approaches for the Atlantic Zone of Costa Rica

3.6.1 Introduction

As mentioned before (§3.5.1), the task of the forester of today is to develop silvicultural systems appropriate for small areas not requiring more input than the farm family can afford; systems within the reach of small landowners.

Suitable silvicultural systems of this nature are not present or at least their ecological and moreover socio-economic viability has not been proven yet in practice; in this paragraph, some silvicultural "approaches" that have been described in literature and which could be appropriate for smaller forest areas in the Atlantic Zone of Costa Rica will be discussed.

3.6.2 The CELOS Silvicultural System (CSS)

This system was developed as part of the CELOS Management System in order to manage the tropical lowland mesophytic forests of Surinam and is applied in swamp forests in the northern Atlantic Zone. The system will be explained on the basis of van Bodegom and de Graaf (1991) who refer to the Surinam situation. It is an example of the use of regular sampling for the control of the development of the commercial stock and for decision taking upon management needs and priorities like refinement to reduce the competition within the stand and to avoid the development of undesirable species.

In the Surinam situation the silvicultural treatments resulted in increments of desirable species of approximately 2 m^3/ha/yr, which means a tenfold increase as compared to a situation without silvicultural interference.

The system consists of the following treatments and operations (the figures refer to the Surinam situation).

1) An 100% enumeration and mapping of potentially harvestable trees (dbh ≥ 35 cm) in the whole stand, in order to achieve aims of damage control, sustainable yield and logging efficiency.
2) The installation and first recording of permanent sample plots in order to check increment of trees and development of basal area.
3) First logging operation; taking away 5-10 stems/ha with a total stem volume of 20-30 m^3/ha. The basal area is lowered from 31 m^2/ha to 28 m^2.
4) A second recording of the permanent sample plots to determine diameter distribution and total basal area;
5) First refinement; two years after logging the basal area should be further reduced to approximately 12 m^2 preferably by arboricide-girdling of all undesirable trees above a diameter limit which ranges between 20 and 30 cm. When marking these trees, the lianas of more than 2 cm in diameter are cut.
6) Third recording of permanent sample plots; 8-10 years after logging in order to check increment, regeneration and development of the basal area. If the basal area is already above 20 m^2, the second refinement should be executed.
7) Second refinement; in order to relieve saplings and small trees of commercial species from competition. The basal area has to be reduced to 10 m^2 by arboricide-girdling of all non- commercial trees with a diameter over 5 or 10 cm, depending on the outcome of the inventory.
8) After 16 years a fourth recording and third refinement can take place. The character of the refinement should be determined on basis of the inventory.
9) Second logging; between year 20 and 25

3.6.3 Operations on basis of "diagnostic sampling"

Diagnostic sampling is a flexible method to obtain effectively information on priorities for beginning silvicultural operations and the overall cutting cycle in a situation where labour is scarce. The method works with the concepts of stem number/diameter distribution, spatial distribution, and quality standards for selected individuals (Hutchinson, 1993).

In short, the method is based on the selection of one Leading Desirable (LD) per quadrat of 0.01 ha, leading to the selection of at most 100 evenly-spaced potential final-crop trees per hectare. An LD should be an individual under the minimum cutting diameter and of commercial interest and good quality. It can be a tree, a sapling or a seedling. In some cases no individual with the required characteristics will be present. Taking into account the mortality, 100 LD's should be enough to end up with a good next crop.

Of the LD, the diameter, crown exposure and lianas infection is recorded. Also in each quadrat a leading tree larger than the minimum cutting diameter should be recorded if present and its commercial quality. These trees could be removed during exploitation or improvement treatment thereby improving the exposure of the LD.

Increasing need for liberation

Increasing time to harvest

Type of Leading Desirable	B. Leading Desirables (LD's) Crown Illumination Classes						
	Emergent 1	Full Vertical 2	Partial Vertical 3	Oblique 4	Indirect 5	Total	Percent
1. TREE:							
30-39 cm dbh	7	48	25	—	—	80	21
20-29 cm dbh	3	40	58	4	4	109	29
10-19 cm dbh	2	14	30	22	6	74	20
	12	102	113	26	10	263	70
	5%	39%	43%	9%	4%	100%	
2. SAPLING:							
5-9 cm dbh	—	—	8	11	24	43	12
			19%	25%	56%	100%	
3. SEEDLING:							
< 5 cm dbh	1	1	3	14	42	61	16
	2%	2%	5%	23%	68%	100%	
9. QUADRATS WITHOUT A LEADING DESIRABLE							
a) Potentially productive site	—	1	2	—	—	5	1
b) Non-productive	—	1	1	1	—	3	1
Total No Quadrats:	13	105	126	53	78	375	100
Percent:	3	28	34	14	21	100	

Table 3.1 Example of results of diagnostic sampling in untreated High Secondary forest 30 years old, Pérez Zeledón, Costa Rica (Source: Hutchinson, 1988a).

The information can be presented like in a figure 3.1. With this information one can directly determine the number of exploitable trees per hectare and whether an exploitation at present is realistic. From the number of LD per diameter class the state of the regeneration (whether sufficient or not) can be determined as well as the time necessary to obtain a next harvestable crop if information on growth rates is present. Classifying the crown exposure and lianas infection helps to indicate the type and urgency of silvicultural operations required to favour selected potential final-crop trees. (adapted from Hutchinson, 1988a)

The operations can be adapted to the labour availability. For example, the liberation of saplings and seedlings can be too costly for a large scale forest project, but on a small property, an owner could choose to invest his labour during slack periods each year, working with hand tools to release young individuals selected to be final-crop trees (Hutchinson, 1988a). Also, attention could be given to encouraging the natural regeneration or artificial regeneration of commercially desirable species on spots where no LD could be selected.

3.6.4 The improvement treatment of Coopemadereros R.L.

The functions of an improvement treatment were already discussed in §3.5.3. In this paragraph an example will be given of such a treatment as used in secondary forest of 30 years by Coopemadereros R.L. in Pérez Zeledón, Costa Rica (in: Hutchinson, 1993). In this case, the method was used to obtain a first harvest and thus a first income and select trees for a final harvest. In short the method is as follows:
- each tree over 50 cm dbh is cut for timber or fire-wood if there is demand for the latter;
- trees of commercial species, with complete stem of at least 4 meters straight without big knots and a complete vigorous crown are conserved and marked for selection;
- lianas on selected trees are cut;
- when two potential trees for selection are positioned within two meters of each other the minor in characteristics is eliminated
- around a selected tree one eliminates:
  * trees with their crown at the same level as the selected tree, touching these or being very close;
  * trees with their crown above those of a selected tree;
- trees are never eliminated because of their species.

3.6.5 Traditional and improved exploitation systems in Costa Rica

At present, forest utilization in Costa Rica is executed as an exploitation with the sole objective of extracting all the commercial timber in diameters above the 60 cm. The extraction is executed without previous planning which results in severe destruction of the forest (Müller in Méndez Gamboa, 1993). In the management plan which is a requirement of the forest service to get a cutting-permit, the only planning of the harvesting operation is an inventory of the forest to determine the volume of harvestable trees and subsequently the tax to be paid over the commercial value. In most cases two different minimum cutting diameters are applied, 60 cm for *Carapa guianensis* and 50 cm for other species.

The newest regulations of the forest service (MIRENEM, 1992) in relation to the management plan mention that 60% of the trees over 60 cm of diameter can be cut, leaving the other 40% as seed trees. However, still no other silvicultural operations than exploitation are required.

The Forestry Development Commission of San Carlos (CODEFORSA) has modified the regulation such that for each commercial species a minimum cutting diameter is determined, starting at 30 cm dbh, and that only 50% of the harvestable trees is cut, leaving the remaining as seed trees (Méndez Gamboa, 1993). By applying a variable minimum cutting diameter one counts with the fact that different species have different maximum sizes. Depending on the outcome of diagnostic sampling, a liberation thinning can be applied. The cutting cycle is determined at 10 years.

Finegan and Sabogal (1988b) give a cutting intensity of 20-60% (higher intensity in higher diameter classes) of the commercial trees of good quality over 40 cm dbh. This equals some 20 trees/ha or 30-50 m^3/ha in the tropical rainforests of the Atlantic Zone. Afterwards, a liberation thinning to develop the regeneration on basis of diagnostic sampling can be carried out.

In a preliminary study, Poels (1993) mentions a harvesting level of 25-50 m^3/ha for the Atlantic Zone, independent of the soil type or drainage condition, but dependent of the stocking with valuable species. However, when cutting 50 m^3/ha the nutrient supply becomes more tight in the long run. The cutting cycle is set on 24 years, in accordance with the CELOS Silvicultural System of Surinam. He advises a first refinement treatment following the harvest and a second one after 10 years. A cutting cycle of 20 years could be possible, but in that case smaller stems will be harvested.

4. FARM FORESTS IN LAND USE PLANNING

4.1 Introduction

When developing a forest management system the conditions in which it is placed should be analyzed. The conditions include vegetation, site, timber market, official policy and administration, labour supply, staff training, population pressure (or the absence of it), and the use and tenure of land (Hutchinson, 1988b). In the analysis of these conditions land use planning can play a role. Land use planning has the function to guide decisions on land use in such a way that the resources of the environment are put to the most beneficial use for man, whilst at the same time conserving these resources for the future (FAO, 1976).

In this chapter will be discussed how land use planning can be used in the development of management systems for farm forests as an integral part of land use. Two tools of land use planning, land evaluation and farming system analysis will be treated.

4.2 Land use planning

Land use planning is considered a form of (regional) agricultural planning. Land use planning is a means of helping decision-makers to decide upon the 'best' use of land by evaluating land and alternative patterns of land use, in view of accepted objectives, and of environmental and societal opportunities and constraints. The outcome should be the drawing up of policies and programmes on different hierarchical levels for the use of land (adapted from Fresco et al., 1989).

In regional agricultural planning objectives can be derived from national objectives, but should be made region specific. In this context the goals of farm households[1] in the region play a key role (Fresco et al., 1989).

Change from the present land use to a projected, presumably improved, land use can only be achieved gradually with the participation of the users of the land, who are in most cases farm households with specified rights to (the use of) the land (Fresco et al., 1989). The households are the decision-makers at farm level. They have different objectives regarding the use of their land. A land use that will often in the first place consist of agriculture and/or cattle holding, and next to that natural forest. The decisions on the way the farm household allocates the available inputs for farm production depend on the objectives, opportunities and constraints of the household and the relative importance of the different land uses in reaching the objectives. This implies that the use of farm forests cannot be analyzed as a solitary activity, but that it has to be studied in the context of the farm.

[1] Farm household: A group of people, often related, who individually or jointly provide the management, labour, capital, land and other inputs for the production of crops and livestock and who consume at least part of the farm produce (Fresco et al., 1989).

Several tools for land use planning have been developed such as Diagnosis and Design, Land Evaluation, Farming Systems Analysis and Research, Agroecosystems Analysis and some integrated methods (Overmars, 1990). Only within Land Evaluation a procedure for the analysis of forestry activities has been developed: Land Evaluation for forestry (FAO, 1984). However, this procedure focuses only on forest and forestry. Farming System Analysis can be a tool for describing and analyzing the farm as a whole. Both Land Evaluation (LE) and Farming Systems Analysis (FSA) can be part of the procedure for land use planning as visualized in figure 4.1.

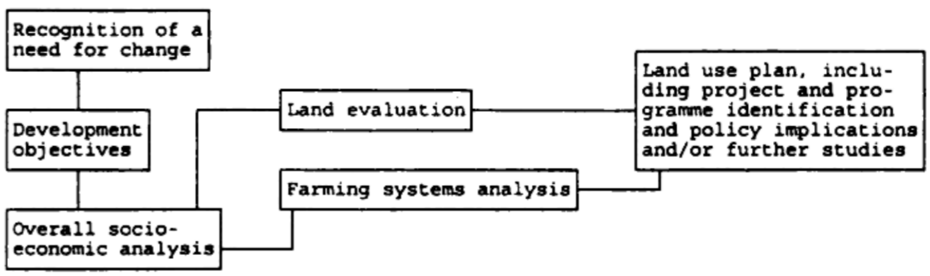


Figure 4.1 A generalized procedure for land use planning
(Source: Fresco et al., 1989)

The contributions of land evaluation to land use planning are threefold:
- it looks at future possibilities for the use of land;
- the possibilities are based on an evaluation of physical and biological resources coupled to an evaluation of economic and social opportunities and constraints;
- it maps present and potential land uses in land mapping units (Fresco, et al., 1989).

In its turn farming systems analysis contributes to the planning in two ways:
- a diagnosis of the present situation with regard to farming and land use by categorizing, describing and analyzing farms and their components, indicating and analyzing the linkages of the farm system[2] with aspects of higher level systems that impose constraints on farm level performance.
- this analysis gives insights in possible and necessary improvements in existing ways of farming (Fresco, et al.,1989).

When the two, LE and FSA, are combined, types of land use can be placed properly into the physical, biological and socio-economic setting of the farm as a whole. They can be regarded complementary. In this following paragraphs will be dealt with both LE and FSA.

[2] Farm system: A decision making unit, comprising the farm household, cropping and livestock systems, that produces crop and animal products for consumption and sale.

4.3 Land evaluation for forestry

4.3.1 The land evaluation procedure

The objective of land evaluation (LE) is to assess the suitability of different stretches of land, for selected and specified land uses (Fresco et al., 1989). LE recognizes major kinds of land use as a first division of rural land use, such as rainfed agriculture, irrigated agriculture, grassland, forestry, or recreation (FAO, 1976). In case of LE for forestry the land uses considered can range from broadly defined classes, e.g. softwood plantations, conservation forestry, to uses described in more detail, e.g. by tree species, silvicultural methods and harvesting practices. Land, in the context of LE, refers to all features of the natural environment which can influence its use by man; land includes not only landforms and soils but also climate and vegetation, including existing forest stands (FAO, 1984).

In the LE procedure (see figure 4.2), the suitability assessment of land for specified land uses results in specific Land Use Systems (LUS). The LUS consists of two components called Land Utilization Type (LUT) and Land Mapping Unit (LMU) (FAO, 1984). A LUT can be defined as a technical organizational unit in a specific socio-economic and institutional setting (Bennema in Paap, 1993; Andel in Paap, 1993). Each LUT has certain land use requirements and each LMU has certain land qualities (FAO, 1984). If inputs are provided through the LUT, the resulting LUS will yield certain outputs, as products, services and other benefits from the LMU (FAO in Paap, 1993).

The two components of a LUS, the LUT and the LU, will be elaborated into more detail in the next paragraphs for the case of natural forests.

4.3.2 Land Utilization Types

When a kind of land use needs to be described or defined in a degree of detail, it will be determined as a LUT. LUTs are not a categorical level in a classification of land use, but refer to any defined use below the level of the major kind of land use (FAO, 1976). The LUT[3] is a specific kind of land use under similarly biophysical and socio-economic conditions (current or future) seen as a subsystem of a farm or other entity and described according to its physical, economic and social setting, through specifying this in key attributes; a set of technical specifications and requirements (Overmars, 1990).
The Guidelines: Land Evaluation for forestry (FAO, 1984) gives the following list of Key Attributes (see for an elaborated description appendix III :

1) Outputs
2) Labour
3) Capital
4) Technology
5) Management
6) Scale of operations
7) Markets
8) Infrastructure requirements
9) Land improvements

[3] The terminology of LE as a whole distinguishes as a special case a multiple land utilization type, as one in which more than one kind of use or purpose are simultaneous undertaken on the same area of land, since forestry land use often is multi-purpose (FAO, 1984).

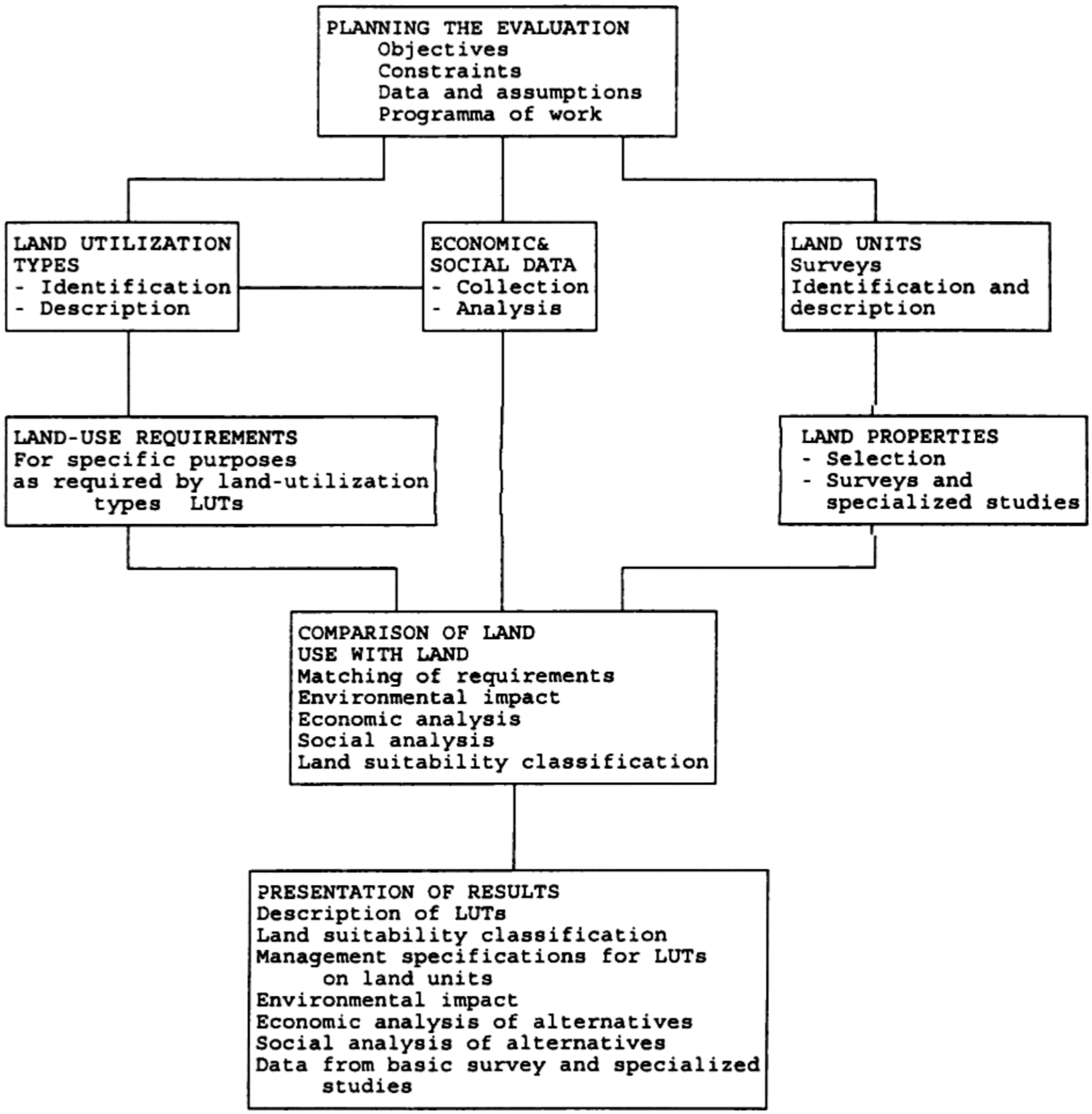


Figure 4.2 Land evaluation procedures (Source FAO in Fresco et al., 1989)

Each of these features can influence the land use requirements (LUR) and limitations of the specific LUT. The LURs are the conditions of land necessary or desirable for the successful and sustained practice of a given LUT (FAO, 1984). LURs can be divided into three groups (FAO, 1984):

1) growth requirements or in case of natural forests: estimates of the present forest condition, since the forest itself forms part of the land resources

2) management requirements
3) conservation requirements

The description of the key attributes should be done with as much detail and precision as the purpose requires (FAO, 1976). It should be sufficiently informative for an easy identification of the LURs (Beek in Paap, 1993). A difference should be made in this view between the description of present land use and that of possible alternatives. When the current land use is little pragmatic, a detailed description of the key attributes might not be realistic and the list of key attributes could be used as a checklist. Alternative land uses should be treated as precise as the purpose requires. When comparing the key attributes of present land uses and of the proposed alternatives, the differences between them determine the requirements of the alternatives towards the land.

4.3.3 Land Mapping Units

The other major component in LE is the land itself. This comprises factors like the climate, landforms, hydrology, soils and vegetation, fauna and diseases. Their characteristics determine the land qualities (LQ): a complex of attributes of land which act in distinct manner in its influence on the suitability of land for a specific kind of use (FAO, 1984). There is a large number of LQs but only those relevant to the land use alternatives need to be determined. A LQ is relevant to a LUT if it either influences the level of inputs required and/or the magnitude of benefits obtained (FAO, 1976). An overview of relevant Land Qualities is given in appendix IV.

Different combinations of LQs determine different land mapping units (LMU). There are three ways to distinguish LMUs (FAO, 1984):
1) based on land forms and their associated soils, commonly employed in agricultural land evaluation;
2) based on vegetation and ecological relationships; and
3) based on observed or estimated tree growth using timing of land characteristics. (FAO, 1984)

The vegetation-based or ecological approach may be appropriate to surveys for forest land use, particulary at smaller scales with a limited availability of time.

In cases where the use of natural forests is being analyzed, and where no substantial improvements to the forest are envisaged, techniques of forest mensuration, largely or entirely, constitute the survey for land qualities affecting growth (FAO, 1984); the condition of a forest stand determines the forests' productivity and the original forest vegetation is the result of climate and soil characteristics. Studies of landforms, drainage and soils remain necessary for management and conservation requirements. The methods of forest mensuration involved are standard techniques in forest resource assessment like forest inventory, diagnostic sampling and forest yield prediction (FAO, 1984).

4.3.4 Matching land use with land

The focal point in Land Evaluation is the matching of land use alternatives and land in a land suitability classification; the requirements of LUTs are compared with the qualities of LMUs (FAO, 1984). Matching serves (FAO, 1984):
- to refine the description of LUTs;
- to determine the management and improvement specifications of each LUT on each LMU to which it is suited, and thus to estimate the required inputs;
- to estimate the magnitude of the outputs from each LUT on each LMU to which it is suited;
- to appraise the provisional suitabilities in terms of environmental impact and social consequences;
- to provide an economical analysis of the relative costs of each relevant combination of LUT with LMU; and
- to produce a set of suitability classes for kinds of land use on LMUs.

4.3.5 Some critical notes on Land Evaluation

For the case of natural forests it should be stressed that in Land Evaluation the land (c.q. forest) and the land use (c.q. forest use) are related at forehand and cannot be separated when planning the land use. The LUT alternatives are reduced to those regarding forest products and services, and growth requirements are replaced by estimates of growth (FAO, 1984). This is recognized by replacing a survey of land qualities for growth by forest mensuration, but the emphasis in the LE procedure on matching Land Use Requirements and Land Qualities easily makes one overlook this aspect.

A major point of criticism on LE is that socio-economic aspects are hardly studied; the concern becomes the land, not the users (Duchhart in Van Leeuwen and Hofstede, forthcoming). A drawback, related to the former is that the key attributes only pay attention to the technical aspects of the forest use itself and not to forest as a component of the farm system in relation to other components, such as the farm household or livestock systems. Labour, for instance, is a key attribute, but labour availability is not discussed in the matching procedure. For this reason the land evaluation should be integrated with, for instance, farming systems analysis, which is concerned with diagnosis and analysis of farm level variables (Fresco et al., 1989).

4.4 Farming systems analysis

4.4.1 Objectives

"Farming is not only a source of food, but very often also a source of feed, of fuel, of fibre, of pharmaceutical products, of cash income, and last but not least, a source of pride. In other words, farmers use agricultural production to satisfy many, diverse needs. Thus they have multiple goals, and it is this acknowledgement that has provided an important starting point for farming system analysis (FSA)" (Fresco et al., 1989; p.27). FSA is nearly exclusively concerned with developing agricultural technology for small farmers, i.e. farmers who undertake a variety of cropping and/or livestock activities often on fields of limited size and who use family labour and relatively few externally purchased inputs. Mostly, the focus is not on increasing yields of one crop, but on increasing the long-term stability of yields and reducing risks (Fresco et al., 1989).

FSA distinguishes between systems at various hierarchical levels, ranging from the plant system via the crop system, the cropping system or for this study the silvicultural system, the farm system, to the higher level land use systems (Fresco et al., 1989), as illustrated in figure 4.3.

In this stage it is important to distinguish between "farm system", referring to a specific system level in the hierarchy at which the individual farm is studied as a system, and "farming system", referring to a class of similarly structured farm systems (Fresco et al., 1989). Farming systems are defined by their physical, biological, and socio-economic setting and by the farm households goals (adapted from Shaner in van Leeuwen and Hofstede, forthcoming). For the purpose of studying the role of forests and trees in farming systems, farming systems should be defined by parameters responsive to the factors relevant to decisions with regard to forests and trees (van Leeuwen and Hofstede, forthcoming).

4.4.2 Procedures

FSA procedures involve two clearly distinct phases (Collinson in Fresco et al., 1989):
- analytical procedures or diagnosis; and
- translating development options into agricultural research.

For the purpose of this study only the first phase will be discussed.

FSA starts with a given area and analyzes the problems faced by farmers in that area. It identifies the target groups composed of farmers operating in about the same environment. This implies that these farmers are part of similar systems at different levels of the hierarchy. In general the farmers belong to the same target group if they experience the same problems and opportunities. For this study this is the group of farmers with natural forest on their farm. The outcome of the diagnosis consists of possible solutions and opportunities to alleviate constraints. or, to be more specific, it contains:

- a description of the physical, biological and socio-economic environment in which farmers operate;
- a comprehension of the skills and knowledge, the constraints and aspirations of farm households;
- an evaluation of existing systems, i.e. their performance in terms of the processing of inputs into outputs; and
- an identification of the most constraining factors that research should concentrate on (Fresco et al., 1989).

The diagnosis should concentrate on different hierarchical levels and should, for the purpose of this study, lead to the recognition of different farming systems in relation forests, i.e. groups of similar farm systems with comparable factors relevant to decisions with regard to forests and trees.

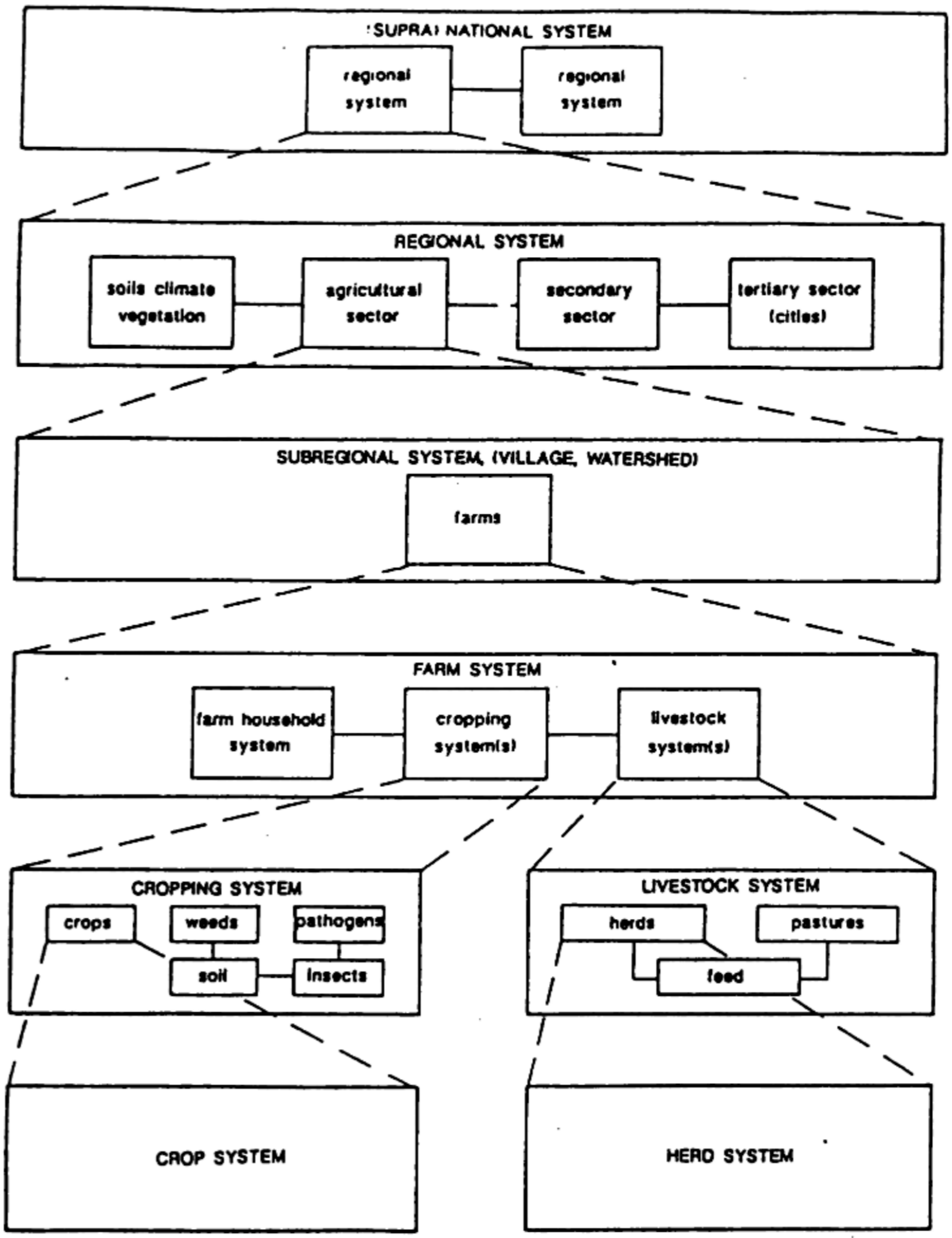


Figure 4.3 Agriculture as a hierarchy of systems (Source: Fresco et al., 1989)

Sources of data for the diagnosis can be secondary data, exploratory surveys and formal surveys (Fresco et al., 1989). An overview of relevant data is given in appendix V.

4.4.3 Some critical notes on farming systems analysis

According to Fresco et al. (1989). the main benefits of FSA are, among others, the development of a greater awareness of the constraints and potentials of small farmers. However, FSA as a tool to design sustainable land use systems has been relatively neglected and rather minor improvements in existing farming patterns are the outcome (Simmonds in Fresco et al., 1989). The checklist of relevant data of FSA leads to a description of the present situation and the potentials for improvements in current systems but it does not give a comprehensive impression of farming systems allowing the successful introduction of a not yet present land use system. This makes in its turn LE an useful addition to FSA since LE allows the consideration of other types of land use.

4.5 Combining land evaluation and farming systems analysis

LE indicates the best uses of land on the assumption that these are technically feasible, economically viable and socially acceptable. FSA has drawn attention to the fact that these conditions are often not met, especially under rapidly changing environmental and economic circumstances. In contrast to LE, FSA has emerged out of the explicit concern over less well-endowed regions and subsistence-oriented farmers using low quantities of external inputs, and its approach focuses on these problems (Fresco et al., 1989). While the two approaches show great differences and both have their weaknesses, this should be more reason to integrate the two tools for the purpose of this research: the diagnosis of the present situation, regarding the use of natural forest on farms and the search for possible improvements or alternative uses.

The demand is for potentially viable forest management systems, appropriate to small areas. In order to design such systems, the potentials of the forest and its user have to be analyzed: the present forest use, their physical, biological and socio-economic setting and the farmers' goals.

LE serves to describe and analyze the current uses of forest on farms in technical terms by means of the key attributes. LE also gives a procedure to recognize and describe different forest conditions by classifying them in land mapping units. The descriptions of current forest use and forest conditions allow the formulation of alternative LUTs or forest management systems which should be technically feasible and economic viable. However, these alternative LUTs put requirements on the farm systems they have to be part of.

FSA should provide information on the degree to which farm systems can meet the requirements. This will depend of the other components of the farm system: the objectives of the households and the relative importance the households give to cropping and livestock systems, but also of limitations and possibilities imposed by higher hierarchical levels; regional or national. Different farm systems will have different possibilities, for that reason they have to be grouped in farming systems which might be able to apply different silvicultural systems.

The LE and FSA procedures should be executed simultaneously. That way unrealistic LUTs can be eliminated or adapted during the analysis.

5. METHODOLOGY FOR THE ANALYSIS OF THE UTILIZATION AND COMPOSITION OF NATURAL FOREST

In this chapter the methodology for the analysis of the utilization and composition of natural forests on farms will be delineated. The methodology follows the structure of the former chapter on land use planning, in which two parts were identified: the description of forest use on farms in the technical terms of land utilization types (LUT) and in the relation between LUTs and farming systems on the one hand and the description of different forest stands in land mapping units (LMU) on the other hand.

5.1 Description of LUTs

As mentioned in chapter 4, a LUT has to be described in two ways, as a system in itself and by its relations to the farm as a whole. The former has to be executed by means of the key attributes (appendix III), the latter by means of the checklist of farming systems analysis (appendix V).

Hulsebosch (1992) selected 105 farmers in the three research areas (§2.2) and provided information on their property sizes, land use and activities with trees and forest. 55 farmers were mentioned to have forest on their farm (Hulsebosch, 1992) and therefore constitute the research population in this research. All members of the group were to be visited for an interview in order to discern the present utilization types by describing their technical and organizational specifications and to determine the present knowledge, attitudes and availability of labour and tools of farmers in relation to forest use. Not all of these farmers really had forest, were encountered or were willing to cooperate. To compensate this some farmers outside the pre-selected group were visited as well. The methodology and format of the interviews is given in Appendix II. Additional data on farming in the three research areas were gathered from literature.

During the research forest utilization by farmers appeared to be little consistent. The distinction of utilization types, being specific kinds of land use, was difficult, as was consequently a detailed description. Therefore, the data representation in chapter 6 will be restricted to an overview of farmers' activities by means of the checklists mentioned above. Moreover, a study on harvesting methods among farmers was in process (Engelage, forthcoming) and did make a detailed technical discussion superfluous.

5.2 Description of LMUs

In chapter 4 was mentioned that in case of studies on natural forests the land mapping units can be selected and described on basis of the condition of the forest. Hardly any detailed literature could be found on forests in the plains of the Atlantic Zone of Costa Rica.

Therefore, for this thesis the inventory of forests in the research areas was decided necessary for obtaining data on composition and condition of forests. The methodology consisted of the selection of sites and inventory plots, and the execution of a conventional inventory and a diagnostic sampling.

5.2.1. Selection of the inventory sites

Two criteria were used for the selection of the inventory sites:
A) the drainage class of the soil
B) the former utilization of the forest-site

ad A) In chapter 3 it was stated that climatic and soil variation produce a diversity in forest types. However, as mentioned in chapter 2, the elevation in the Atlantic Zone doesn't differ much and the climate and soil are rather homogeneous. Of particular importance for the floristic composition of forests in the Atlantic Zone are the soil drainage and humidity, according to Peralta et al. (1987) and Lieberman et al. (1985) for the Atlantic Zone of Costa Rica and INDERA (1991) for the Atlantic Zone of Nicaragua. No literature was found on relations between soil and vegetation types in the northern plains of the Atlantic Zone. For this reason a sole distinction in vegetation types was made between those on well-drained and those on poorly-drained soils, in accordance with the soil classification mentioned in chapter 2. Until further research gives more clearness, the selected forest types have to be seen as important examples of the forests in the northern Atlantic Zone. In accordance with the objective of the research to describe the management possibilities of forest on farms, local variations are not taken into consideration either.

ad B) The silvicultural situation of a forest is principally determined by the forest's condition as a result of human intervention (see chapter 3). In order to know what the effect of a certain type of forest utilization is on the forest condition and to determine the management possibilities and requirements, the inventory of different types of forest stands was necessary; stands which differed due to former utilization. This also allowed the estimation of the regeneration potential of forests by measuring the state of development of stands after different types of exploitation, avoiding time consuming inventories of permanent sampling plots.

Information on drainage (good/poor), soil-fertility (high/low), elevation (plain/hilly) and former utilization of forest stands on different farms was gathered during the interviews with farmers. On basis of this information seven forest stands have been selected, being the maximum number that could be inventoried in the time available.

In order to increase the comparability of the data, preferably stands with similar drainage (good), soil-fertility (good) and elevation (plain) characteristics were selected. However, for the last two characteristics this was not always possible. In order to compare the forest types with good and bad drainage, one poorly-drained site was selected as reference.

In accordance with the classification in chapter 3, the selected sites represented three types of forest stands:

- primary forest : 2 sites (good versus poor drainage) in one forest stand;
- exploited forest : 4 sites in forests with different human interventions;
- secondary forest : 1 site.

5.2.2 The size and position of the inventory plots

Detailed analyses cannot be carried out on the basis of studies of large areas, but only by a process of systematic sampling. The first question to be answered is: What is the minimum representative area? (Lamprecht, 1989). Hartshorn (in Manta, 1988) found 88-118 species per hectare in the Atlantic Zone, which may be considered as a forest rich in tree species. In such forest types, the minimum areas may be 1 ha or more (Lamprecht, 1989). Also Whitmore in Hoogveld (1990) assumes 1-10 ha as most instructive for studying the forest structure. However, Sabogal (pers. comm.) mentioned a standard of 10% of the area as minimum. Decisive was the available time. Decided was that of the smaller stands ($\leq$ 5 ha) 0.5 ha would be inventoried, which represents at least 10% of the total area. Of the larger stands ($\geq$ 40 ha) 1 ha would be measured, less than 10% of the total area but equal to the minimum of for example Lamprecht (1989).

The selection of a sample plot can be done at random (stratified), systematic or on the basis of an expert study (Lamprecht, 1989). Because of the limited time a choice was made for the expert study; on basis of a reconnaissance in each forest stand a site was selected with a good drainage and in one stand a site with a bad drainage. On each site a starting point was chosen 50 m from the forest boundary in order to minimize the influence of the different boundary-vegetation on the results. At each selected site the following steps were taken (from Carrera, pers. comm.):

- a direction was chosen which led straight into the forest
- in this direction a base line of 250 or 500 m (depending the size of the plot) was measured out and cut; when the boundary of the forest or a spot with a different drainage condition was reached, the direction of the line was changed before that point
- with measuring tape and compass, on both site of the base line, squares of 10 x 10 m were cut and staked out

In each square a conventional forest inventory and a diagnostic sampling have been executed. These methods will be discussed in the following paragraphs.

5.2.3 The conventional forest inventory

With a conventional survey the parameters can be measured which describe the condition of a forest stand (see §3.3) where upon silvicultural measures can be based. A benefit of this method is its general and standard application. One can compare the results with stand analysis and results of other studies. For this study, the standard method of the RENARM/PBN-project (program for the processing of the information on the management) was used. The inventory was executed with assistance of a tree spotter of the CATIE/RENARM-project.

Per square, all trees and palms with diameter ≥ 10 cm were recorded with the following characteristics:
a) local or scientific name of tree;
b) estimated diameter at breast height (1.3 m); in case of a stem fork below breast height, the separate stems were measured;
c) quality class of the bole*;
d) in case of tree with DBH ≥ 50 cm, the length of the bole with quality class 1*;
e) exposure class of the crown*;
f) shape class of the crown*;
g) lianas infection class*.

* The classification criteria are shown in appendix VII.

5.2.4 Diagnostic Sampling

In §3.6.3 the benefits of Diagnostic Sampling (DS) were already discussed, being a flexible method to obtain effectively information on priorities for beginning silvicultural operations where labour is scarce. The method was applied for several reasons. First of all, DS can easily be combined with the conventional survey. Secondly, it gives directly information on the number of trees that can make up a next harvest and the measures necessary to favour those trees. Finally, and related to the latter reason, it could be an option for farmers to determine management needs of their forest and therefore worthwhile testing.

For DS the instructions of Manta (1988) and Picado (1991) were followed. At forehand, the tree species were grouped according to their commercial value using the species list and ranking of CATIE (undated). The groups are defined as follows (Finegan and Sabogal, 1988a):

- Desirable species (D): species of medium and high value, commercialized at national level.
- Acceptable species (A): species of low value, used at local level or, according to technical studies, having adequate properties to be utilized.
- Other species (O): species without known actual or potential use.
- Palms (P)

The species list as used in this thesis is given in Appendix I. An important difference with the species list of CATIE is the ranking of *Pentaclethra macroloba* for this study as Desirable species in stead of Acceptable because of its wide acceptance by timber companies.

Per quadrat (10 x 10 m) of each selected site the following procedure was executed (explication of classes in appendix VII) in order to select a Leading Desirable (LD):

1) If the quadrat contained a TREE (10 ≤ dbh < 40 cm) which met the standards of a LD then this tree was selected. That tree had to,
   - be the best (and often the tallest of the largest in diameter) among the commercially desirable trees in the quadrat,
   - have a single trunk with bole quality class 2 of at least 4 meters in length,
   - have a crown with shape-class 1 or 2.
2) If the quadrat did not contain any such TREE, but it did contain a SAPLING (5 ≤ dbh < 10 cm) which complied the following requirements then the sapling was selected;
   - of a desirable species,
   - having a single straight trunk, sound, free of defects and deformations and without heavy limbs,
   - having a well-formed and vigorous crown.
3) If the quadrat contained no such TREE or SAPLING, but it did contain a suitable SEEDLING (dbh < 5 cm, height ≥ 1.5 m) with the requirements listed under point 2) the seedling then was selected.
4) If the quadrat did not contain such tree, sapling or seedling, it was technically classified as UNSTOCKED

Of the selected Leading Desirable the following data have been recorded:

a whether tree, sapling or seedling; in case of a tree, the dbh was noted as well.
b the crown exposure class
c the lianas infection class; this classification was different from the one in the conventional survey: class 1: free of lianas
class 2: lianas on the trunk
class 3: lianas in the crown

When comparing the results with the methodology of Hutchinson (1988a) it appeared that seedlings should have been selected with a minimum height limit of 30 cm, signifying that where in this study a quadrat was marked as unstocked, a seedling between 0.3 and 1.5 m in height could have been present. A complete description of the DS methodology can be found in Hutchinson (1988a).

6. UTILIZATION OF NATURAL FOREST ON FARMS

6.1 Introduction

In this chapter the data from the 40 interviews within the target group of farmers with forest are presented and analyzed. The information should give a description of the present forest use and the possibilities and constraints for improving the forest use on farms. General aspects of the farm systems in the research areas, the acreage of forest on farms, practices in the forest and the farmers' objectives towards forest will be discussed. As mentioned in chapter 4 a LUT is any defined land use under the level of major kind of land use. Considering this, two LUTs will be discussed in this chapter although the forest utilization appeared to be little pragmatic and consequently difficult to categorize. In the last paragraph a classification of the farm systems in farming systems will be presented on basis of the objectives and possibilities of farmers for implementing forest management systems.

6.2 General aspects of the farmers

In table 6.1 general information on the interviewed farmers per research area is given. The farm sizes show a large amplitude which might be of great consequence for the relative importance of forest within the farm systems. In comparison to these great differences the number of interviews per research area is rather small and requires a careful interpretation of figures on "average" farmers and practices.

The number of interviews per research area can be considered typical for the number of farms with forest per research area (table 6.1). When searching for farmers with forest outside the pre-selected group only one could be found in Río Jiménez and several in the area of Neguev. This indicates that in Neguev forest is still more common on farms than in Río Jiménez. Moreover, three of the Río Jiménez farmers had their forest situated outside the research area on remote land. Therefore, the forest cover in Río Jiménez may be presumed lower than the figures indicate.

Of the 14 farms smaller than 20 ha, 11 are situated in Neguev. Those farms in Neguev also show the most diverse land use with substantial shares of pasture as well as forest and other types of land use, where farms in the other areas show pasture as major land use.

In Cocorí, the share of farms with a land title is lower and with caretaker higher than in the other areas, which might imply an obstacle when developing forestry activities, since without a land title, forest utilization is prohibited by law. A caretaker is not the decision maker on a farm; the owner of such farms often lives in the city and is, therefore, difficult to involve in development projects.

6.3 Forest acreage on farms

In this study natural forest has been defined as "any forest not being a tree plantation. However, the by law obliged and protected vegetation strips on river and creek banks have been excluded of the definition as well since in practice these didn't show any interesting features for silviculture.

Hulsebosch (1992) concluded that the larger farms more frequently had forest. Largest forests also occur on the largest farms. Of the 15 forests equal or larger than 10 ha, 14 are situated on farms larger than 45 ha (18 farms in total).

Table 6.1 Overview of the average farm data of the 40 interviewed farmers in the research areas (Source: Hulsebosch, 1992)

factor	RIO JIMENEZ		NEGUEV		COCORI		TOTAL
total no. of farmers in research area	424		311		142		
farmers interviewed	9		11		20		40
farm size[1]							
average	85		16		83		65
largest	185		20		280		
smallest	10		10		19		
forest size[1]							
average[5]	16	(19%)	4	(25%)	35	(42%)	22
largest	50		8		210		
smallest	1		1		3		
pasture[2,5]	62	(73%)	6	(35%)	40	(48%)	36
other land use[2,3,5]	5	(5%)	6	(38%)	6	(7%)	6
origin of farmers[4]							
Atlantic Zone	3		3		1		7
outside	5		8		14		27
land title[6]	9	(100%)	8	(73%)	11	(55%)	28
caretaker	1		0		5		6

[1] in ha.; [2] average in ha.; [3] under this heading: summation of annuals, perennials, tree plantation and fallow; [4] number of farmers that provided information; [5] between brackets % of total farm size; [6] between brackets % of interviewed group per area.

Table 6.2 demonstrates the forest share in relation to farm size. Río Jiménez shows a significantly lower percentage of forest on farms due to its older development stage with a longer period of deforestation. The farms in Neguev and Cocorí are still in evolution and therefore show higher grades of forest coverage; the forest just has not been cut yet. This especially accounts for the farms over 50 ha in Cocorí, where there is often no need to create more pasture nor is the labour present to maintain it. In other words on larger farms in Cocorí there is less pressure on the land under forest.

Table 6.2 Average share of forest on farms (%) in relation to farm size; between () the number of farms

Farm size ha	Río Jiménez	Neguev	Cocorí
1-20	18 (2)	25 (11)	28 (2)
20-50	16 (2)	--	28 (7)
>50	21 (5)	--	43 (11)

The gradual conversion of forest with the development of a farm is independent of the soil type or drainage condition of the land under forest, thus independent of the suitability of the land. Field observations make clear that forests in general are situated on the part of the farm most remote of the road and that certainly in Cocorí and Neguev the tree density in pastures increases closer to the forest indicating a gradual conversion of the forest. This is confirmed by Mucher (1992) for the Neguev area.

According to the questioned farmers, more than 50% of them has the forest located partial on hilly or bad drained land, or on red soils (Neguev) which are least attractive for other land use (see table 6.3). This was mentioned as well by Koster (1993) and Mucher (1992). But when labour is available and expansion necessary, forest on land of any quality will be converted into pasture. As table 6.3 shows as well, forest is not only encountered on soils less suitable for pasture and agriculture, but on black soils as well. Van Uffelen (in: Koster, 1993) showed that the classifications of black, red and swampy soils match well with respectively the soil use classes 'well drained fertile', 'well-drained unfertile' and 'poorly-drained soils' (see Chapter 2). Río Jiménez has for the major part black soils and Neguev red soils.

Table 6.3 Distribution of forests over soil and relief types (%) per research area

Soil/relief type	Río Jiménez	Neguev	Cocorí	Total
red soil	0	80	29	39
black soil	83	10	42	39
red and black	17	10	29	22
part swampy	50	50	29	39
part hilly	0	60	65	52

Almost all forests had been exploited before the arrival of the present owners. In Neguev the farmers mentioned that the exploitation of their forest took place in ± 1976 by the owner of the large cattle estate Neguev was part of. In Río Jiménez, two farmers mentioned to have had virgin forest located outside the research area, north of the river Río Jiménez when they arrived. The other farmers mentioned exploitation by a chinese company for cedro amargo (*Cedrela mexicana*) some 30 years ago. In Cocorí 7 farmers said to have virgin forest when they arrived. Others spoke of exploitation 20-40 years ago. This is subscribed by Verbraeken (1988) who mentions exploitation of cedro amargo for the Cuban market from 1942-1962. Only one farmer, in Neguev, mentioned to have a secondary forest.

6.4 Forest utilization in the research areas

6.4.1 Introduction

In practice forest utilization in the research areas is restricted to two activities, both directed to wood harvesting. They are distinguished on basis of the applied technology: respectively intermediate (medium) and low technology. Next to these activities some farmers apply silvicultural operations like cleaning or planting sometimes in combination with harvesting and other farmers gather insects or medicines in the forest. Some convert their forest into pasture or don't make use of their forest at all. In appendix VI an overview is given of all the combinations of activities as mentioned by farmers in order to show that an "average" forest use is difficult to describe. Moreover, there hardly are connections between the different activities.

The importance of the single activities are displayed in table 6.4. It should be remembered that on one farm different activities can be encountered. The LUTs, defined on basis of the harvesting activities, will be described in § 6.4.2. Other (silvicultural) operations, gathering, conversion and "no activities" will be discussed in § 6.4.3.

Table 6.4 Frequencies of single activities of farmers per research area

	Río Jiménez (9 farmers)	Neguev (11 farmers)	Cocorí (20 farmers)	Total (40 farmers)
no activities	3	2	8	13
medium tech harvesting	2	6	5	13
low tech harvesting	3	7	4	14
other operations	2	5	2	9
gathering			2	2
conversion		1	2	3

The data for the descriptions bear on the activities of the farmers since their purchase or occupation of the land, which can be some thirty years ago. Conversion as part of the first reclamation and development of a farm and the farm land is not included in these activities; on almost all farms in Neguev and Cocorí the forest had to be cleared in the last decades to start crop and livestock production. The term "conversion" in this chapter refers to clearing of forest to obtain more land for crops and pasture on farms where agricultural and livestock production already take place.

6.4.2 Major LUTs in the research areas

The applied technology for wood extraction from the forest was the most determining key attribute the utilization of the forest could be determined upon. This resulted in two LUTs for natural forests:

A) wood production with low technology (low tech);
B) wood production with intermediate technology (medium tech)

On seven farms both LUTs occurred in the same forest; a so called compound LUT. A discussion of the compound LUT would be superfluous since except for the location there is no relation between the two components.

As can be seen in table 6.5, the difference between the two LUTs is the way in which the wood is transported out of the forest to the processing site. The other key attributes will be discussed separately for both LUTs. More technical elaborations of the labour and technology input during forest exploitation can be found in the study of Engelage (forthcoming)

I	a)	chainsaw and/or portable sawing machine	+ transport by oxen
	b)	idem	+ transport by hand
	c)	idem	+ transport by oxen/hand
	d)	idem	+ transport by horse
	c)	idem	+ transport by tractor
II	a)	chainsaw and/or portable sawing machine	+ transport by bulldozer + truck
	b)	idem	+ transport by oxen + truck
	c)	idem	+ transport by bulldozer + oxen + truck

A) WOOD PRODUCTION WITH INTERMEDIATE TECHNOLOGY

13 farmers (33% of the group) mentioned this type of forest utilization (see table 6.4). The output of this LUT is wood that is transported in logs or at full length. In all but one case the timber was sold to wood processing industries. The only exception was a farmer in Neguev, nine years ago, who processed the trees to built a farm house. The moment of harvesting is in the first place determined by a need for money to buy e.g. cattle or goods for the household.

The number of harvested trees varied from 10-600 trees. According to the farmers the average tree contains 2,000-3,000 pulgadas[1] (4-7 m^3) and he receives 6-25 C/pulgada[2] for standing trees. In general the price is in between 12-18 C/pulgada, depending on the species and the knowledge of the farmer of the market prices. This is only some 3-8% of the market price of timber after the first processing in the sawmill (Carlos Reige[3]).

The number of species cut according to the farmers is rather small in comparison to the number of species accepted by sawmills nowadays. The four most cut species are gavilán (*Pentaclethra macroloba*), caobilla (*Carapa guianensis*), pilón (*Hieronyma alchorneoides*),

[1] 462 pulgadas = 1 m^3

[2] Colon/pulgada; 1$ = C140 (June 1993)

[3] Lecture during conference on the occasion of the 24th anniversary of DGF, december 1993, San José.

and aceituno (*Simarouba amara*). Valuable species like surá (*Terminalia oblonga*), cedro amargo (*Cedrela odorata*) and jícaro (*Lecythis ampla*) are rare and therefore scarcely cut.

The scale of operation is very diverse. The smallest felling area was 3 ha and the largest was 160 ha but this concerned a contract between a farmer and a contractor with a validity of 4 years for the whole stand.

The labour was in all cases provided by a wood processing industry or by a contractor (a middleman who buys, cuts and transports the timber and sells it to a wood processing industry). They also provided the capital: chainsaws and/or portable sawing machines, bulldozer, oxen and trucks for transportation. Roads to and in the forest were constructed or improved if necessary. When roads to and in the forest are already present, a higher price for the timber can be negotiated by the farmer.

The harvest technology is basic. When using oxen the timber is extracted in logs of three meter length; bulldozers can extract complete stems. The combination of bulldozer and oxen concerned a case in which a part of the forest was too swampy to enter with heavy machinery. Because of the heavy machinery the transport of the wood is preferably executed in the drier season when the soil is firmer, although delays in the release of the necessary cutting permission by the forest service often urges the contractor to work in the rainy season.

The level of technology can influence the tree species being cut. For instance, only recently it became technically possible to cut the trees of almendro (*Dipteryx panamensis*) and now this is only done by contractors who can dispose of the appropriate machinery (Carrera, pers. comm.).

The silvicultural technology is restricted to marking trees by the forest service at forehand and the legal obligation to plant trees in the trails as a post harvest operation. Marking is only based on commercial value and not on forest inventories and the planting was executed in only two cases and in none of the cases it was checked by the forest service. The number of trees cut is not checked either.

The market for the farmer is the contractor. It is an easy option for the farmer in the sense that he doesn't have to invest any capital or labour to obtain the profit. The cutting permission is in most cases arranged by the contactor. Only in one case the harvesting was executed without a permission but that was nine years ago when the control was not that strict.

The distance to the market is, in the first place, the distance to the paved roads and none of the farmers mentioned that it was difficult to find a buyer for their wood because of the distance or that the distance influenced the price. As mentioned before, when necessary the contractor improves the road himself.

The contracts between farmer and timber company can be of different types. Sometimes payment is per pulgada, in other cases per tree or per stand as a whole. Sale per tree seems better in order to avoid damage to the stand; the contractor has to select the trees he is going to cut beforehand in order to avoid that he has to pay for a tree which appears to have a low quality afterwards. Per pulgada seems better in the sense that the farmer has more control on the amount of wood extracted, although a lot of cheating takes place in the measurements. Moreover, the contractor might cut a tree and leave the whole or part of it when it appears to be bad. Problem when selling per stand is that the contractor has free play in the forest and may damage it severely.

B) WOOD PRODUCTION WITH LOW TECHNOLOGY

14 farmers (35% of all farmers) mentioned to utilize their forest this way (see table 6.4). For 10 farmers this was a yearly activity, for the other 5 this just had happened once. intermediate technology in their forest.

The output consisted of poles, planks and in one case logs. In two cases trees were frequently cut in order to sell to neighbours, the others cut for maintenance of the farm. In the latter cases one deals with 2-5 trees per year for fences, the farm house and once in a while firewood. The moment of cutting is determined by the need of the product.

The species that were cut did not differ much from the species used in the LUT 'medium tech wood production'. For firewood deformed trees are cut. One tree per year seems enough for this purpose.

The scale of operations is very variable: the forest size could range from 0.5-50 ha or more.

In 10 cases all the labour and capital was provided by the owner of the farm. In the other cases a neighbour provided a chainsaw or oxen and the labour, but the neighbour never did both the cutting and the transportation. The owner of oxen always has to drive the span himself.

The harvest technology is simple. Poles and planks are sawn in the forest. This is done with a portable sawing machine (local name: marco). This is a large type of chainsaw which can be changed into a sawing machine by attaching a metal frame. Adjusting the position of the frame changes the thickness of the plank. The planks are normally three meters of length. As can be seen in table 6.5, the general method of transport is by hand. In case of oxen or tractor the wood could be transported in logs of three meters length. In case of a horse only planks or poles can be transported. A specific silvicultural technology was not mentioned.

The market consisted in two cases of a neighbour.

None of the farmers had a cutting permission, but some said that the permissions once obtained for middle tech wood production still had value. According to officials of the forest service this is not right; the permission has a limited validity.

6.4.3 Other activities in natural forest

In this paragraph some aspects of forest utilization will be treated that cannot be classified as LUT since they lack all similarity in their execution (other silvicultural operation) or occur too rarely (gathering) or cannot be seen as an forestry activity (conversion and "no activity").

Other operations
"Other operations" refers to other silvicultural operations than harvesting. This consists on the farms of planting trees and cleaning. In seven of the nine cases these operations were executed in forests where harvesting had taken place as well, but there was hardly any relation with the harvest operation. In two of these seven cases farmers cleaned the understorey of their forest, cut lianas and planted trees in order to enrich the forest, enhance the growth of timber species and maintain overview on the performed work. For one farmer it was a kind of hobby, for the other it was part of a management plan. Three more farmers had planted trees; one because he liked growing rare species and two others in order to enrich their forest and thereby the value of the farm. Three farmers cleaned their forest frequently (each year) which implied literally removing dirt c.q. useless vegetation with no other objective than making the forest look orderly. Cleaning can be done throughout the year.

The seedlings used for planting come from of the pasture or from other places in the forest. The time of sowing is the rainy season; when a seedling is found it is transplanted. The most popular species to plant are caobilla (mentioned 5 times), laurel (*Cordia alliodora*) (3), pilón, roble sabanna (*Tabebuia rosea*) and cedro amargo (all 2 times). Also manú negro (*Minquartia guianensis*), roble coral (*Terminalia oblonga*), jícaro and gavilán were planted.

Gathering
Gathering refers to the gathering of insects (flies, butterflies) and snakes in the forest and the pasture for a foreign institute. This was a regular income for one farmer, reason why he did not have interest to exploit his forest. The other case was the wife of a caretaker. Both had taken a course of the institute that contracted them.

On a few farms plants were gathered for home-consumption. A lot of farmers knew of the medicinal value of some forest plants but considered the medicines, sold at the local grocery shop, easier to obtain and use.

Conversion
All 3 farmers who converted a part of their forest, changed the land use to pasture. Two sold the timber to a wood company and one used it to make a corral and fences. All three did it in the usual way of first cutting a number of trees, then cleaning the understorey and afterwards sowing pasture. Following this procedure the conversion, which is illegal, can hardly be noticed.

No activities
13 farmers mentioned never having cut a single tree in their forest. Some of the farmers had plausible explanations for leaving a part of their farm unproductive like this; four farmers mentioned to have a forest poor in harvestable trees because of former exploitations and in one case extremely swampy conditions. Two farmers only had 0.5 ha of forest and didn't need the land and one was working on a management plan. However, the other six farmers did not have very likely reasons for not touching their forest and were somewhat reticent in their answers. They all were farmers without a land title and therefore cannot extract trees, whether standing or fallen, legally. Fear for the forest service could have been the reason for their reaction. Furthermore, these farmer did fear the declaration of their land to be part of a national park, a rumour spread by the IUCN[4] in Cocorí. It is more likely that these farmers are gradually converting their forest to pasture since they cannot use it legally and neither the land nor the forest will be of any use when declared to forest reserve. Conversion would also be more in agreement with the development process of farms in the Atlantic Zone, as described in § 2.5.

6.5 The perspectives for forest on farms

In the former paragraph the current LUTs for natural forests were identified. In order to formulate improvements which can fit in the farm systems, objectives, possibilities and constraints of the farmers in relation to forest use have to be determined.

Table 6.6 The farmers' major objectives towards forest

	Río Jiménez	Neguev	Cocorí	Total
Commercial exploitation	1	5	11	17
Consumptive exploitation	5	2	3	10
Conservation	2	2	2	6
Conversion	1	2	1	4
Add value to the farm			2	2
Unknown			1	1
Total farmers	9	11	20	40

6.5.1 The farmers' objectives towards forest

When asking farmers about their forests confusion existed about what was meant by natural forest: tree plantation, living fences, trees in the pasture? A lot of farmers didn't perceive their natural forest as a part of their farm; they never thought about it as something productive, not even when they had exploited it in the past. Table 6.6 gives the farmers'

[4] International Union for Conservation of Nature and Natural Resources

major objectives towards their forest. In line with the latter remarks, the objectives were very general since the farmers hardly had concrete ideas about the future of their forest.

In the following part the objectives will be elaborated.

Commercial and consumptive exploitation
27 farmers (68% of all the farmers) thought about exploiting their forest. The question to the farmers was, what the importance of their forest was, for them or for their farm. Most farmers first reacted with answers like: maintenance of humidity (mentioned 11 times), flora and fauna conservation (6 times), standard part of the farm (3), river bank protection (3), timber and money for the children, later (2), to add value to the farm (2). Maintenance of humidity was related to pasture; farmers mentioned the increased dryness of their pasture because of higher temperature and lower precipitation after deforestation. An officer of the forest service called this the romanticization of the forest by farmers; the forest is getting a romanticized value instead of a productive value. This might be the influence of the media and (inter)national conservationists organisations which are constantly pointing at the destructive consequences of deforestation for nature.

Only when the farmers were directly asked for their future plans with the forest, 17 mentioned commercial exploitation and 10 exploitation for home consumption. The use for home consumption was often mentioned as well by the first group.

Although the farmers had not really thought about it yet, most said that probably a contractor would execute the work in case of commercial exploitation. Since contractors use bulldozers and trucks, this would imply that these farmers plan the LUT "wood production with intermediate technology" for their forest. They acknowledged that the profits would be higher doing the exploitation themselves but this was considered too difficult because of difficulties with getting the cutting permission and the tools, marketing problems and the lack of time. Only one farmer thought of exploiting the forest himself. He was working on a management plan and planned to do the transport of the wood out of the forest by oxen and to the road by tractor (low technology).

Of these 17 farmers ten had an exploitation before in their forest; only two of them had applied some cleaning and planting operations to improve the quality of the stand somewhat. Four (in Cocorí) had never touched their forest, nor had a land title to do so legally.

Of the 10 farmers who only wanted exploitation for home consumption, 5 said so because their forest already had been exploited and would be too poor in commercial volume in the next 20 years. Three others said that their forest was too small for commercial exploitation (0.5-2.5 ha).

The farmers mentioned that they had the necessary tools and/or oxen to do the work themselves or that these were present with the neighbours. This is similar to the LUT "wood production with low technology". In this respect it is interesting that farmers with oxen say to have interest in offering their services more often (Engelage, pers.comm.). This could be an opportunity in case of commercial exploitations.

Conservation
Conservation implies the maintenance of the forest without exploitation. Like the farmers who mentioned "no activities" in the past, conservation seems somewhat strange from a farmer's view since land is left unproductive. However, 5 of the 6 farmers had credible reasons. Three of them did not need the income of exploitation nor the forest land since they had enough income and sufficient land under pasture or perennials; they did not exploit their forest in the past either. So, as long as other farm components provide enough income the forest will remain untouched. Two farmers had a forest of 0.5 ha in combination with a tree plantation and mentioned ecotourism and flora and fauna conservation as reasons to maintain their forest.

Conversion
Conversion was in all four cases directed towards the extension of the area under pasture. Two farmers emphasized that pasture has a higher value than forest. One mentioned the profits from the commercialization of the wood as a reason as well.

Typical for the attitude of farmers towards forest was a farmer who first planned to convert his forest but who changed his mind some two months after the interview. He found a job in a banana plantation and now decided to maintain his forest since he did not need the land any more. The perspectives of the forest often depend on the socio-economic situation of the farmer and is not valued independently.

6.5.2 Farmers' constraints for forest utilization

Whether the perspectives for forest on farms can be improved by changing their management depends on the feasibility of the changes. The changes have to be possible and attractive from farmer's view which is determined greatly by the farmers' constraints.

A first set of constraints is based on the skills and knowledge of farmers of silvicultural aspects; knowledge that should be the basis of future forest management. As mentioned in chapter 3, a silvicultural tradition is not present in the Atlantic Zone. This also appeared from the interviews.

When asked about forest management, most farmers said that the forest knows how to manage itself and that human intervention only would damage the forest. Only two farmers knew something about the function of e.g. liberation of valuable species. Some farmers who had exploited stands said their forest looked like a brush without any value and had no idea how this situation could be improved.

When asked about the tree species present in their forest, gavilán, pilón, caobilla, almendro and fruta dorada (*Virola sebifera/V. koschnyi*) were mentioned most, which is in accordance with their abundance and value. Rare, but valuable species like manú negro, surá (*Terminalia oblonga*) and campano (*Sacoglottis trichogyna*) were mentioned frequently as well. These species were also the few species that farmers were able to recognize in the field. Few farmers are conscious of the large variety of commercially accepted trees in their forest or are able to recognize these trees. This may be a result of the fact that a lot of farmers originate from other parts of Costa Rica.

The number of harvestable trees was often unknown (30% of the farmers) or with "over 40 per hectare" far from reality (22% of the farmers).

Another group of constraints decreasing the attractiveness of forest management for farmers is related to the Costarican legislation. The Costarican forest policies will be elaborated in Schinkel (forthcoming). Most complaints of farmers had to do with the land title and the procedures of the forest service.

A land title is required to obtain a felling permit. The land title is costly and could be financed with the income of selling wood, which is impossible by lack of the same title. According the officials of the forest service, the providence of farmers with a land title would be a bad option, since some farmers than would sell the farm and invade a new one (the principle of squatting, see § 2.5)

A felling permit is required, even when it concerns the cutting of a single tree or the extraction of fallen, dead trees. In order to obtain a permit some costs and guarantees have to be settled in advance by the farmer. The costs include the marking of the trees by an officer of the service; a forestry tax which is 10% of the value of the standing volume. A guarantee has to be paid to assure that the forest will not be turned into pasture and that, in case of a management plan, the exploitation is executed according the plan.

The procedures in order to obtain a felling permit are time consuming, taking weeks and several visits of the farmers to the forest service, lawyer and bank. When the permission concerns a few trees, the forest service often does not pass by (according the farmers).

On the other hand, due to unfamiliarity of farmers with regulations and rapid changes of the law some of the complaints of the farmers are outdated.

A third group of constraints are those hindering the execution of forest exploitation by farmers. When discussing the objective "commercial exploitation" in § 6.5.1, apart from the felling permit, marketing problems, lack of equipment and the required labour were already mentioned as reasons why farmers hand out the work to a contractor. A contractor can via his contacts easily obtain a permit (with or without land title) and has better access to customers. On the other hand farmers also acknowledged that they know that they often get swindled during the measurement of the tree volume by the contractor as well as by the forest service. The officers of the forest service measure a higher volume in order to become more tax income and the contractor measures a lower volume in order to pay a lower price, while the farmer does not know how to measure. Moreover the prices are already low anyway since a lot of farmers have no good knowledge of the value of their trees. As long as they get a lot of money without investing any labour, it seems to be a good price for the farmer.

Cooperation between farmers in the exploitation and/or the commercialization of forest lacks. According to farmers this is not possible since they cannot trust each other and knowledge of trade and book-keeping fails. Neither is there government support in these matters.

6.6 Farming systems and forest utilization

In several paragraphs reference was made to the relation between the forest cover in research areas and on farms and the development stage of the research area. Development always implied deforestation. Whether the trend of deforestation will continue in this way depends largely on socio-economic conditions. Hulsebosch (1992) already acknowledged that "the distribution of the farm components and especially the tree and forest components are variable and possibly more related to social aspects like off-farm employment or origin than to physical aspects like farm size or soil fertility". In order to influence the farmers' management of the forest component on farms and to come to recommendations on improved forest utilization, patterns have to be distinguished on which farm systems can be arranged in groups or farming systems with equal opportunities (see §4.5); groups of farms with a comparable physical, biological and socio-economic setting and farm households' goals. In case of studying the use of natural forests, the criteria for classification should be factors influencing decisions about these forests. Decisions of farmers on the use of their forest seem to depend on the condition of other components of the farm or on the relative importance of forest for the farm. A farming system classification in four groups on basis of the relative importance of natural forest will be discussed below.

Group A) The first group consists of **small farmers** which have forest as part of a complete farm: annuals, perennials, pasture, forest and off-farm income. These farms show regular activities in the forest; wood production with low as well as medium technology and other forest operations. Also eco-tourism and cultivating ornamental plants were mentioned by this group. The farmers need the forest for its products for the maintenance of the farm and when the forest is of sufficient size, income can be obtained from selling the standing trees to a contractor or by selling some timber to neighbours. However, the moment they loose the off-farm work or the prices of crops and cattle rise, conversion might be seen an easy option by the farmers to maintain or raise the productivity of the farm. The group consists of farms of less than 20 ha, 2 in Río Jiménez and 10 in Neguev.

Group B) This group consists of farmers who may be referred to as **pastoralists**. Cattle is the major activity and since the capacity to extend the area of pasture is present it is likely that those farmers are going to convert a part of their forest, while maintaining a minimum areal for consumptive exploitation. A relatively large part of these farms is still covered with forest. Most of the farmers (8 in Cocorí and 1 in Neguev) do not have a land title and therefore, they cannot make use of the forest legally. One may expect that they will gradually convert their forest to pasture. For the Cocorí farmers this is even more likely since they fear that their forests will be put under total protection when the area is declared to national reserve. These farmers also mentioned that for them pasture has more value than forest. This was also the argument of a large cattle farmer in Río Jiménez to convert his forest to pasture.

Group C) The third group consists of **farmers ignoring their forest** as it is. The owners have their income from coconut or banana plantations, insect gathering or cattle breeding. They need neither land nor income from the forest and thus can think of conservation, exploitation in a far away future or experiments with tree planting or making a management plan. The forest is something they experiment with, depending their general interests. They are medium-sized and large farmers in Cocorí (6) and Río Jiménez (4) with relatively little forest.

Group D) The last group consist of **farms with as principal activity forestry**. The owners, often via a caretaker, exploit the forest for financial gain, pasture is a side activity. Where, in the past, some of these owners moved from farm to farm, exploiting the forest and selling it afterwards to cattle farmers, the trend seems to change because of the scarcity of forest and the rising prices of farms with forest. Confronted with this development, they start with forest exploitation, using a management plan which includes silvicultural treatments, in stead of forest mining. Two farms in Río Jiménez and three in Cocorí with large areas of forest belong to this group.

Table 6.7 Occurrence of farming systems in the research areas (No.); between brackets the share of the total of 40 farmers

	Río Jiménez	Neguev	Cocorí	Total
Group A	2	10		12 (30%)
Group B	1	1	8	10 (25%)
Group C	4		6	10 (25%)
Group D	2		3	5 (13%)
Others			3	3 (7%)

Table 6.7 shows the distribution of the farmers over the different groups in the research areas. For 50% of the farmers the forest is not of major importance, reason why 25% wants to convert it to pasture and the other half leaves it as it is. For 30 % of the farmers the forest is an important part of the farm and for 13% it is the principal land use. The other 7% wants to sell the farm. The figures can also be interpreted that 25% is directed at clearing the forest and that 68% maintains and/or uses the forest for its products as long as another use is not more attractive or necessary.

In relation to the research areas the conclusion can be drawn that in the forest-rich Cocorí-area conversion still is the trend, that in Río Jiménez farmers show little interest in their forests and that in Neguev the farmers work intensively with their forests.

7. NATURAL FOREST ON FARMS

7.1 Introduction

This chapter constitutes of the presentation and analysis of the results of a series of inventories of natural forest stands which form the basis for the selection and description of land mapping units. The inventories were carried out in order to get knowledge of the floristic composition of different forest types and stands in the northern Atlantic Zone of Costa Rica, and their management possibilities and requirements. For this purpose six farm forests were selected on basis of their former utilization and to a lesser degree based on the fertility and drainage class of the soil type (see map 7.1). In one of the forests, a primary forest, two inventories were executed, in a moderate to well drained part and in a poorly drained to swampy part. In total seven plots were investigated on their composition and condition by means of a conventional inventory and diagnostic sampling (see § 5.2). After a description of each forests (§7.2 - 7.6), a discussion of the management options will be given (§7.7).

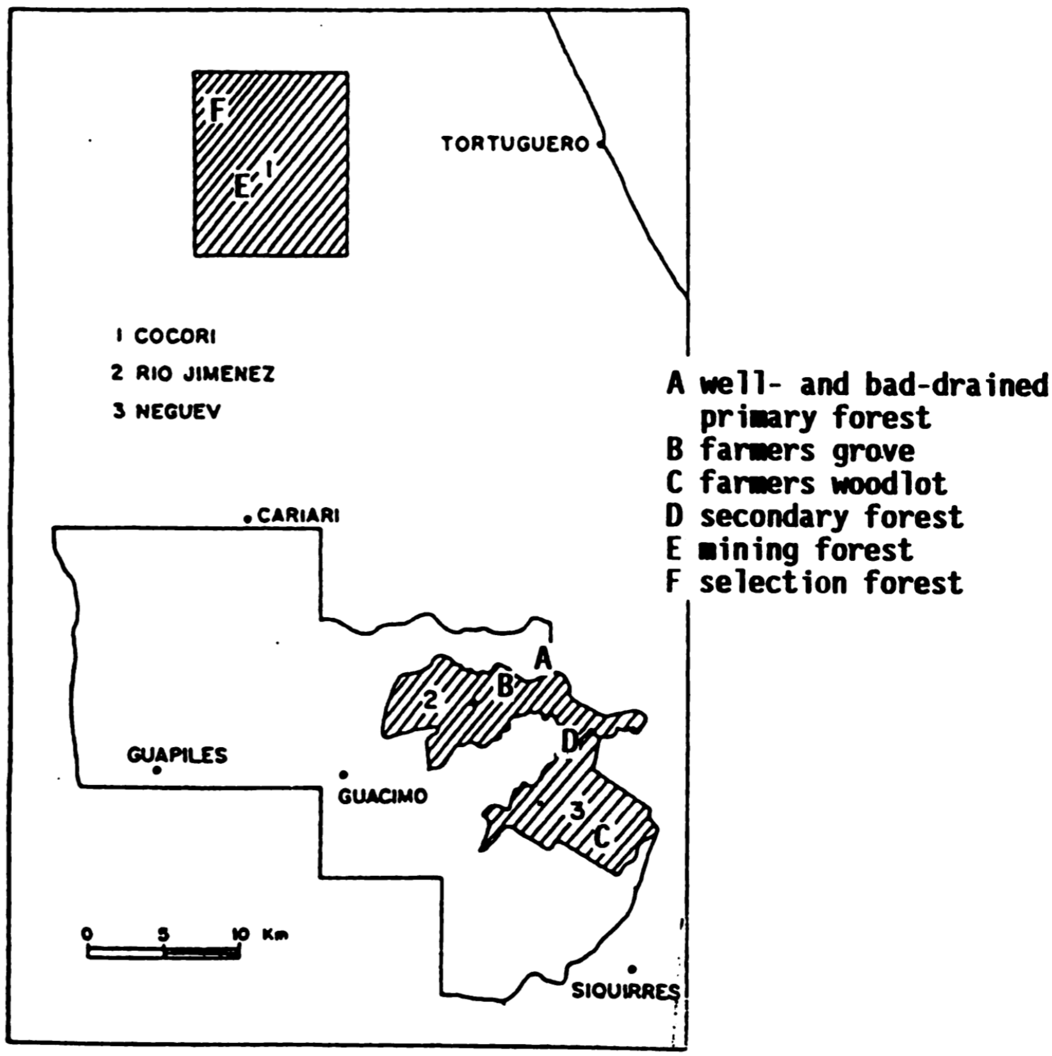
7.2 The primary forest

7.2.1 Site description

The two inventories of 1 ha were executed in a forest of 50 ha on a moderate to **well-drained** and a **poorly-drained** site. The elevation was close to zero and the soils were characterised by the owner as black. The poorly-drained site showed stagnation of water with the water table up to 40 cm and some dry spots.

7.2.2 The composition and condition of the vegetation

Apart from the group of unknown species, in the well-drained part 29 species were identified, 4 commercial desirables (D) and 5 acceptables (A), and in the poorly-drained part 28 species, 9 D and 4 A. Only 18 species appeared in both parts. Appendix VIIIa and VIIIb show the complete species lists of these stands. In both the well-drained and the poorly-drained forest *Pentaclethra macroloba* and *Carapa guianensis* are the most abundant species (table 7.1), although little pronounced. The dominance of the two species (on basis of the basal area) is more pronounced due to their presence in higher diameter classes. However, none of the two forests shows an absolute dominance of one or two species. Only in the poorly-drained stand *Pentaclethra*, with 35% of the basal area can be regarded as such. This species can be seen as the ruling species. The absence of absolute dominance of *Carapa* and *Pentaclethra* is in contrast to swamp forests in the northern Atlantic Zone where over 50% of the basal area consisted of these species (Peralta, pers. comm.) and to observations on hill-sides in the central part of the Atlantic Zone, near Siquirres, where *Carapa* was



Map 7.1 Location of the seven inventoried forest stands in the Atlantic Zone of Costa Rica

dominant and *Pentaclethra* absent. Such deviating patterns were found regularly and demand carefulness in generalizing the results of the inventories.

The basal area (trees ≥ 10 cm dbh) of the well-drained site (table 7.1) is similar to the basal area found by Hartshorn (Manta, 1988) in Sarapiqui and Finegan and Sabogal (1988b) in Río Corinthes, both in the northern Atlantic Zone. The basal area of the poorly-drained stand approaches the figure of 20.6 m^2/ha found in swamp forests in the Talamanca region of the southern Atlantic Zone (Kapp et al., 1991).

The number of stems ≥ 10 cm dbh is 342/ha and 282/ha in respectively the well-drained and poorly-drained part. The diameter distribution as can derived from table 7.1 shows in both forests the shape of an "inverse J" indicating a sufficient regeneration for sustainable management (de Graaf, pers. comm.). The commercial species participate with 35% of the total stem number in the well-drained part and 46% in the poorly-drained part. In the exploitable range ≥ 40 cm dbh the shares are respectively 70% and 77%. These figures are some 15-20 points lower than those given by Finegan and Sabogal (1988b) and Kapp et al. (1991) but still high enough to acknowledge the fact that, at present, most trees growing to saw-log size in the Zone are accepted on the timber market.

Table 7.1 The diameter distribution and basal area of the commercial groups and most dominant species for

The stem quality, crown exposure and lianas infection of the trees of desirable and acceptable species shows, as well in the class of the juvenile trees as in those of the mature trees, better properties in the well-drained forest; less poor illuminated trees, less damaged, deformed or rotten stems and more trees free of lianas (appendix VIIIc). However, both forests have the large part of their juveniles (± 60%) in conditions of poor exposure which, subsequently, will have a sub-optimal growth. The large majority of the trees is infected by lianas, but only with 2% (well-drained part) and 9% (poorly-drained part) of the trees with more than 50% of the crown covered, lianas cause a serious decrease of the growth rate (Finegan and Sabogal, 1988b).

In both forests *Carapa* and *Pentaclethra* take up the main part of the commercial volume of trees over 50 cm dbh (appendix VIIId). This volume is much larger in the well-drained than in the poorly-drained part, respectively 88.6 m^3/ha and 60.5 m^3/ha. *Carapa* takes up the main part of the volume due to its very large diameters and long straight boles.

The total number of leading desirables (LD) per hectare was 94 in both forests. Thus in 6 of the quadrates, no LD was encountered. The list of LD recorded shows a very high dominance of *Carapa* (52%) and to a lesser degree *Pentaclethra* (24%) in the well-drained part, and the same pattern although less pronounced in the poorly-drained part (39% against 33%). Only 6% (well-drained as well as poorly-drained part) of the LD are trees which receive a good quantity of light, class 1-2 (appendix VIIIe)
For the lianas infection (appendix VIIIe) can be noticed that at least 14% (well-drained) and 18% (poorly drained) of the LD should be liberated from lianas in the crown (Hutchinson, 1988a).

7.3 The secondary forest

7.3.1 Site description

The inventory was executed in a forest of 2.5 ha on a well-drained black soil. The slope percentage is 0-10%; the difference in height between the highest and lowest spots in the plot was 7 m. The forest was cleared 20 years ago, with the aim of establishing pasture; some trees of the original vegetation were left over. After the operation, the site was abandoned. The forest lays isolated between pastures and agricultural land. A plot of 0.5 ha was inventoried. The figures in the following analysis refer to 1 ha.

7.3.2 The composition and condition of the vegetation

In this forest 18 species were identified of which 5 commercially desirable (D) and 6 acceptable (A). Appendix IXa shows the complete species list of this stand.

The basal area per ecological group (appendix IXb), shows the dominance of the long-lived light demanding species of rapid growth (mainly *Goethalsia meiantha*) with a 45% of the basal area and the partial shade tolerating species (mainly *Pentaclethra macroloba*) with 43%. In comparison with the results from Sarapiqui in the northwestern Atlantic Zone (Finegan and Sabogal, 1988a), the low abundance of the long-lived light demanders is remarkable. There, the light demanding species made up 73% and 79% of the total basal area after respectively 15 and 25 years. *Goethalsia* and *Pentaclethra* are the most abundant and dominant species (see table 7.2). They take up 75% of the basal area. The abundance of *Pentaclethra* in this stage of development of the forest is, however, not in accordance with its classification as partial shade-tolerant species, nor with the dynamics of the secondary forest described in §3.4.2. But as Finegan (1993) indicated "the" secondary forest does not exist. The composition can differ due to differences in the way the site was cleared, former land use, near vegetation and seed dispersal mechanisms. The history of this stand is not exactly known.

The basal area is already 74% of the average encountered in primary forest. The development of the basal area is in accordance with Finegan and Sabogal (1988a) where 19.9 m^2 and 23.9 m^2 was measured after respectively 15 and 25 years.

The number of stems, 336 per ha, differs considerably from the results of Finegan and Sabogal (1988a). They found a stem number of 931 after 15 years and 677 after 25 years was found. This indicates that the starting point of development of the stand was probably not a completely cleared site. The commercial species as a whole make 83% and 94% of respectively the total stem number and basal area, which makes this type of forest commercially very attractive. The diameter distribution of *Goethalsia* as can be deducted from table 7.2 is neutral, typical for light demanding species, where *Pentaclethra*, considered a shade tolerant species has a more inverted-J shaped tendency, pointing at a species of relative slow growth.

Table 7.2 The diameter distribution and basal area of the commercial groups and most dominant species for the secondary forest, on one ha

	DIAMETER CLASSES (cm)							BASAL AREA (G/m^2)
	10.0 19.9	20.0 29.9	30.0 39.9	40.0 49.9	50.0 59.9	60.0 +	Total	
Total	160	58	62	36	12	8	336	20.8
D spec	48	26	20	22	8	4	128	9.6
A spec	64	28	38	14	4	4	152	10.0
O spec	34	4	4				42	1.0
Palm	14						14	0.3
MOST ABUNDANT SPECIES[1]								
PENTM D	42	22	18	20	6	4	112	8.4
GOETM A	36	28	34	12	2		112	7.3
± 66% of the total stem number							224	15.7

1 Codes of the species correspond respectively with: *Pentaclethra macroloba* and *Goethalsia meiantha*

The crown exposure, stem quality and lianas infection of the individuals of the commercial species is shown in Appendix IXc. In comparison to the primary well-drained forest, the crown exposure is very good, especially for the trees over 40 cm dbh due to the fact that they are even aged. The stem quality (26% damaged), however, matches bad to the primary forest. For the larger diameters this is caused by *Pentaclethra macroloba*, which, in general, shows very bad properties. The lianas infection in secondary forest is almost equal to the primary forest, with 15% of the trees with lianas in the crown.

The commercial volume of trees over 50 cm dbh is made up of 14 trees, together measuring 17.4 m^3 and dominated by *Stryphnodendron microstochym* (49%) and *Pentaclethra* (26%).

The total number of leading desirables per hectare was 86 (appendix IXe). The list of LD recorded shows the absolute dominance of *Virola sebifera* and *V. koschnyi*. Apart from *Pentaclethra* and some *Guarea rhopalocarpa*, no other species were encountered. The development of the species composition seems to have stopped with a vegetation dominated by these four species. Only 24% of the LD are trees, of which 50% has sufficient light (class 1-3). A 62% of the next harvest thus are seedlings and saplings, which are all poor illuminated. The lianas infection is very low, probably due to the dense vegetation in which the regeneration had to grow up.

7.4 The exploited forest; wood extracted with intermediate technology

7.4.1 Site description

In this paragraph two forest stands will be discussed which were exploited with use of intermediate technology for the wood extraction (see §6.4.2). The first case concerns a forest selectively exploited under a management plan, therefore quoted as the "**selection forest**". The second case concerns a forest exploited by a contractor who had the permission to remove all standing value during four years, therefore subjectively quoted as the "**mining forest**".

The selection forest is a parcel of 40 hectares part of a forest of 108 ha. The forest was exploited in the first half of 1991, when 240 trees (200 *Carapa guianensis*) of seven species were cut with a total commercial stem volume of 885 m^3, according to the management plan. The elevation of the parcel is close to zero and the soil was classified as a black soil, with a moderately well drainage.

The mining forest is a parcel of 40 hectares part of a forest of 200 ha. The forest was exploited in 1989. The composition and size of the exploited volume is not known. Part of the inventoried plot was a hill of some 10 meters high and one hill-side, with a slope angle of 15%. The soil was classified as a red soil on the hill and black in the plain parts with a good drainage condition.

In the selection forest a plot of 1.5 ha was inventoried, in the mining forest 1 ha. The figures in the following analysis refer for both forests to 1 ha.

7.4.2 The composition and condition of the vegetation

In the selection forest 53 species were identified, 9 Desirables (D) and 7 Acceptables (A), and in the mining forest 47 species, 9D and 6A. 33 of these species appeared on both sites. Appendix Xa and Xb show the complete species lists of the stands. The number of species is almost twice as big as in the primary forest indicating a difference in forest types. In both forests *Pentaclethra* is the most abundant species but only in the mining forest this is pronounced (23% of the total population). The dominance of *Pentaclethra* in the mining forest is absolute, 49% of the basal area, since none of the large individuals was cut. In comparison to the primary forest *Carapa* has almost become extinct.

The basal area (trees ≥ 10 cm dbh) is 19 m^2/ha on the selection site and 17 m^2/ha on the mining site (see table 7.3). The first figure, however, is somewhat distorted by the occurrence of a left over *Ceiba pentandra*, which alone measured 1.5 m^2. Without this tree both sites show a basal area of ±62% of the basal area of primary forest, although there was 2 years between the exploitation. Consequently the exploitation of the mining forest must have been more severe.

Table 7.3 The diameter distribution and basal area of the commercial groups and most dominant species for the selection (S) and mining (M) forest, both for 1 ha

The number of stems ≥ 10 cm dbh is 295/ha and 336/ha in respectively the selection and mining part, a difference, which can be attributed to the smallest diameter class of 10-19.9 cm (table 7.3). This is probably due to the difference in time since the exploitations. In the mining forest a great part of the regeneration-boom after the exploitation already has reached tree size. For the same reason the stem number in the mining forest is almost equal to the well drained primary forest and in the selection forest this is lower.

From table 7.3 the distribution of the number of individuals per diameter class for the different commercial groups can be obtained.

In the diameter range of juvenile trees ± 30% of the individuals are of commercial species in both forests, where in the exploitable range the shares are 71% and 87% for respectively the selection and mining forest. Except for the last figure all those results are in accordance with the information on primary forest. The high percentage of mature commercial trees in the mining forest is due to the low presence of non-commercial trees in the high diameter class and the high number of *Pentaclethra macroloba* which apparently was not considered of interest at the time of exploitation. The high number of *Pentaclethra* in the lowest diameter class might be because of the growth reaction of the saplings of this species on the increased illumination after the exploitation.

Considering the commercial groups, the composition of these forests thus does not differ significantly from the primary forest. But on species level the share of the commercially most attractive species *Carapa* is alarmingly low and in the mining forest *Pentaclethra* makes up no less than 58% of the individuals of commercial species.

The stem quality, crown exposure and lianas infection of the trees of desirable and acceptable species are shown in Appendix Xc. The selection forest shows a smaller number of trees of commercial species, as well as in the class of the juvenile trees as in those of the mature trees but has considerable better properties for each of the parameters; far less poorly illuminated trees, less damaged or deformed trees and less trees with lianas in the crown. The difference in exposure of the trees might be the result of the difference in time since exploitation; the canopy of the mining forest already has covered up the gaps and thus overshadowing the smaller trees. Where the figures of the selection forest compare good to those of the primary forest, the figures of the mining forest show in every respect a worse sanitary condition.

The commercial volume of trees over 50 cm dbh is shown in Appendix Xd. In the selection forest a cutting limit of 60 cm for *Carapa* was applied and 50 cm for the other species. Furthermore does the left over *Ceiba pentandra* distort the outcome with its 16.5 m^3 and will therefore be excluded in the analysis. Without the *Ceiba*, the selection forest still has the largest volume (40.5 m^3). When an average of 22 m^3/ha was removed, the commercial volume before the harvest was some 80 m^3 which comes close to the 88 m^3 of the primary forest. Following the same way of calculating for the mining forest, some 50 m^3 should have been extracted.

In both forests *Pentaclethra* dominates the commercial volume, but it is clear that this species was exploited in the selection forest. In both forests the next harvest is already present, although represented by only a small number of species in the mining forest.

The lists of LD recorded show the dominance of *Carapa* and *Pentaclethra* in the selection forest contrary to the mining forest where this species is less abundant and the composition of the LD is more diverse; an opposite pattern to that encountered in the conventional inventory.

The total number of leading desirables (LD) per hectare was 89 in the selection forest and 85 in the mining forest. These figures (appendix Xe) are far below those of the primary forest. The situation of the selection forest is classified by Hutchinson (1988a) as a "maturing forest with poorly illuminated regeneration":

- A 64% of the LD-trees are well to acceptably illuminated (class 1-3).
- On 14 + 50 = 64 percent of the area, the next crop can only be represented by seedlings and saplings under deficient illumination (in 55 quadrates)
- A 9 % of the LD having lianas in the crown.

The situation in the mining forest is hardly any different, having less LD, a higher percentage of trees and equally high percentage of bad illuminated and by lianas infected LD.

7.5 The exploited forest; wood extracted with low and intermediate technology

7.5.1 Site description

In this paragraph a forest stand will be discussed, in which the owner cuts frequently (3 trees per year) with low technology and which was exploited by a contractor in 1989 (19 trees) with medium technology. During this occasion a trail for the extraction was constructed, which is still present. Some 18 years before, the forest was already exploited as part of a large cattle farm. Because of its intensive use the forest will be referred to as a "**farmers woodlot**". It concerns a forest of 3.5 ha on a hilly site with a height difference of 15 m and a slope percentage up to 20%. The soil was classified as a red soil. In the middle of the stand is a shallow with water stagnation. The inventoried plot was 0.5 ha in size, crossing the hill, but avoiding the shallow.

7.5.2 The composition and condition of the vegetation

In this forest 30 species were identified, 8 acceptables (A) and 7 desirables (D), an overview of which is given in appendix XIa. None of the species is remarkably abundant. Only *Pentaclethra*, with a share of 22% of the basal area, is relatively dominant. *Carapa* is hardly present, which is in contrast with the other forest stands. The species *Dipteryx panamensis*, *Tabebuia rosea*, *Terminalia amazonia* and *Hieronyma alchorneoides*, which were exploited by the contractor, did not appear in the inventoried plot.

The basal area (trees ≥ 10 cm) is 15.8 m^2/ha, which is 56% of the basal area of primary forest.

The number of stems ≥ 10 cm dbh is 404/ha (table 7.4); much higher than in the well-drained primary forest (342/ha). The difference can be traced, like in the mining forest, in the smallest diameter class of 10-19.9 cm. The commercial species (D+A) participate with 39% of the total number of individuals; a figure which does not differ significantly from the 35% (D+A) of the primary forest and is equal to the figure of the mining forest. In the diameter range of juvenile trees 36% of the individuals are of commercial species and 87% in the exploitable range. These figures seem high in comparison to all other stands, but the absolute number of mature trees is much lower than in the mining and selection forest (30 to respectively 51 and 46).

Table 7.4 The diameter distribution and basal area of the commercial groups and most dominant species for the farmers woodlot, over 1 ha

	DIAMETER CLASSES (cm)							BASAL AREA (G m^2)
	10.0 19.9	20.0 29.9	30.0 39.9	40.0 49.9	50.0 59.9	60.0 +	Total	
Total	268	72	34	12	14	4	404	15.8
D spec	50	28	10	6	6	2	102	5.8
A spec	30	8	8	4	8		58	3.8
O spec	138	36	16	2		2	194	5.4
Palm	50						50	0.8
MOST ABUNDANT SPECIES[1]								
PALM P	50						50	0.8
PENTM D	16	12	2	4	6	2	42	3.4
VIROL D	18	14	2	2			36	1.5
POUTV O	14	6	2			2	24	1.2
± 38% of the total stem number							213	6.9

1 Codes of the species correspond respectively with: Palm, *Pentaclethra macroloba*, *Virola sebifera/V. Koschnyi* and *Pouteria viridis*.

The stem quality, crown exposure and lianas infection of the trees of desirable and acceptable species are shown in Appendix XIb. The low number of trees over 40 cm dbh reflects the rather severe exploitation in 1989. The crown exposure of these trees compares good (8% poor illuminated) to the other inventoried stands but the number of damaged and deformed stems is very high. This can be ascribed again to *Pentaclethra* of which 50% of the trees over 50 cm dbh are damaged or deformed, a form of negative selection. Furthermore, can be noticed the high percentage of the exploitable trees with crowns infected by lianas.

The stand has a low number of commercially interesting trees and a low commercial volume, with only 14.3 m^3/ha in 12 trees (appendix XIc). This is due to the fact that every year some three trees are removed. The low average volume per tree of 1.2 m^3 is the consequence of the low number and quality of trees in higher diameter classes ($\geq$ 60 cm).

The total number of leading desirables (LD) per hectare was only 72 (appendix XId), a very low figure in comparison to the other forest stands, which puts great question marks on the possibilities for future harvests. However, on 38% of the area, the next harvest is represented by LD-trees (10-39.9 cm), of which 42% need liberation; this compares good to the primary forest. It is clear as well, however, that the exposure of the saplings and seedlings is bad. On the other hand, the lianas infection appears to be positive with only 6% of the LD with crown infection. The list of LD recorded shows the abundance of *Virola* and *Pentaclethra* (22%), and a very low share of *Carapa*.

In general, it can be said that this forest is in a bad condition and that at present sustainable exploitation focusing on commercially desirable species is not possible.

7.6 The exploited forest: wood extracted with low technology

7.6.1 Site description

In this paragraph a forest stand will be discussed, in which the owner cuts every year 2 or 3 trees for home consumption. For this reason it will be referred to as the **"farmers grove"**. In the view of its species composition, it is probably a secondary forest, or a forest which was very heavily exploited, at least 15 years ago, before the present owner bought the farm.

The forest measures 0.4 ha and the site is flat and classified by the owner as having a black soil. All trees were measured, as well as the regeneration. The latter was not very abundant since the owner had cleaned the whole understorey. Conversion of the data to a hectare would not be realistic, neither was Diagnostic Sampling.

7.6.2 The composition and condition of the vegetation

In this stand, 24 species were identified, 3D and 5A (appendix XII). *Cordia alliodora*, *Goethalsia meiantha* and *Spondias Mombin* are the most abundant species (see table 7.5). Remarkable is the total absence of *Pentaclethra macroloba* and *Carapa guianensis* in this forest, this affirms the assumption that this forest is secondary. The low numbers of juvenile trees is the result of the repeatedly cleaning of the understorey.

The number of stems > 0 cm dbh and ≥ 1.5 m in height was 179, of which 144 ≥ 10 cm dbh. The commercial species participate with 52% of the total number of individuals. However, in the classes up to 19.9 cm, the group of Other species is dominant.

The forest shows a very low percentage of damaged or deformed commercial trees, a high illumination grade and little lianas infection of the tree crowns. The good stem quality can be ascribed to the abundant *Cordia* with its straight boles. The trees that survived the forest cleaning can grow under optimal circumstances. The circumstances should also be good for the development of the regeneration of commercial species of ecological groups of long-lived light-demanders of rapid (*Simarouba amara, Cedrela mexicana, Cordia alliodora* and

Goethalsia meiantha) and regular growth (*Dendropanax arboreus, Apeiba menbranaceae* and *Hieronyma alchorneoides*) of which the sprouts were already present.

Table 7.5 The diameter distribution and basal area of the commercial groups and most dominant species for the farmers grove, on 0.4 hectare

	DIAMETER CLASSES (cm)							
	0.0 4.9	5.0 9.9	10.0 19.9	20.0 29.9	30.0 39.9	40.0 49.9	50.0 59.9	Total
Total	2	32	66	33	33	12	1	179
D spec	1	1	12	12	20	8		54
A spec	0	6	12	13	6	3		40
O spec	1	25	41	8	7	1	1	85
MOST ABUNDANT SPECIES[1]								
CORDA D	0	1	5	12	19	8		45
GOETM A	0	3	9	12	5	3		32
SPONM O	0	8	11	2	1	1	1	24
±50% No.								101

1 Codes of the species correspond respectively with: *Cordia alliodora, Goethalsia meiantha* and *Spondias mombin*.

7.7 Stand analysis and management options

In table 7.6 the most important characteristics of the forest stands' conditions are summarized. In the following part the differences will be discussed for respectively the primary, exploited and secondary stands, as well as management options. The farmers grove will be treated separately.

THE PRIMARY FOREST

The difference between the well-drained and poorly-drained forest is mainly expressed in the higher tree number, basal area and commercial volume of the well-drained part, and the higher commercial share in the total stock in the poorly-drained part. The commercial share for both forests, however, is low in comparison to other inventories in the Atlantic Zone and improvement treatments are appropriate to raise these shares. For this purpose the higher number of trees and basal area in the well-drained part give more flexibility for silvicultural interventions than in the poorly-drained part.

The number of commercial trees with insufficient illumination and lianas in the crown is somewhat lower in the well-drained forest, but both forests clearly need an improvement of the illumination situation, but this could be combined with a harvesting operation.

The outcome of the diagnostic sampling shows comparable figures for both forests. According to Hutchinson (1988a) the situation is somewhat critical on the two sides; only

40% of the LD are trees. The next crops are for some 60% represented by saplings and seedlings of which only a fifth part receives sufficient light and which are highly susceptible to loss and damage during felling. Liberation thinning and postponement of the harvest operation would be advisable for this situation (Hutchinson, 1988a). The LD belong mostly to *Carapa*. This gives the opportunity to direct silviculture to this species, moreover because it is a partial shade tolerant species that gives a good reaction on treatments which improve the crown exposure. *Pentaclethra* is abundant as well but due to its generally bad stem quality it does not seem wise to select many of them as potential future crop trees.

On basis of the Diagnostic Sampling Hutchinson (1988a) advises as a first treatment poison girdling of large trees ($\geq$ 40 cm dbh) which are non-commercial because of species or defect (21 and 17 trees/ha in respectively the well-drained and poorly drained part) and lianas cutting in order to improve growing conditions. Later, when the saplings and seedlings have grown to trees, a harvest operation can be executed.

The harvest, whether directly or after the above mentioned treatment, should result in the extraction of 5-10 trees (van Bodegom and de Graaf, 1991; Finegan, 1991). For the well-drained forest this could signify the 9 trees over 70 cm dbh, extracting 50 m^3 and reducing the basal area with $\pm$5.4 m^2. Together with the first treatment the basal area should be reduced to 47% of the original basal area. The same calculation should imply for the poorly-drained forest the extraction of 7 trees over 70 cm dbh, or 34 m^3 with an basal area of $\pm$4.2 m^2. Together with the first refinement this would result in a basal area which is $\pm$50% of the primary forest. When a liberation thinning and/or refinement is not executed before the harvest, the operations should be combined for a sufficient reduction of the light competition in the stand. In both calculations the logging damage was not included so a more conservative harvesting operation (extracting less trees) might be advisable. Lianas cutting one or two years before harvesting for instance combined with the first operation could reduce the harvesting damage as well as by means of a good planning of the harvesting operation. In the following years with Diagnostic Sampling the need of new liberation thinning could be determined.

Provisional estimations of Poels (1993) that the growth figures of swamp forest are 30% lower than well-drained forests on the same soil type, together with the significant lower volume, make clear that the productivity of the swamp forest will be considerably lower.

THE EXPLOITED FOREST

In the mining forest and farmers woodlot the commercial share in the diameter class ≥ 40 cm is considerably higher than in the inventoried primary forest, principally represented by *Pentaclethra* which was not exploited in these forests. In the lower diameter classes the commercial shares of the different stands are similar. This indicates that, although, the forest composition of different stands might vary on basis of vegetation type, the commercial potential remains equal.

The inventories show that shortly (2 years in the selection forest) after the exploitation the number of stems is lower than in primary forest, but that already after 4 years, in the mining and farmers woodlot, the regeneration boom has reached the smallest tree-class and that subsequently the number of stems is almost equal or higher than under undisturbed circumstances. Since the commercial share in the smallest diameter class is low a refinement should be appropriate.

In the three forests the basal area ranges between 56-62% of that of primary forest which is equal to the figure above which the light conditions are sub-optimal. This shows the need for a liberation thinning, for instance on basis of the diagnostic sampling, freeing the LD. The figures on the basal area, which express only the result of harvesting, without an improvement treatment, show that the exploitations were severe and that neither the competition position of the commercial species nor the commercial share was purposefully improved.

The percentage of damaged or deformed commercial trees is relatively high in the mining and farmers woodlot due to the, in general, bad quality of *Pentaclethra* individuals. This implies that the high commercial share in the stem number is treacherous due to the bad quality. Also the exposure compares relatively bad in these forests. The favourable exposure in the selection forest is probably a result of the short period since exploitation. Implying that in a few years, the need of a silvicultural treatment might be as high as in the other stands.

The differences in exploitation intensity can be derived from the standing commercial volume. Due to frequent cutting, this volume is very low in the farmers woodlot and comprises for 75% of acceptable species. The mining forest has a lower commercial volume than the selection forest, but for 96% consisting of desirable species. In the selection forest, a next harvest is already present.

Except for the percentage infected with lianas, the diagnostic sampling shows bad characteristics of all three forest stands. A high number of unstocked quadrates, a low number of LDs of tree size and in the mining forest even 70% of those trees being poor illuminated, make that it will take considerable time before these LDs will produce a next harvest and that liberation treatments are necessary to improve the growth rate as well as clearance of the understorey or even artificial regeneration to raise the number of LDs, especially with commercially desirable species. In the farmer's woodlot the number of LD-trees is still good, but careful management, especially of the desirable species, is necessary to provide future crops. Also for these stands, it can be remarked that the selection of *Pentaclethra* as LD is not preferable because of the often bad stem form.

The management of the different stands can be of the same type. Refinement in the understorey is necessary to improve the commercial share in the smaller diameter classes and liberation thinning as well as lianas cutting to improve the exposure conditions. The basal area should be brought between 40 and 60% (12-18 m^2/ha) of that of primary forest (van Bodegom and de Graaf, 1991; Finegan, 1991). An option could be poison girdling of all trees over 30 cm dbh which are not commercially interesting because of species or defect. In the selection forest this would be a reduction of the basal area with 5 m^2/ha to 45% of that of the primary forest and in the mining and farmers woodlot a reduction of 3.5 m^2/ha to respectively 49% and 44%. Depending of the available labour, LD saplings and seedlings could be freed of direct competition as well. The minimum cutting diameter for the refinement should be determined on basis of the necessary grade of reduction of the basal area.

After ten years, a second treatment should be carried out on basis of a inventory. In 20 years a next harvest might be possible (see §3.6.5).

In the case of the farmer's woodlot, the possibility of a future exploitation by, for instance, a contractor seems impossible due to the, at present, low volume, the absence of desirable species and the yearly cuttings, impeding a structural volume increase. In forests of this size a combination of home-consumption and commercial exploitation does not seem possible. When, with silvicultural treatments, the increment of the commercial volume can be raised to 2 m^3/ha/yr this would imply that every time, that a tree of $\pm$ 2 m^3 (50 cm dbh, bole of 10 m) is cut on one hectare, the next commercial harvest will have to be postponed one year. The smaller the forest, the more frequent the set back.

THE SECONDARY FOREST

The data on the secondary forests make clear the great commercial potential of these stands. A 83% of the individuals is of commercial species and this figure does not seem to decrease in the lower classes. Invasion of this stand by other commercial species with a higher value does not seem to take place any more.

Not many management options on secondary forests were found in literature. Clear-cut can be an option in view of the rapid and commercially rich regrowth and the increasing acceptance of smaller diameters by wood processing companies. The system as presented in §3.5.4 could be an option. Cut the 16 trees over 50 cm dbh (10 of commercial value) for a first income and select and liberate future crop trees from competition. In this stand future crop trees should be trees of commercial species like *Goethalsia*, *Pentaclethra* and *Virola*, which, certainly in these concentrations, are commercially interesting. When the final cut can take place is not given in the literature, but should be possible within 10 years considering the fast growth of the mentioned species.

Selective cutting could be an option when cutting down to a diameter of 40 cm, signifying 35 trees with an estimated volume of 40 m^3. Problem is the high number of stems to be cut to get a sufficient volume and the consequent damage to the remaining stand. Furthermore, is the present regeneration is not sufficient, neither in quantity (the low number of LD) nor in quality (lack of LD of desirable species) to provide a good next crop within an economically interesting time span, since the next crop would consist of relatively slow growing shade-tolerant species.

THE FARMERS GROVE

The commercial stock of this stand is heavily dominated by *Cordia* and *Goethalsia*. However, the latter has little use for home-consumption. No information was found in literature on the regeneration of *Cordia* after selective exploitation, thus whether the now followed schedule of cutting, each year 2-3 trees, can be maintained is not clear. The 39 individuals over 20 cm dbh show good possibilities for the near future whenever the cleaning operations will be left undone. Another option is given by Holdridge (1956). He mentions clear-cut as a possibility to come to secondary growth forest consisting of *Cordia* on basis of natural regeneration and a cutting cycle of 25 years with harvest thinning every 5 years from 10 years on, but then the frequent home-consumption cuttings would be impossible, which is the function of the forest at present.

8. DISCUSSION ON IMPROVED FOREST UTILIZATION

The problem to be addressed in this study is the search for possibilities to improve the function of forest within farming systems. As far as the function implies the providence of timber, this implies interference in the forest. To make that the extracted timber is replaced in the forest by new trees of good quality as soon as possible, management systems are a necessity. Such systems are not practised by farmers at present and should be introduced. Just copying a system from another region is not effective; an appropriate system should be based on environmental and socio-economic conditions in which it is be placed. In chapter 6 the socio-economic conditions were described and led to the formulation of farming systems consisting of farmers with similar objectives, possibilities and constraints towards forest utilization. Chapter 7 gave a description of different forest stands and their management needs and options.

In this chapter, first, options for improved forest utilization will be discussed on basis of the present LUTs and the conditions of the forest stands. Second, the suitability of these options for the different farming systems will be reviewed as well as the requirements to be fulfilled.

EXPLOITATION

Improvements in the function of the forest for farmers concern the providence of income and/or products. Two types of objectives of farmers towards the use of forest products were identified: wood exploitation for home consumption and wood exploitation for sale to neighbours or wood processing companies.

Consumptive exploitation and sale to neighbours can be linked to the LUT wood production with low technology whereby labour and capital are provided by the farmer or a neighbour. The farmers did not mention any constraints for this activity except obstructions of legal nature: the obligation of and control on having a felling permit.

Exploitation for sale to wood processing industries can be linked to the LUT wood production with intermediate technology whereby labour and capital are provided by a contractor. Reason of farmers to sell cutting rights to contractors is the easy way income can be obtained without any labour investment. The negative aspects of this procedure according to the farmers were the low prices obtained and the logging damage to the forest. A possible improvement of this type of exploitation could be the execution of a part of the work by the farmer himself or by hiring local labour. In other words the LUT with low technology combined with intermediate technology. Amour (1993) mentions three options for the farmers, determined by the location where the timber is sold to the contractor or wood processing industry: (1) sale on stem, (2) sale of logs at the forest border or a trail accessible for a truck of the forest or (3) sale at the processing plant. The first option could be adapted by selling felled trees. The more labour is invested by the farmer or his labourers the higher can be the negotiated price and also the financial return of the activity (Amour, 1993). Furthermore, the farmer himself will be able to limit the logging damage to the remaining commercial stock and the regeneration capacity of the forest by directing the fall of trees, planning of trails and using lighter machinery for extraction of the wood.

MANAGEMENT

At present silvicultural technology is hardly part of forest utilization on farms in the Atlantic Zone. Chapter 7 showed that different silvicultural operations are possible and necessary. They should be based on sampling. For sampling the conventional inventory and Diagnostic Sampling (DS) are an option. Dependent of the scale of operation a choice from these two methods or a combination can be made. When the forest stand is small or a large stand is divided in smaller units which are treated in different epochs, DS can be applied as a practical method to determine the commercial value of the whole stand and the need for an operation to reduce the competition for LDs. In the same treatment LDs can be selected and marked and be freed of competition from lianas and surrounding non-commercial trees. Such a treatment can be executed once in a few years.

In larger stands a management plan is a legal prerequisite for exploitation and should be based on a conventional inventory determining commercial volume, regeneration and competition level in the stand. On basis of this information the number of harvestable trees can be determined and the need for combining a harvest with a liberation thinning or refinement. After exploitation DS could show its value. LDs can be selected and marked and their liberation requirements can be determined once in a few years. In large stands the conventional inventory will be more suitable since not the whole stand has to be measured. It should be repeated some 2, 10 and 16 years after harvest to measure the competition in the stand as a whole and the need for another refinement or liberation thinning.

The kind of operation that is required depends on the condition of the stand. In primary forest a harvest will be the first operation in combination with a refinement or liberation thinning in order to provide a first income and to domesticate the stand. In exploited stands liberation thinning or refinement is a necessity. This should be based on a conventional inventory but might be a costly operation when it is not followed directly by a harvest. DS in combination with a liberation thinning might be more suitable. The grade of thinning will depend on the scale of operation, where the stand is smaller or where more time is available, also saplings and seedlings can be freed of competition.

In all cases the operations can be executed by the farmer himself. The execution of a conventional inventory and the translation of it to silvicultural operations will probably always require a professional forestry engineer.

MANAGEMENT OPTIONS FOR DIFFERENT FARMING SYSTEMS

As might be clear from the above, the options are still diverse. On the level of this study a more specific description of the options would not be realistic. The difference in farm systems (sizes and composition), even within farming systems, and the difference in forest sizes and conditions do not allow the proposal of standard management. However, the distinction of farming systems makes it possible to distinguish some management options for different groups of farmers.

The group of **small farmers** regularly makes use of the forest and, when familiar with a method like Diagnostic Sampling via an extension program, they will be able to recognize, maintain and use the value of their forest in stead of only extracting the valuable part. This way the forest may become a "real" part of the farm with a higher intrinsic value other than a romanticized and incidently a productive one. This could make the future of the forest less dependent on development of other farm components as happens at present. Exploitation will mainly consist of extracting a few trees for home-consumption or sale to neighbours. Exploitation for sale to wood processing companies as well will not be possible due to the small sizes of the forests. For the farmers with somewhat larger forests (> 3 ha) sale could be an option but then timber for home-consumption has to be obtained from other sources like dispersed trees in the pasture. In that case the options mentioned under the group of pastoralists could be considered.

As a possibility to make the maintenance of forest financially more interesting, two farmers in Neguev suggested that a cooperatively ran, small saw-mill could be an option such that high value timber products like furniture can be sold. A lot of farmers work off-farm on other farms and industries and instead, this kind of "off-farm" work could make them more independent of the other off-farm work, according to these farmers.

The group of **pastoralists** often does not have the legal right to exploit their forest and subsequently do not consider the maintenance of their forest. Investigations of CATIE show that under the present timber prices on the Costarican market, forest exploitation by farmers can compete as an economic activity with cattle breeding (Amour, 1993).

In Cocorí, where a lot of these pastoralists can be found, forests of different farmers are often adjacent and could be brought together under a management plan which contains a harvesting scheme and the necessary silvicultural operations. Farmers could co-operate in the exploitation and management of the forests by dividing the forests in management units and each year treating one of these units. Tools are available as well as in many cases farmers with oxen or even a tractor who are willing to rent out their labour and equipment. Sale of the timber at the forest border or even at the processing plant could be possible. Since these farmers still seem to have the capacity to extend and maintain more pasture, labour could be available as well for forest exploitation and maintenance or even the transfer of labour from cattle breeding to forestry.

Constraints are numerous for such a development. Often these farmers do consider pasture of more value than forest since they lack the legal opportunity to use the forest and the knowledge of prices and species to estimate the value of their forest. There is little knowledge about silviculture, their position towards contractors is weak since they do not know market prices of species in their forest and subsequently the prices obtained are low. Mutual distrust hinders cooperation in order to execute the work as a group. An extension programme on silviculture, marketing and cooperation as well as a flexible attitude of the forest service with regard to the required land title is a necessity to overcome these obstacles.

The group of **farmers ignoring their forest** could be provided with the management possibilities for their forest with the objective of showing them the economic interest of their forest in case other farm income might decline. When they have an exploited stand the methods for improving the value of the stand could be shown. In case of primary forest, the option of a conventional inventory and making a management plan could be shown. This can show them the value of their forest through selective exploitation.

The farms, on which **forestry is the principal activity**, are already under a management plan, but these plans do not take into account other operations than harvesting and artificial regeneration in the trails. The conventional inventory which is part of the plan should be used for planning stand improvement operations which could be done by the forestry engineer who makes up the plan. The advantages of the other silvicultural operations for the productivity of the forest should be shown.

9. CONCLUSIONS AND RECOMMENDATIONS

9.1 Introduction

In this chapter the research questions posed in the introduction of this thesis will be answered. The methods by which the data were obtained will be discussed (§9.2) as well as the conclusions drawn on basis of the data (§9.3). In the last paragraph (§9.4) recommendations will be made on the possibilities to improve the function of forest in farming systems and on further research.

9.2 Suitability of the used methodologies

In this report it has been attempted to describe and analyze the composition and present utilization of forest on farms in the northern Atlantic Zone.

Only within Land Evaluation a procedure for the analysis of forestry activities has been developed: Land Evaluation for forestry (FAO, 1984). Although the procedure acknowledges the strict connections between the forest and the farm system it is part of, it makes in no way clear the consequences this should have for the evaluation of the forest utilization. The methodology of this study, based on two separated, but not independent parts, the description of forest utilization and forest inventories, tried to overcome this problem.

In this report Land Evaluation (LE) and Farming Systems Analysis (FSA) were applied to describe forest utilization. The two methods combined worked out to be useful tools for such a description and the determination of the importance of forests within farm systems.
The key attributes of LE concentrate strongly on forestry specific, technical aspects of LUTs and, therefore, FSA was a necessary tool to facilitate the reconnaissance of the relevance of the LUTs within different farm systems. On basis of this information and the objectives of households towards forest on farms, farming systems could be formulated.

A problem with LE is that the descriptions of the key attributes in literature are little consistent and that different key attributes show overlap and had to be adapted. The LE procedure for forestry (FAO, 1984) was found too vague and did not pay any attention to the relation of forestry with land use in general. In fact, only use was made of the general procedure for land evaluation (FAO, 1976; Beek, 1978).

The replacement of surveys for land qualities by forest mensuration worked out to be useful as far as it concerned recommendations for the management of different forest stands. For a comparison of different stands, a survey of the land qualities affecting forest growth remains necessary since the inventoried stands showed considerable differences in composition.

FSA stresses the importance to base improved land use on the objectives and constraints of farmers and on the integration within the farm system as a whole. In a situation where a certain land use is little pragmatic such a basis is difficult to develop if the formulation of improvements is not coupled with extension to the farmers on the possibilities of the land use under consideration.

Furthermore, any kind of forest use is restricted by law in Costa Rica and reticence of farmers in the supply of information is the logic consequence. In order to obtain the cooperation of farmers the research should be combined with extension on the objectives of the research and the way the results of the research can be beneficial for the farmer. In this study informal interviews were used to overcome the reticent attitude of farmers towards the research; only indirect reference to farmers' activities in the forest could be made during the conversations. The collaboration with a Costarican assistant, acquainted with farmers' way of thinking, working and conversing, was indispensable in this approach. As a result the activities and attitudes of farmers in relation to the forest had to be deducted from the dialogues which makes it impossible to give exact figures.

9.3 Natural forest and its utilization on farms in the northern Atlantic Zone

Natural forest utilization

In the past, agricultural development in the Atlantic Zone has always been coupled to deforestation. This is still visible in the present attitude of farmers towards forest on their farm. The forest is used for the providence of poles and planks for maintenance of the farm house and fences, and cutting rights can be sold to a contractor to obtain an income. But the forest is hardly seen as a basic source of income and products and there is no silvicultural tradition among farmers. As a consequence, the forest is not considered as a productive part of the farm with a need for management; it is there by nature and used as long as it is present. The presence of the forest on most farms depends on other farm components. When labour is available the forest will often be turned into pasture. The same can happen when the income from off-farm labour falls away and extension of the area under pasture is seen as a way to obtain additional or extra income.

The present general trend is that the forest is given a romanticized value by farmers, like the protector of humidity, plants and animals, instead of a productive value. This cannot be seen as a secure base for the maintenance of the forest. Forestry as an economic activity can compete with cattle breeding. There are several reasons why farmers do not recognize this. First, the historical process of development coupled to deforestation; forest never had a value for the farmers. Secondly, the farmers do not know what the actual economic value of the forest is, nor how to determine it or how to use and improve that value. And when they want to make use of their forest they are confronted with legal and bureaucratic obstacles. The easiest option for them is to convert it into pasture and/or sell the cutting rights to a contractor and obtain a sum of money without labour investment.

Natural forest composition
In the northern Atlantic Zone three major types of natural forest stands can be distinguished: primary, exploited (primary) and secondary forest. This classification is from a practical point of view the most suitable in contrast with the distinction of only primary (c.q. untouched) and secondary forest. The regeneration, composition and silvicultural potentials are totally different for exploited (primary) and secondary forest.

Although factors like basal area and commercial stocking are comparable for primary forests on well-drained as well as for those on poorly-drained soils throughout the Zone, the composition of the vegetations is very diverse and compels to inventories on sites with different soil types, drainage, precipitation and inclination. General guidelines for forest management thus can only contain the way of executing forest inventories and how to translate them into silvicultural treatments and should not give a minimum cutting diameter independent of forest condition and species composition.

It became clear, that primary as well as secondary forests show very good properties for production of timber due to the high share of commercial trees in the number of stems. The primary forest could, dependent on soil and drainage, carry a harvesting scheme of 25-50 m^3 every 20-25 years, where the secondary forest considered in this study could yield already 35 trees over 40 cm in diameter, when clear-cut every 20-25 years. The composition of the secondary forests, however, appears very diverse due to differences in seed sources and little is known on regeneration of secondary forest after clear-cut.

The principal difference between the inventoried exploited stands which can be ascribed to the difference in the severity of the exploitations, was the left commercial volume. The regeneration was high in all stands but also showed a need for silvicultural treatments decreasing the light competition in the stands and increasing the commercial share in lower diameter classes. The small differences between the exploited stands could signify that the way of extraction (selective or via the traditional mining) does not matter for the damage to the stand. However, since in literature (van Bodegom and de Graaf, 1989; Finegan, 1991; Hutchinson, 1993) the importance of carefully planned harvesting is stressed to avoid unnecessary damage, it may be assumed that the selective exploitation was, therefore, not selective and controlled enough.

9.4 Recommendations

At present, forestry is not a relevant activity for most farmers, in contrast to livestock. Farmers should be made acquainted with the possibilities of forest management in order to enable them to make a rational choice between, for instance, a forest management and a livestock system or between different forest management systems as the "best" use of their land. An extension program should be started in which the forest is presented as an economical interesting activity and forest as a component of the farm that can be managed like any part of the farm. In a next phase, interested individuals or groups of farmers could be assisted with the development of a silvicultural system adapted to their specific interests and possibilities as discussed in chapter 8. In order to improve the forest utilization, such systems should consist of techniques for forest mensuration, and silvicultural and harvesting operations.

Constraints related to legislation and marketing of forest products should be removed to make forest utilization more attractive and to improve the quality of the practices. The legislation will have to be adapted to the objectives of the government towards forest on farms. When these forests are considered of regional or national importance by the government, their maintenance should be promoted and supported by the same government. Farmers should be provided with technical and financial assistance in order to allow them to obtain a management plan for their forest, procedures to obtain a felling permit should be improved and shortened, and the accomplishment of the management plans should be controlled more regular by the forest service. Furthermore, directives could be given to the farmers, about the market prices of timber and the types of contracts between farmers and contractors, in order to enable them to obtain a greater share in the profits out of wood production.

The introduction of forest management by farmers should be supported by further research. In the first place management systems suitable for farmers have to be developed. Research should focus on simplicity and practicability of silvicultural operations which fit within the possibilities of farming systems. In the second place the possibilities, suggested by farmers, for the production of non-timber forest products like ornamental and medicinal plants and insects should be investigated, as well as the marketing prospects of these products.

In relation to the different forest types and stands in the Atlantic Zone, it was already concluded that there is a large variety in the composition of primary forests and particularly of secondary forests. Research is necessary on the causes of the differences and the implications they have for forest management. In addition, investigations could be executed on the possibilities to improve the wood production of forests by silvicultural operations. The focus should be on correlations between the parameters which determine the condition of a stand such as regeneration, growth, stem quality, crown illumination, crown form and lianas infection of specific tree species or ecological groups and how these can be manipulated to optimize growth with a minimum of intervention. At present, these parameters are recognized in forest inventories but translation to management options is hardly present.

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APPENDIX I: Tree species

Tree species[1]	Family	Local name	Comm.[2]	Ecol.[3]	Sc.[4]
Ampelocera hottlei	Ulmaceae	Frijolón	O	9	Cat
Anacardiun excelsum	Anacardiaceae	Espavel	A	9	Pov
Annona spp.	Annonaceae	Anona	O	9	Arb
Apeiba membranaceae	Tiliaceae	Peine de mico	A	3	Cat
Astronium graveolens	Anacardiaceae	Ron Ron, Jovillo	D	9	Pov
Bactris gasipaes	Palmae	Pejibaye	P	9	Hol
Bixa orellana	Bixaceae	Achiote	O	9	Arb
Brosimum lactescens	Moraceae	Ojoche	O	4	Pov
Calophyllum brasiliense	Guttifereae	Cedro maría, María	D	4	Pov
Carapa guianensis	Meliaceae	Caobilla, Cedro macho	D	4	Pov
Carica cundinamarcensis	Jacaraticia	Papaya de montaña	O	9	Arb
Casearia spp.	Flacourtiaceae		O	2	Cat
Cassia bicapsularis	Caesalpiniaceae	Candelillo	O	9	Hol
Castilla elastica	Moraceae	Caucho, Hule	O	9	Hol
Cecropia spp.	Moraceae	Guarumo	O	1	Cat
Cedrela odorata	Meliaceae	Cedro amargo	D	2	Pov
Cedrela spp.	Meliaceae	Cedro dulce	D	9	Hol
Ceiba pentandra	Bombacaceae	Ceiba	A	9	Pov
Cespedesia macrophylla	Ochnaceae	Tabacón	O	9	Pov
Chimarrhis parviflora	Rubiaceae	Yema huevo, Chimba	A	9	Pov
Chrysophyllum panamensis	Sapotaceae	Caimito	O	9	Hol
Colubrina ovalifolia	Rhamnaceae	Piche de pan	O	9	Cat
Cordia alliodora	Boraginaceae	Laurel	D	9	Pov
Cordia spp.	Boraginaceae		O	9	Cat
Cynometra hemitomophylla	Caesalpiniaceae	Cativo	A	9	Pov
Dendropanax arboreus	Araliaceae	Papa miel, Fósforo	A	3	Pov
Dipteryx panamensis	Papilionaceae	Almendro	D	9	Pov
Eugenia spp.	Myrtaceae	Guayabillo	O	9	Cat

(continued)

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1 Native tree which were found in different forest types in the Atlantic Zone, including secondary and or exploited forest. The list is not exhaustive.

2 Commercial groups: D = Desirable species, A = Acceptable species, O = Other species, and P = Palm.

3 Ecological groups: 1 = short-lived light-demander, 2 = long-lived light-demander of rapid growth, 3 = long-lived light-demader of regular growth, 4 = partial shade-tolerator, and 5 = total shade-tolerator.

4 Source of nomenclature: Arb = Geilfus (1989), Cat = CATIE (undated), Hol = Holdridge and Poveda (1975), Man = Manta Nolasco (1988), Per = Pers. comm. Peralta, Pic = Picado Villalobos (1991), and Pov = Jimenez Madrigal and Poveda Alvarez (1991),

Tree species	Family	Local name	Comm.	Ecol.	Sc.
Eschweilera spp.	Lecythidaceae	Repollito	O	9	Per
Faramea occidentalis	Rubiaceae		O	9	Cat
Ficus werckleana	Moraceae	Chilamate	A	9	Pov
Genipa americana	Rubiaceae	Guaitil	O	9	Pov
Goethalsia meiantha	Tiliaceae	Guácimo blanco	A	2	Pov
Guarea spp.	Meliaceae	Ocora, Cocora, Pocora	O	5	Cat
Guarea rhopalocarpa	Meliaceae	Ocora, Cocora, Pocora	D	5	Pov
Guatteria spp.	Annonaceae		O	9	Cat
Hasseltia floribunda	Flacourtiaceae		O	9	Man
Hasseltia vaganum	Flacourtiaceae		O	9	Man
Heliocarpus spp.	Tiliaceae	Burío	O	2	Hol
Hernandia didymantha	Hernandiaceae	Corcho	O	3	Cat
Hieronyma oblonga	Euphorbiaceae	Pilón	D	3	Pov
Hirtella triandra	Chrysobalanaceae	Campano renose	O	5	Cat
Hymenolobium mesoamericanum	Papilionaceae	Cola de pavo	D	4	Pov
Inga coruscans	Mimosaceae	Guabo colorado	A	4	Pov
Inga spp.	Mimosaceae	Guabo	O	3	Pic
Iriartea gigantea	Palmae	Iriartea	P	9	Hol
Jacaranda copaia	Bignoniaceae	Gallinazo, Jacaranda	A	2	Pov
Jacaratia costaricensis	Caricaceae	Papayillo, Barrilón	O	9	Cat
Lecythis ampla	Lecythidaceae	Jícaro, Olla de mono	D	4	Pov
Licinia platypus	Chrysobalanaceae	Matacansado	O	9	Pov
Lonchocarpus costaricensis	Papilionaceae	Chaperno	O	9	Pov
Lonchocarpus velutinus	Papilionaceae	Comenegro	A	3	Hol
Luehea seemannii	Tiliaceae	Guácimo colorado	O	3	Pov
Manilkara spp.	Sapotaceae	Níspero	A	9	Pov
Maranthes panamensis	Chrysobalanaceae	Campano piedrillo	O	9	Cat
Miconia spp.	Melastomataceae	Lengua de vaca	O	9	Pic
Minquartia guianensis	Olacaceae	Manú negro, Manú	D	5	Pov
Naucleopsis naga	Moraceae	Quina	O	9	Pov
Nectandra nitida	Lauraceae	Quizarrá aguacatillo	O	9	Pov
Nectandra spp.	Lauraceae	Quizarrá	A	4	Pic
Ochroma lagopus	Bombacaceae	Balsa	O	1	Cat
Ocotea spp.	Lauraceae	Aguacatillo	A	4	Pic
Pachira aquatica	Bombacaceae	Pachira	O	9	Hol
Pentaclethra macroloba	Mimosaceae	Gavilán	D	4	Pov
Pourouma bicolor	Cecropiaceae	Chumico	A	3	Pov
Pouteria viridis	Sapotaceae	Zapote	O	4	Pov
Prioria copaifera	Caesalpiniaceae	Cativo	A	9	Pov
Protium glabrum	Burseraceae	Copalillo	O	5	Pov
Protium spp.	Burseraceae	Copalillo	O	9	Pic
Psidium guajava	Mirtaceae	Guayabo	O	9	Arb
Pterocarpus hayesii	Papilionaceae	Paleto	A	3	Man
Pterocarpus officinalis	Papilionaceae	Sangrillo	O	9	Pov
Quararibea asterolepsis	Bombacaceae	Garrocho	O	9	Pov
Quararibea bracteolosa	Bombacaceae	Palanca	O	9	Cat

(continued)

Tree species	Family	Local name	Comm.	Ecol.	Sc.
Rapanoa spp.	Myrsinaceae	Ratonsillo	O	9	Hol
Rollinia pittieri	Annonaceae	Anonillo	A	2	Pov
Sacoglottis trichogyna	Humiriaceae	Campano colorado	D	5	Pov
Simarouba amara	Simaroubaceae	Aceituno	A	2	Pov
Socratea durissima	Palmae	Maquenque	P	9	Hol
Spondias mombin	Anarcardiaceae	Jobo	O	9	Hol
Sterculia apetala	Sterculiaceae	Panamá	O	9	Pov
Stryphnodendron microstachyum	Mimosaceae	Vainillo	A	2	Pov
Tabebuia rosea	Bignoniaceae	Roble sabana	D	9	Pov
Tabernaemontana arborea	Apocynaceae	Huevo caballo	O	9	Cat
Tapirira guianensis	Meliaceae	Sonsapote	A	3	Man
Tapura spp.	Dichapetalaceae	Frijolón	O	9	Cat
Terminalia amazonia	Combretaceae	Roble coral, Amarillón	D	9	Pov
Terminalia oblonga	Combretaceae	Surá	D	9	Pov
Tetragastris tomentosa	Burseraceae	Copalillo	O	3	Cat
Trema interrigima	Ulmaceae	Capulín	O	1	Man
Virola sebifera/V. koschnyi	Myristicaceae	Fruta dorada	D	4	Pov
Vitex cooperii	Verbenaceae	Manú plátano	D	3	Pov
Vochysia ferruginea	Vochysiaceae	Botarrama, Chancho	D	2	Pov
Welfia georgii	Palmae		P	9	Hol
Zanthoxylum insulare	Rutaceae	Lagartillo	O	9	Pov

APPENDIX II : Interview

The interview was conducted among 40 farmers; 11 in Neguev, 9 in Río Jiménez and 20 in Cocorí. Of earlier interview cycles was known that these farmers had forest on their properties. The questionnaire consisted of a structured list of questions. The structure of the questionnaire was as such that questions on exploitation, a sensitive subject due to matters of legislation, were treated at the end of the interview in order to built up some confidence when discussing the forest vegetation and the farmer's objectives or during the informal conversations of the Costarican assistant with the farmer.

The questionnaire is rather formal, with open-ended questions. The interviews, however, were executed via conversations, using the questionnaire as a checklist. If the answers of the farmers did not provide enough information, the farmers were encouraged to go on by formulating the questions more exact or in different ways.

The intention was to visit the farmers' forest during the interviews. This did not work out since in many cases the farmers were working on their farm an it did not seem right to ask for a "few" hours of their time.

<u>Introduction</u> (originally in spanish)
What is the present composition of the farm?

<u>Forest</u>
What is the composition of your forest?

- single plot or several.
- exploited by arrival, when, who.
- tree species and their use.
- what other products than timber can the forest produce; seeds, fruits, seedlings, medicines, fodder, river bank protection, plant/animal protection etc.
- use of products.
- exploitable trees, size, species, quantity.
- failing species fail because of exploitation or other reasons.

<u>Importance and future of forest</u>
What is the importance of the forest for you or your farm?

- other values than timber.
- future use of forest.
- intention to exploit; if not, what happens with old trees.
- who will do what part of exploitation; management plan, roads, harvesting, transportation.
- problems when exploiting; labour, equipment, distances, marketing, roads, legislation, technical assistance.
- ideas to avoid problems; cooperation of farmers.
- future; own forest, forest in region, timber prices, future timber sources.

(continued)

Exploitations

Did you use your forest in the past?

- timber, medicines, posts, seeds?
- if not; why?
- if yes; why, when, by whom, how, what species, quantity, what products, state of regeneration.

Management

Did you execute any kind of management?

- cleaning, removing bad trees, collecting seedlings, other?
- need for forest management.

Activities last year

What activities did you execute last year?

- harvesting, management, collecting plants, medicines, seeds, firewood, etc.
- why; product, income, conversion, future harvest.
- what determined moment of exploitation.

Fallow

Do you have any fallow land on your farm?

- amount, age, species composition, tree sizes.
- former and future use.

Management plan

Do you have a forest inventory, a management plan or a cutting permit?

Conversion

Did you convert a part of your forest in the last years?

- what area, how, purpose.
- soil type and possible use of land under forest.
- need for more land for pasture or crops.
- intending conversion.

Technical assistance

Did you receive any kind of assistance in relation to your forest?

- from whom, experiences.
- need for any kind of information; management, legislation, harvesting, etc.

Do you have any kind of question or observation in general or in relation to this interview?

APPENDIX III : Key Attributes

From § 4.3.2 the key attributes have been mentioned as given by the Guidelines: Land Evaluation for forestry (FAO, 1984). These key attributes are:

1) Outputs;
2) Labour;
3) Capital;
4) Technology;
5) Management;
6) Scale of operations;
7) Markets;
8) Infrastructure requirements;
9) Land improvements.

These key attributes will be discussed here.

1) <u>Outputs</u>
Produce is the most diversified and important key attribute. It determines to a great extent the essence of the other key attributes (Beek, 1978) and of the growth requirements. The outputs consist of **products**, including both timber and non-timber forest products; and **other benefits**, such as conservation and tourism (FAO, 1984). The description of produce should be as precise as possible (Beek, 1978) and quantitative where relevant (FAO, 1984).

2) <u>Labour</u>
Labour is a key attribute closely connected with the level of applied capital and technology, and with the labour requirements of the outputs. Land may differ in its response to labour inputs (Beek, 1978).

Labour is described initially in qualitative terms as high, intermediate or low labour intensity, according to the relative extent of mechanized and manual operations (FAO, 1984). The high, medium and low boundaries of labour intensity, even when expressed in specific numbers, remain indicative (Paap, 1993). Besides, other aspects such as labour productivity, labour absorption and labour substitution are important variables in land use planning (Beek, 1978).

3) <u>Capital</u>
Capital is described qualitatively as high, intermediate or low capital intensity, according to the scale of initial costs for land improvements, infrastructure, road construction, machinery, etc. and establishment costs. Because of the long rotations in forestry and the considerably greater costs of establishment as compared with maintenance, capital requirements are relative more important, as compared with recurrent costs, than in most forms of agriculture (FAO, 1984).

Technically it may be possible to condition virtually any site to satisfy a particular requirement of a land utilization type. However, the extent to which land conditioning

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(continued)

occurs depends in practice on: inherent characteristics of the land conditions, the cost of modifying them in relation to the value of the desired product, and the availability of private and public capital (Beek, 1978).

There is normally an inverse relation between labour and capital intensities, capital-intensive operation requiring skilled labour but in relatively smaller quantities, whilst low-capital intensive land utilization types require a high labour intensity (FAO, 1984).

4) Technology

Technology is the key attribute complementing the factors capital and labour (Beek, 1978). In forestry it is useful to distinguish three groups of practices: silvicultural technology, harvesting technology and measures for the protection and conservation (FAO, 1984).

Silvicultural technology covers the technical operations necessary for forest establishment or regeneration, and maintenance. For natural forests, the corresponding measures to ensure regeneration of desired species are given (FAO, 1984).

Harvesting technology is an area of special techniques that requires separate description. Not only can logging operations have various degrees of mechanization, but this can take many forms (skidding, overhead leads, etc.) each having specific requirements as to terrain conditions. For natural forests, harvesting technology should include the construction of the necessary road network (FAO, 1984).

Protection and conservation technology covers a group of management activities which are necessary in plantation forestry and in both commercial and environmental natural forestry. Fire protection and measures for protection from illegal incursion are widespread requirements (FAO, 1984).

Mechanization and power can be distinguished within each technology. The source of **power** can be four-wheel and crawler tractors, two-wheel and one-wheel power operated, animal power, and hand power (Beek, 1978). **Mechanization** is closely related to power source and is distinguished on basis of the extent of mechanization on the farm: largely, partly or non-mechanized farming (FAO in Paap, 1993).

5) Management

Management is closely related to capital intensity and technology, but also to outputs, the scale of operations and the labour intensity. Management is responsible for the allocation of production factors and the timing of their applications, makes the decisions within the range of possibilities provided by the other key attributes, and is thus to a great measure responsible for the realization of the potential productivity of the land indicated by the land suitability classification. Difference in management competence are found in all social strata and societies (Beek, 1987). Aspects described include the general level of management skill and form of land tenure (FAO, 1984), but in fact needs constant consideration when defining land utilization types, because of its complexity (Beek, 1978).

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6) Scale of operations
The scale of operations poses limits to the size of the land area for which the land evaluation type is relevant (Beek, 1978). It includes the anticipated scale of the total area covered by the land utilization type, the size of the individual management units, and the proposed annual felling unit (FAO, 1984).

7) Markets
Markets refer to the intended destination of produce, and also to the beneficiaries of intangible benefits. Location and distance to primary markets, e,g, sawmills, pulp mills, urban markets, may be given (FAO, 1984).

8) Infrastructure requirements
Infrastructure requirements specify the on- or off-site infrastructure needed for the proposed operation of the land utilization type. Examples are the required capacity of sawmills, and any necessary construction or improvement of roads from the forest to markets (FAO, 1984), but also the presence of and access to nurseries or technical assistance.

9) Land improvements
Land improvements are alterations in the properties of the land which improve its potential for use, e.g. improvement of patty land by construction and maintenance of drainage works (FAO, 1984).

APPENDIX IV : Land Qualities

In § 4.3.3 reference was made to the Land Qualities. The land qualities for forestry will be listed here, together with the characteristics which may be used to estimate the qualities.

LAND QUALITY	LAND CHARACTERISTICS
<u>Estimates of forest volume, growth and yield</u>	
- Present timber volume	By species, from forest inventory
- Predicted timber yield	By species, from forest yield prediction or growth-site correlation: site index
- Seedling survival rate	Recorded average for site types or area as a whole, by species
- Predicted yield of non-timber products	From forest inventory or prediction
<u>Qualities affecting management</u>	
- Terrain factors affecting mechanized operations and internal access	Terrain class; slope angle, relative relief, stream frequency, micro relief, soil bearing capacity, presence of swamps, cracking clays
- Conditions affecting nursery sites	Available water supply, soil texture
- Size of the potential management units	Size of blocks of suitable land
- Location	Distances from earth road, tar road, rail, river; and from sawmills or other markets
<u>Qualities affecting conservation</u>	
- Erosion hazard	Estimated soil loss; slope angle, rainfall erosivity, soil erodability, rainfall intensity, soil permeability, soil texture, vegetation cover; soil type
- Tolerance to vegetation degradation	Observed or estimated; present condition of vegetation, vegetation type
- Presence of valuable plant and animal species	Presence, rarity

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Qualities affecting growth

- Radiation regime	Total radiation, sunshine hours; day length: latitude, climate type
- Temperature regime	Temperature: mean annual, hottest, coldest months; altitude, climatic type
- Moisture availability	rainfall/evaporation ratio, depth to groundwater; rainfall: mean annual, wettest, driest months
- Soil drainage	Soil drainage class, depth to mottling
- Nutrient availability	Mean levels of N, P, K, etc., soil pH; topsoil thickness, soil type
- Rooting conditions	Effective soil depth, soil structure, stones and gravel
- Conditions affecting germination and establishment	Soil texture, gravel, surface sealing or capping
- Salinity/sodicity	
- Other toxicities	
- Climatic hazards: - fire	Observed frequency, length of dry season, rainfall/evaporation ratio, combustibility of ground vegetation
- wind	Frequency/severity of high winds, typhoons
- Physiographic hazards	
- flood	Observed frequency/severity: topographic site
- landslide	Observed frequency/severity; slope angle, rainfall intensity, soil depth, earth quakes
- Incidence of pests and diseases	Observed incidence, relative humidity, temperature, soil factors of known influence

Source: FAO (1984)

APPENDIX V : Checklist Farming Systems

In § 4.4.2 reference was made to the data necessary for the diagnosis of farming systems. Here information needs are related to the farm level and to the subsystem level. The listing is mend to be a 'checklist'.

1) Farm level
- information about the needs/preferences of the households ('consumption side') and the goals of farms ('production side').
- special attention to intra-household decision making with regard to the allocation and use of scarce means ('household economics').
- composition of household, age/sex division.
- availability of money.
- consumption pattern.
- stock of means of production and general allocation/use.

  * land
  - availability of land according to type and quality (parcels, related to land units with land qualities).
  - fragmentation.
  - tenancy arrangements.
  - accessability.
  - use of land per activity: 'cropping pattern'.

  * capital items
  - stock of capital goods like ploughs, tractors, harvest knives, etc.
  - use of capital goods per activity.
  - livestock as a capital input to agricultural activities, e.g. type and number of animals for ploughing.

  * labour
  - availability of household labour according to sex and age.
  - use of labour per activity per period specific according to sex and age and according to categories as household labour, hired labour and exchange labour.
  - use of labour per operation (like ploughing, seeding, harvesting, etc.).

  * management
  - management is the type of labour input which makes decisions about what to produce (which activity), how much and how (which production methods/technology).
  - knowledge, skills and attitudes of decision maker(s).

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2) <u>Subsystem level</u>

1. household activities

* child care
- time allocation by whom.
* collecting water and firewood
- source.
- time allocation by whom.

* cooking
- time allocation by whom.

* artisanal activities
- inputs and outputs.
- time allocation by whom.

2. Off-farm activities

* off-farm/non-farm work
- number of days per year and per periods of year.
- wage labour or exchange labour.
- wages.
- type of employer.
- sector of the economy.

* renting out of land
- how much land.
- income derived.
- tenancy arrangements.

* renting out of capital goods
(e.g. working with oxen-span to plough land of neighbours)
- frequency and time involved.
- payments received and costs incurred.

3. On-farm activities

* general
- general overview: cropping pattern per season and year, rotations, animal husbandry patterns and activities, like for example agroforestry (reminder: on-farm activities are related to land use types with land use requirements in land evaluation).
- results of activities are of two types: outputs)=physical products) and feedbacks.

(continued)

- outputs are mentioned under activities: important is to mention that apart from the outputs which are used directly by the farm household ('subsistence'), apart is sold at 'markets' which provide the farm household with cash to buy inputs and consumer products, and a part is used as capital e.g. young animals to be use d for ploughing.
- feedbacks can be distinguished in socio-economic feedbacks and ecological feedbacks. The result of farming systems do influence community structure, norms, believes, external institutions, policies and programmes and projects. Also the way of farming has its influence on the natural surroundings for example through erosion and deforestation, or land improvements like sawahs.

* crops
- per major crop: inputs, timing of operations, technology, outputs, value of inputs and outputs,gross margins and net returns; part of output for subsistence and for sale; cash/kind character of inputs.
- efficiency measures as gross margin per hectare and gross margin per labour day.
- types and quantity of inputs and outputs, operations, and technology.
- inputs from other activities (e.g. dung for cattle).
- outputs to other activities.

* livestock
- per animal husbandry activity: type of animals, sex and ages, inputs, timing of operations, technology, outputs, value of inputs and outputs, gross margins and net returns; part of output for subsistence and for sale; cash/kind character of inputs.
- efficiency measures as gross margin per hectare and gross margin per labour day.
- types of animals, sex and ages, type and quantity of inputs, operations and technology.
- inputs from other activities.
- outputs to other activities.

Source: Fresco et al. (1989)

APPENDIX VI : Occurrence of activities in forests on farms

Occurrence (No of farmers) of activities in forests on farms in the three research areas

	Río Jiménez	Neguev	Cocorí	Total
no activities	3	2	8	13
medium tech harvesting	1	1	3	5
medium tech + low tech harvesting	1	2	1	4
medium tech + low tech harvest + other operations		3		3
medium tech harvesting + other operations			1	1
low tech harvesting		1	3	4
low tech harvesting + other operations	1	1		2
other operations		1	1	2
conversion	1		2	3
gathering			1	1
others	2			2
TOTAL	9	11	20	40

APPENDIX VII : Classification criteria for: bole quality, crown exposure, crown shape, and lianas infection

CLASSIFICATION OF TREES ACCORDING THE QUALITY OF THE BOLE
(Hutchinson in CATIE, undated)

Code	Definition
1	**Actual commercial:** the major part of the bole is of a size adequate for immediate commercialization. It is sound, straight, has at least four meters length and a DBH of at least 50 cm. May have commercially acceptable knots, but none with a diameter equal or over a third of the diameter on the point where the branch leaves the bole.
2	**Potentially commercial:** the major part of the bole does not have a size adequate for commercialization. However, the stem contains a sound and straight part of at least four meters length which may have a market in the future. The boles in this class are of good quality but still small.
3	**Deformed:** the major part of the stem does not contain four meters with a straight form. Deformed stems include those which are short, crooked, with plank roots, too much branches, or with big knots.
4	**Damaged:** the physical damage does not leave any possibility for industrialization of any bole. The stems of this class are the most abundant in forests which have been exploited recently.
5	**Decayed:** Because of the decay, the stem does not contain a sound and straight part.

CLASSIFICATION OF THE CROWN EXPOSURE
(Dawkins in Lamprecht, 1989)

Code	Definition
1	**Emergent:** Crown in full overhead and lateral light.
2	**Full superior exposure:** Crown in full overhead light, lateral shade.
3	**Some superior exposure:** Crown partially exposed to overhead light, lateral shade.
4	**Lateral exposure:** Crown without overhead light, partial lateral light.
5	**No direct exposure:** Crown shaded on all sides.

(continued)

CLASSIFICATION OF THE CROWN SHAPE
(Synnott in CATIE, undated)

Code	Definition
1	**Full circle:** The crown of the tree is round and symmetric.
2	**Irregular circle:** The crown of the tree is almost ideal, apart from some asymmetry or some dead branches.
3	**Half a circle:** The crown is asymmetric or small but capable to improve when more space is made available.
4	**Less than half a circle:** The tree crown is strongly asymmetric, with few branches and progressive decay. Probably, it will survive.
5	**Only some branches:** Definitive, a tree crown that is degenerated or strongly damaged. Probably, it will not be able to grow.

CLASSIFICATION OF THE LIANAS INFECTION
(CATIE, undated)

Code	Definition
A)	**No lianas visible on the stem:**
1	None visible in the crown.
2	Present in the crown.
3	Covering more than 50% of the crown.
B)	**Lianas loose to the stem:**
4	None visible in the crown.
5	Present in the crown.
6	Covering more than 50% of the crown.
C)	**Lianas wound about the stem:**
7	None visible in the crown.
8	Present in the crown.
9	Covering more than 50% of the crown.

APPENDIX VIIIa : Diameter distribution of species per commercial group in the well-drained forest, on one ha

Botanical species	10-19.9 No. trees	20-29.9 No. trees	30-39.9 No. trees	40-49.9 No. trees	50-59.9 No. trees	60+ No. trees	Total No. trees	G	Comm. Group
	DIAMETER CLASSES IN (cm)/ha								
Apeiba membranaceae	2.0	1.0	0.0	0.0	0.0	0.0	3.0	0.077	A
Goethalsia meiantha	3.0	1.0	0.0	0.0	1.0	1.0	6.0	0.600	A
Nectandra spp.	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.019	A
Ocotea spp.	2.0	0.0	0.0	0.0	0.0	0.0	2.0	0.029	A
Pterocarpus hayesii	0.0	0.0	0.0	0.0	0.0	2.0	2.0	0.785	A
Subtotal	8.0	2.0	0.0	0.0	1.0	3.0	14.0	1.510	
Percentages %	2.3	0.6	0.0	0.0	0.3	0.9	4.1	5.310	
Carapa guianensis	25.0	4.0	1.0	1.0	2.0	10.0	43.0	6.678	D
Guareae rhopalocarpa	3.0	0.0	0.0	0.0	0.0	0.0	3.0	0.039	D
Pentaclethra m.	12.0	10.0	13.0	6.0	5.0	7.0	53.0	6.376	D
Virola s./Virola k.	1.0	1.0	2.0	2.0	1.0	1.0	8.0	1.091	D
Subtotal	41.0	15.0	16.0	9.0	8.0	18.0	107.0	14.184	
Percentages %	12.0	4.4	4.7	2.6	2.3	5.3	31.3	49.886	
Ampelocera hottlei	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.283	O
Brosimum spp.	5.0	1.0	0.0	0.0	0.0	0.0	6.0	0.091	O
Cecropia spp.	4.0	2.0	0.0	0.0	0.0	0.0	6.0	0.156	O
Cespedesia m.	1.0	2.0	0.0	1.0	0.0	0.0	4.0	0.233	O
Genipa americana	11.0	1.0	0.0	0.0	0.0	0.0	12.0	0.237	O
Hernandia didymantha	0.0	0.0	1.0	0.0	1.0	0.0	2.0	0.335	O
Inga spp.	6.0	1.0	1.0	0.0	0.0	1.0	9.0	0.546	O
Jacaratia c.	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.013	O
Licinia platypus	10.0	19.0	2.0	1.0	0.0	0.0	32.0	1.367	O
Lonchocarpus c.	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.010	O
Luehea seemannii	0.0	0.0	0.0	0.0	0.0	3.0	3.0	2.937	O
Maranthes panamensis	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.071	O
Pouteria viridis	2.0	0.0	1.0	0.0	0.0	0.0	3.0	0.092	O
Protium glabrum	4.0	4.0	0.0	0.0	0.0	0.0	8.0	0.239	O
Pterocarpus o.	0.0	2.0	0.0	0.0	1.0	2.0	5.0	1.147	O
Quararibea a.	3.0	2.0	0.0	0.0	2.0	0.0	7.0	0.629	O
Quararibea b.	5.0	0.0	0.0	0.0	0.0	0.0	5.0	0.094	O
Tabernaemontana a.	4.0	0.0	0.0	0.0	0.0	0.0	4.0	0.096	O
Tapura spp.	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.013	O
Tetragastris t.	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.018	O
Unknown	46.0	21.0	9.0	1.0	1.0	2.0	80.0	3.614	O
Subtotal	105.0	55.0	15.0	3.0	5.0	9.0	192.0	12.218	
Percentages %	30.7	16.1	4.4	0.9	1.5	2.6	56.1	42.972	
Palm	25.0	3.0	1.0	0.0	0.0	0.0	29.0	0.521	P
Subtotal	25.0	3.0	1.0	0.0	0.0	0.0	29.0	0.521	
Percentages %	7.3	0.9	0.3	0.0	0.0	0.0	8.5	1.832	
Total	179.0	75.0	32.0	12.0	14.0	30.0	342.0	28.433	
Percentages %	52.3	21.9	9.4	3.5	4.1	8.8	100.0	100.00	

APPENDIX VIIIb : Diameter distribution of species per commercial group in the poorly-drained forest, on one ha

Botanical species	10-19.9 No. trees	20-29.9 No. trees	30-39.9 No. trees	40-49.9 No. trees	50-59.9 No. trees	60+ No. trees	Total No. trees	G	Comm. Group
	DIAMETER CLASSES IN (cm)/ha								
Apeiba membranaceae	0.0	1.0	1.0	2.0	0.0	0.0	4.0	0.398	A
Chimarrhis p.	2.0	1.0	0.0	0.0	0.0	0.0	3.0	0.114	A
Goethalsia meiantha	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.503	A
Rollinia pittieri	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.009	A
Subtotal	3.0	2.0	1.0	2.0	0.0	1.0	9.0	1.024	
Percentages %	1.1	0.7	0.4	0.7	0.0	0.4	3.2	4.792	
Calophyllum b.	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.503	D
Carapa guianensis	16.0	10.0	5.0	1.0	1.0	5.0	38.0	4.469	D
Guareae rhopalocarpa	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.023	D
Hierohyma a.	1.0	0.0	1.0	0.0	0.0	0.0	2.0	0.084	D
Pentaclethra m.	19.0	11.0	15.0	5.0	11.0	7.0	68.0	7.443	D
Sacoglottis t.	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.020	D
Terminalia/Tabebuia	4.0	0.0	0.0	0.0	1.0	0.0	5.0	0.241	D
Virola s./Virola k.	3.0	0.0	0.0	0.0	0.0	0.0	3.0	0.042	D
Vitex cooperii	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.283	D
Subtotal	45.0	21.0	21.0	6.0	13.0	14.0	120.0	13.107	
Percentages %	16.0	7.4	7.4	2.1	4.6	5.0	42.6	61.342	
Ampelocera hottlei	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.008	O
Brosimum spp.	2.0	1.0	0.0	0.0	0.0	0.0	3.0	0.069	O
Castilla elastica	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.049	O
Cecropia spp.	1.0	1.0	0.0	0.0	0.0	0.0	2.0	0.051	O
Cespedesia m.	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.018	O
Colubrina ovalifolia	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.010	O
Genipa americana	10.0	8.0	0.0	0.0	0.0	0.0	18.0	0.479	O
Inga spp.	1.0	0.0	0.0	1.0	1.0	0.0	3.0	0.345	O
Licinia platypus	27.0	9.0	3.0	0.0	0.0	0.0	39.0	1.087	O
Luehea seemannii	4.0	0.0	0.0	0.0	0.0	0.0	4.0	0.060	O
Nectandra nitida	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.011	O
Protium glabrum	5.0	1.0	0.0	0.0	0.0	0.0	6.0	0.138	O
Pterocarpus o.	11.0	6.0	4.0	0.0	2.0	6.0	29.0	3.245	O
Quararibea a.	1.0	1.0	0.0	0.0	0.0	0.0	2.0	0.061	O
Quararibea b.	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.025	O
Unknown	21.0	9.0	4.0	0.0	0.0	1.0	35.0	1.504	O
Subtotal	88.0	37.0	11.0	1.0	3.0	7.0	147.0	7.161	
Percentages %	31.2	13.1	3.9	0.4	1.1	2.5	52.1	33.514	
Palm	6.0	0.0	0.0	0.0	0.0	0.0	6.0	0.076	P
Subtotal	6.0	0.0	0.0	0.0	0.0	0.0	6.0	0.076	
Percentages %	2.1	0.0	0.0	0.0	0.0	0.0	2.1	0.353	
Total	142.0	60.0	33.0	9.0	16.0	22.0	282.0	21.367	
Percentages %	50.4	21.3	11.7	3.2	5.7	7.8	100.0	100.00	

APPENDIX VIIIc : Exposure, stem quality and lianas infection classes of trees of commercial species for the <u>well-drained (W)</u> and the <u>poorly-drained (P)</u> forest

2 the codes between brackets are elaborated in appendix VII

APPENDIX VIIId : Commercial volume of trees with dbh $\geq$ 50 cm on one hectare in the <u>well-drained</u> and <u>poorly-drained</u> forest

COMMERCIAL GROUP/SPECIES	WELL-DRAINED FOREST		POORLY-DRAINED FOREST	
	Trees/ha No.	Comm. volume/ha m^3	Trees/ha No.	Comm. volume/ha m^3
acceptable species				
Goethalsia meiantha	2	3.5	1	3.8
Pterocarpus hayesii	2	3.1		
desirable species				
Calophyllum brasiliense			1	4.4
Carapa guianensis	12	60.3	6	31.5
Pentaclethra macroloba	10	16.7	14	19.1
Virola sebifera/V.koschnyi	2	5.0		
Tabebuia r./Terminalia a.			1	1.7
total	28	88.6	23	61.2

APPENDIX VIIIe : Results of Diagnostic Sampling in the well-drained and poorly-drained forest

Quadrates with LD and the exposure class in the well-drained and poorly-drained forest (%), both on 100 quadrates (= 1 ha)

TYPE OF LEADING DESIRABLE (LD)	WELL-DRAINED FOREST					SWAMP FOREST				
	CROWN EXPOSURE CLASS									
	Good 1+2	Accept. 3	Poor 4+5	Undef.	Total	Good 1+2	Accept. 3	Poor 4+5	Undef.	Total
Tree										
30-39cm dbh	2	6	2	-	10	2	3	4	-	9
20-29cm dbh	-	3	6	-	9	1	5	3	-	9
10-19cm dbh	4	5	15	-	24	3	3	15	-	21
Sapling										
5- 9cm dbh	4	3	12	-	19	6	3	18	-	27
Seedling										
< 5cm dbh	4	1	27	-	32	5	1	22	-	28
Quadrat with none	-	-	-	6	6	-	-	-	6	6
Total	14	18	62	6	100	17	15	62	6	100

Quadrates with LD and the lianas infection class in the well-drained and poorly-drained forest (%), both on 100 quadrates (= 1 ha)

TYPE OF LEADING DESIRABLE (LD)	WELL-DRAINED FOREST				SWAMP FOREST			
	LIANAS INFECTION CLASS							
	Crown	Stem	None	Undef.	Crown	Stem	None	Undef.
Tree								
30-39cm dbh	2	4	4	-	2	4	3	-
20-29cm dbh	3	3	3	-	-	4	5	-
10-19cm dbh	4	10	10	-	7	7	7	-
Sapling								
5- 9cm dbh	3	5	11	-	5	5	17	-
Seedling								
< 5cm dbh	2	7	23	-	4	6	18	-
Quadrat with none	-	-	-	6	-	-	-	6
Total	14	29	51	6	18	26	50	6

APPENDIX IXa : Diameter distribution of species per commercial group per ha in the secondary forest

Botanical species	10-19.9 No. trees	20-29.9 No. trees	30-39.9 No. trees	40-49.9 No. trees	50-59.9 No. trees	60+ No. trees	Total No. trees	G	Comm. Group
	DIAMETER CLASSES IN (cm)/ha								
Dendropanax arboreus	4.0	0.0	0.0	0.0	0.0	0.0	4.0	0.045	A
Goethalsia meiantha	36.0	28.0	34.0	12.0	2.0	0.0	112.0	7.348	A
Jacaranda copaia	2.0	0.0	4.0	0.0	0.0	0.0	6.0	0.302	A
Pourouma bicolor	20.0	0.0	0.0	2.0	0.0	0.0	22.0	0.550	A
Simarouba amara	2.0	0.0	0.0	0.0	0.0	0.0	2.0	0.040	A
Stryphnodendron m.	0.0	0.0	0.0	0.0	2.0	4.0	6.0	1.728	A
Subtotal	64.0	28.0	38.0	14.0	4.0	4.0	152.0	10.013	
Percentages %	19.0	8.3	11.3	4.2	1.2	1.2	45.2	48.110	
Guareae rhopalocarpa	2.0	0.0	0.0	0.0	0.0	0.0	2.0	0.045	D
Hieronyma a.	0.0	0.0	2.0	0.0	2.0	0.0	4.0	0.566	D
Hymenolobium m.	0.0	0.0	0.0	2.0	0.0	0.0	2.0	0.362	D
Pentaclethra m.	42.0	22.0	18.0	20.0	6.0	4.0	112.0	8.400	D
Virola s./Virola k.	4.0	4.0	0.0	0.0	0.0	0.0	8.0	0.211	D
Subtotal	48.0	26.0	20.0	22.0	8.0	4.0	128.0	9.584	
Percentages %	14.3	7.7	6.0	6.5	2.4	1.2	38.1	46.047	
Annona spp.	2.0	0.0	0.0	0.0	0.0	0.0	2.0	0.019	O
Cecropia spp.	4.0	2.0	4.0	0.0	0.0	0.0	10.0	0.518	O
Hasseltia floribunda	6.0	0.0	0.0	0.0	0.0	0.0	6.0	0.088	O
Inga spp.	6.0	0.0	0.0	0.0	0.0	0.0	6.0	0.047	O
Licinia platypus	2.0	0.0	0.0	0.0	0.0	0.0	2.0	0.041	O
Pachira aquatica	0.0	2.0	0.0	0.0	0.0	0.0	2.0	0.063	O
Unknown	14.0	0.0	0.0	0.0	0.0	0.0	14.0	0.185	O
Subtotal	34.0	4.0	4.0	0.0	0.0	0.0	42.0	0.960	
Percentages %	10.1	1.2	1.2	0.0	0.0	0.0	12.5	4.614	
Palm	14.0	0.0	0.0	0.0	0.0	0.0	14.0	0.256	P
Subtotal	14.0	0.0	0.0	0.0	0.0	0.0	14.0	0.256	
Percentages %	4.2	0.0	0.0	0.0	0.0	0.0	4.2	1.229	
Total	160.0	58.0	62.0	36.0	12.0	8.0	336.0	20.814	
Percentages %	47.6	17.3	18.5	10.7	3.6	2.4	100.0	100.00	

APPENDIX IXb : Number of trees and the basal area of the ecological groups per diameter class (dbh in cm) per ha in the secondary forest

Ecological group	10.0 13.9	+40	Total	(%)	G (m^2)	(%)
1 short-lived light demanders	10		10	(2.9)	0.52	(2.4)
2 long-lived light dem. (rapid growth)	106	20	126	(37.5)	9.42	(45.3)
3 long-lived light dem. (regular growth)	32	4	36	(10.7)	1.22	(5.8)
4 partial shade tolerators	90	32	122	(26.4)	8.97	(43.1)
5 total shade tolerators	2		2	(0.6)	0.05	(0.2)
9 Unknown or not-applicable	40		40	(11.9)	0.66	(3.2)
TOTAL	280	56	336	(100.0)	20.8	(100.0)

APPENDIX IXc : Exposure, stem quality and lianas infection classes of trees of commercial species for the secondary forest

	DIAMETER RANGES[1] (cm)		
	10.0-39.9 (224)	>40.0 (56)	>10.0 (280)
CROWN EXPOSURE CLASS[2]			
Good (1+2)	33	89	44
Acceptable (3)	13	11	12
Poor (4+5)	54	-	44
STEM QUALITY CLASS[2]			
Exploitable (1)	-	64	13
Potential exploitable (2)	76	-	61
Damaged or deformed (3-5)	24	36	26
LIANAS INFECTION CLASS[2]			
Free of lianas (1)	44	40	43
Lianas on the stem (4+7)	41	46	42
<50% crown covered (2+5+8)	13	14	14
>50% crown covered (3+6+9)	2	-	1

1 The number of commercial trees per hectare between breackets
2 The codes between brackets are explained in appendix VII.

APPENDIX IXd : Commercial volume of trees with dbh ≥ 50 cm for one ha in the <u>secondary</u> forest

COMMERCIAL GROUP/SPECIES	SECONDARY FOREST	
	Trees/ha No.	Comm. volume/ha m^3
acceptable species		
Goethalsia meiantha	2	1.4
Stryphnodendron microstochyum	6	8.4
desirable species		
Hieronyma alchorneoides	2	2.8
Pentaclethra macroloba	4	4.6
total	14	17.4

APPENDIX IXe : Results of Diagnostic Sampling in the <u>secondary</u> forest

Quadrates with LD and the exposure and the lianas infection class in the secondary forest (%), on 50 quadrates (= 0.5 ha)

TYPE OF LEADING DESIRABLE (LD)	CROWN EXPOSURE CLASS					LIANAS INFECTION CLASS			
	Good 1+2	Accept. 3	Poor 4+5	Undef.	Total	Crown	Stem	None	Undef.
Tree									
30-39cm dbh	2	2	-	-	4	-	-	4	-
20-29cm dbh	8	-	6	-	14	2	4	8	-
10-19cm dbh	-	-	6	-	6	-	2	4	-
Sapling									
5- 9cm dbh	-	-	12	-	12	-	2	10	-
Seedling									
< 5cm dbh	-	-	50	-	50	2	4	44	-
Quadrat with none	-	-	-	14	14	-	-	-	14
Total	10	2	74	14	100	4	12	70	14

APPENDIX Xa : Diameter distribution of species per commercial group in the selection forest, on one ha

Botanical species	10-19.9 No. trees	20-29.9 No. trees	30-39.9 No. trees	40-49.9 No. trees	50-59.9 No. trees	60+ No. trees	Total No. trees	G	Comm. Group
	DIAMETER CLASSES IN (cm)/ha								
Apeiba membranaceae	2.0	0.7	0.0	0.0	1.4	1.4	5.4	1.341	A
Ceiba pentandra	0.0	0.0	0.0	0.0	0.0	0.7	0.7	1.534	A
Chimarrhis p.	2.0	0.7	0.0	0.0	0.7	0.0	3.4	0.201	A
Dendropanax arboreus	2.0	0.0	0.7	0.0	0.0	0.0	2.7	0.075	A
Pterocarpus hayesii	1.4	1.4	0.0	1.4	2.0	0.7	6.8	0.898	A
Stryphnodendron m.	0.0	0.0	0.0	0.0	0.7	0.0	0.7	0.133	A
Tapirira guianensis	0.7	0.0	0.0	0.0	0.0	0.0	0.7	0.015	A
Subtotal	8.1	2.7	0.7	1.4	4.7	2.7	20.3	4.196	
Percentages %	2.7	0.9	0.2	0.5	1.6	0.9	6.9	21.987	
Carapa guianensis	8.8	1.4	4.7	1.4	1.4	2.0	19.6	1.621	D
Dipteryx panamensis	0.7	0.0	0.0	0.7	0.7	0.0	2.0	0.296	D
Guareae rhopalocarpa	0.0	0.0	0.7	0.0	0.7	0.0	1.4	0.187	D
Hieronyma a.	1.4	0.7	0.0	0.0	0.0	0.0	2.0	0.052	D
Minquartia q.	0.7	0.0	0.7	0.0	0.0	0.0	1.4	0.070	D
Pentaclethra m.	14.2	8.8	8.1	4.7	8.1	4.1	48.0	4.954	D
Sacoglottis t.	0.7	0.7	0.0	0.0	0.0	0.0	1.4	0.041	D
Virola s./Virola k.	4.7	2.7	0.0	0.7	0.0	0.0	8.1	0.253	D
Vitex cooperii	0.0	0.7	1.4	0.7	0.7	0.7	4.1	0.580	D
Subtotal	31.1	14.9	15.5	8.1	11.5	6.8	87.8	8.054	
Percentages %	10.5	5.0	5.3	2.7	3.9	2.3	29.7	42.202	
Ampelocera hottlei	0.0	0.0	0.0	0.0	0.7	0.0	0.7	0.161	O
Brosimum spp.	0.7	0.0	0.0	0.0	0.0	0.0	0.7	0.010	O
Carica c.	2.0	0.0	0.0	0.0	0.0	0.0	2.0	0.022	O
Casearia spp.	0.7	0.0	0.0	0.0	0.0	0.0	0.7	0.005	O
Castilla elastica	0.0	0.7	0.0	0.0	0.7	0.0	1.4	0.154	O
Cecropia spp.	2.7	0.7	0.0	0.0	0.0	0.0	3.4	0.051	O
Cespedesia m.	2.0	0.0	0.0	0.0	0.0	0.0	2.0	0.017	O
Chimarrhis p.	3.4	0.7	0.0	0.0	0.0	0.0	4.1	0.067	O
Chrysophyllum o.	0.7	0.0	0.0	0.7	0.0	0.0	1.4	0.097	O
Colubrina ovalifolia	3.4	0.0	0.0	0.0	0.0	0.0	3.4	0.045	O
Eschweilera spp.	2.0	0.0	0.0	0.7	0.7	0.0	3.4	0.280	O
Faramea occidentalis	0.7	0.0	0.0	0.0	0.0	0.0	0.7	0.008	O
Genipa americana	10.1	4.1	0.7	0.7	0.0	0.0	15.5	0.407	O
Gomilla	0.7	0.0	0.0	0.0	0.0	0.0	0.7	0.012	O
Guarea spp.	0.7	0.0	0.0	0.7	0.0	0.0	1.4	0.090	O
Guatteria spp.	0.7	0.0	0.0	0.0	0.0	0.0	0.7	0.015	O
Hasseltia vaganum	0.0	0.0	0.0	0.7	0.0	0.0	0.7	0.085	O
Hernandia didymantha	0.0	0.0	0.0	0.7	0.0	0.0	0.7	0.085	O
Hirtella triandra	0.0	0.7	0.0	0.0	0.0	0.0	0.7	0.031	O
Inga spp.	4.7	2.0	0.0	0.7	0.0	0.7	8.1	0.483	O
Licinia platypus	0.0	2.0	0.0	0.0	0.0	0.0	2.0	0.089	O
Lonchocarpus c.	0.0	0.0	0.7	0.0	0.0	0.0	0.7	0.048	O

(continued)

Maranthes panamensis	1.4	0.0	1.4	0.0	0.0	0.0	2.7	0.139	O
Naucleopsis naga	0.0	0.0	0.0	0.7	0.0	0.0	0.7	0.094	O
Ochroma lagopus	6.1	0.0	0.0	0.0	0.0	0.0	6.1	0.056	O
Pachira aquatica	1.4	1.4	0.0	0.0	0.0	0.0	2.7	0.078	O
Pejibayo chimp.	0.7	0.0	0.0	0.0	0.0	0.0	0.7	0.005	O
Pouteria viridis	3.4	0.7	1.4	0.0	0.0	0.0	5.4	0.185	O
Protium glabrum	1.4	0.7	0.0	0.0	0.0	0.0	2.0	0.050	O
Pterocarpus o.	4.1	2.0	1.4	0.7	2.0	0.0	10.1	0.714	O
Quararibea b.	2.7	0.0	0.0	0.0	0.0	0.0	2.7	0.036	O
Rapanoa spp.	16.2	2.0	0.0	0.0	0.0	0.0	18.2	0.286	O
Spondias mombin	0.0	0.7	0.0	0.0	0.0	0.0	0.7	0.026	O
Sterculia apetala	0.0	0.0	0.7	0.0	0.0	0.0	0.7	0.061	O
Tetragastris t.	0.7	0.0	0.0	0.0	0.0	0.0	0.7	0.012	O
Unknown	23.0	10.1	8.1	2.0	2.0	0.7	45.9	2.161	O
Uña de gatto	0.7	0.0	0.0	0.0	0.0	0.0	0.7	0.005	O
Subtotal	96.6	28.4	14.2	8.1	6.1	1.4	154.7	6.171	
Percentages %	32.7	9.6	4.8	2.7	2.1	0.5	52.4	32.335	
Palm	27.7	4.7	0.0	0.0	0.0	0.0	32.4	0.663	P
Subtotal	27.7	4.7	0.0	0.0	0.0	0.0	32.4	0.663	
Percentages %	9.4	1.6	0.0	0.0	0.0	0.0	11.0	3.475	
Total	163.5	50.7	30.4	17.6	22.3	10.8	295.3	19.085	
Percentages %	55.4	17.2	10.3	5.9	7.6	3.7	100.0	100.00	

APPENDIX Xb : Diameter distribution of species per commercial group in the <u>mining</u> forest, on one ha

Botanical species	10-19.9 No. trees	20-29.9 No. trees	30-39.9 No. trees	40-49.9 No. trees	50-59.9 No. trees	60+ No. trees	Total No. trees	G	Comm. Group
	DIAMETER CLASSES IN (cm)/ha								
Apeiba membranaceae	0.0	1.0	0.0	1.0	0.0	0.0	2.0	0.190	A
Dendropanax arboreus	1.0	3.0	0.0	0.0	0.0	0.0	4.0	0.192	A
Goethalsia meiantha	2.0	0.0	0.0	1.0	0.0	0.0	3.0	0.193	A
Ocotea spp.	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.010	A
Pterocarpus hayesii	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.008	A
Simarouba amara	0.0	1.0	0.0	0.0	1.0	0.0	2.0	0.238	A
Subtotal	5.0	5.0	0.0	2.0	1.0	0.0	13.0	0.831	
Percentages %	1.5	1.5	0.0	0.6	0.3	0.0	3.9	4.773	
Carapa guianensis	5.0	2.0	0.0	2.0	1.0	2.0	12.0	1.463	D
Guareae rhopalocarpa	6.0	1.0	1.0	0.0	0.0	0.0	8.0	0.209	D
Hieronyma a.	0.0	0.0	0.0	0.0	1.0	0.0	1.0	0.196	D
Lecythis ampla	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.038	D
Minquartia g.	0.0	0.0	0.0	1.0	0.0	0.0	1.0	0.126	D
Pentaclethra m.	26.0	12.0	10.0	11.0	9.0	8.0	76.0	8.541	D
Sacoglottis t.	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.025	D
Terminalia/Tabebuia	2.0	2.0	3.0	0.0	0.0	2.0	9.0	0.900	D
Virola s./Virola k.	6.0	1.0	0.0	0.0	0.0	0.0	7.0	0.109	D
Vitex cooperii	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.023	D
Subtotal	47.0	19.0	14.0	14.0	11.0	12.0	117.0	11.630	
Percentages %	14.0	5.7	4.2	4.2	3.3	3.6	34.8	66.803	
Ampelocera hottlei	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.008	O
Brosimum spp.	0.0	1.0	1.0	0.0	0.0	0.0	2.0	0.120	O
Casearia spp.	5.0	1.0	0.0	0.0	0.0	0.0	6.0	0.081	O
Castillo elastica	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.012	O
Cespedesia m.	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.008	O
Chimarrhis p.	2.0	0.0	0.0	0.0	0.0	0.0	2.0	0.031	O
Colubrina ovalifolia	2.0	0.0	0.0	0.0	0.0	0.0	2.0	0.026	O
Cordia spp.	2.0	0.0	0.0	0.0	0.0	0.0	2.0	0.019	O
Eschweilera spp.	7.0	1.0	0.0	0.0	0.0	0.0	8.0	0.174	O
Eugenia spp.	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.017	O
Faramea occidentalis	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.023	O
Genipa americana	1.0	0.0	1.0	0.0	0.0	0.0	2.0	0.098	O
Guatteria spp.	6.0	0.0	0.0	0.0	0.0	0.0	6.0	0.058	O
Heliocarpus spp.	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.031	O
Hernandia didymantha	4.0	0.0	0.0	0.0	0.0	0.0	4.0	0.070	O
Inga spp.	5.0	3.0	0.0	0.0	0.0	0.0	8.0	0.200	O
Jacaratia c.	2.0	0.0	0.0	0.0	0.0	0.0	2.0	0.031	O
Licinia platypus	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.035	O
Lonchocarpus c.	4.0	0.0	0.0	0.0	0.0	0.0	4.0	0.046	O
Maranthes panamensis	2.0	2.0	0.0	0.0	0.0	0.0	4.0	0.130	O
Miconia spp.	1.0	0.0	0.0	0.0	0.0	0.0	1.0	0.011	O

(continued)

Naucleopsis naga	3.0	2.0	0.0	0.0	0.0	0.0	5.0	0.120	O
Nectandra nitida	2.0	0.0	0.0	0.0	0.0	0.0	2.0	0.036	O
Ochroma lagopus	7.0	0.0	0.0	0.0	0.0	0.0	7.0	0.078	O
Pouteria viridis	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.042	O
Pterocarpus o.	1.0	0.0	0.0	2.0	0.0	0.0	3.0	0.390	O
Quararibea b.	15.0	0.0	0.0	0.0	0.0	0.0	15.0	0.142	O
Rapanoa spp.	7.0	3.0	0.0	0.0	0.0	0.0	10.0	0.182	O
Tabernaemontana a.	0.0	0.0	1.0	0.0	0.0	0.0	1.0	0.080	O
Trema interrigima	9.0	3.0	0.0	0.0	0.0	0.0	12.0	0.247	O
Unknown	53.0	6.0	4.0	2.0	2.0	0.0	67.0	2.105	O
Subtotal	145.0	25.0	7.0	4.0	2.0	0.0	183.0	4.652	
Percentages %	43.2	7.4	2.1	1.2	0.6	0.0	54.5	26.719	
Palm	23.0	0.0	0.0	0.0	0.0	0.0	23.0	0.297	P
Subtotal	23.0	0.0	0.0	0.0	0.0	0.0	23.0	0.297	
Percentages %	6.8	0.0	0.0	0.0	0.0	0.0	6.8	1.704	
Total	220.0	49.0	21.0	20.0	14.0	12.0	336.0	17.409	
Percentages %	65.5	14.6	6.3	6.0	4.2	3.6	100.0	100.00	

APPENDIX Xc : Exposure, stem quality and lianas infection classes of trees of commercial species for the selection (S) and the mining (M) forest

2 the codes between brackets are elaborated in appendix VII

APPENDIX Xd : Commercial volume of trees with dbh ≥ 50 cm on one hectare in the selection and mining forest

COMMERCIAL GROUP/SPECIES	SELECTION FOREST		MINING FOREST	
	Trees/ha No.	Comm. volume/ha m^3	Trees/ha No.	Comm. volume/ha m^3
acceptable species				
Apeiba menbranaceae	2.7	9.6		
Ceiba pentandra	0.7	16.5		
Chimarrhis parviflora	0.7	0.8		
Pterocarpus hayesii	2.7	3.9		
Simarouba amara			1	1.4
Stryphnodendronm.	0.7	1.0		
desirable species				
Carapa guianensis	3.4	8.0	3	7.5
Dypteryx panamensis	0.7	1.2		
Guarea rhopalocarpo	0.7	1.0		
Pentaclethra macroloba	12.2	13.4	11	18.0
Tabebuia r./Terminalia a.			2	4.9
Vitex cooperii	1.4	1.4		
total	25.9	57.0	17	31.8

APPENDIX Xe : Results of Diagnostic Sampling in the <u>selection</u> and <u>mining</u> forest

Quadrates with LD and the exposure class in the selection and mining forest (%), on resp. 148 and 100 quadrates (resp. 1.48 and 1 ha)

TYPE OF LEADING DESIRABLE (LD)	SELECTION FOREST					MINING FOREST				
	CROWN EXPOSURE CLASS									
	Good 1+2	Accept. 3	Poor 4+5	Undef.	Total	Good 1+2	Accept. 3	Poor 4+5	Undef.	Total
Tree										
30-39cm dbh	3	3	1	-	7	4	-	-	-	4
20-29cm dbh	3	2	2	-	7	2	2	8	-	12
10-19cm dbh	2	3	6	-	11	1	-	13	-	14
Sapling										
5- 9cm dbh	-	3	11	-	14	-	-	10	-	10
Seedling										
< 5cm dbh	3	3	44	-	50	-	1	34	-	35
Quadrat with none	11	14	64	11	11	-	-	-	15	15
Total	11	14	64	11	100	7	3	65	15	100

Quadrates with LD and the lianas infection class in the selection and mining forest (%), on resp. 148 and 100 quadrates (resp. 1.48 and 1 ha)

TYPE OF LEADING DESIRABLE (LD)	SELECTION FOREST				MINING FOREST			
	LIANAS INFECTION CLASS							
	Crown	Stem	None	Undef.	Crown	Stem	None	Undef.
Tree								
30-39cm dbh	2	5	-	-	-	-	4	-
20-29cm dbh	1	3	3	-	2	5	5	-
10-19cm dbh	1	8	2	-	6	11	7	-
Sapling								
5- 9cm dbh	4	3	7	-	2	3	5	-
Seedling								
< 5cm dbh	1	4	45	-	1	2	32	-
Quadrat with none	-	-	-	11	-	-	-	15
Total	9	23	57	11	11	21	53	15

APPENDIX XIa : Diameter distribution of species per commercial group in the <u>farmers woodlot</u>, on one ha

Botanical species	10-19.9 No. trees	20-29.9 No. trees	30-39.9 No. trees	40-49.9 No. trees	50-59.9 No. trees	60+ No. trees	Total No. trees	G	Comm. Group
	DIAMETER CLASSES IN (cm)/ha								
Apeiba menbranaceae	2.0	0.0	0.0	2.0	2.0	0.0	6.0	0.660	A
Dendropanax arboreus	12.0	4.0	2.0	2.0	2.0	0.0	22.0	1.235	A
Goethalsia meiantha	0.0	0.0	2.0	0.0	0.0	0.0	2.0	0.209	A
Inga coruscans	0.0	0.0	0.0	0.0	2.0	0.0	2.0	0.410	A
Lonchocarpus v.	8.0	0.0	0.0	0.0	0.0	0.0	8.0	0.110	A
Ocotea spp.	6.0	4.0	2.0	0.0	0.0	0.0	12.0	0.487	A
Simarouba amara	2.0	0.0	0.0	0.0	2.0	0.0	4.0	0.426	A
Tapirira guianensis	0.0	0.0	2.0	0.0	0.0	0.0	2.0	0.227	A
Subtotal	30.0	8.0	8.0	4.0	8.0	0.0	58.0	3.765	
Percentages %	7.4	2.0	2.0	1.0	2.0	0.0	14.4	23.863	
Carapa guianensis	4.0	0.0	0.0	0.0	0.0	0.0	4.0	0.042	D
Guareae rhopalocarpa	8.0	2.0	2.0	0.0	0.0	0.0	12.0	0.419	D
Hymenolobium m.	2.0	0.0	0.0	0.0	0.0	0.0	2.0	0.033	D
Lecythis ampla	2.0	0.0	2.0	0.0	0.0	0.0	4.0	0.166	D
Pentaclethra m.	16.0	12.0	2.0	4.0	6.0	2.0	42.0	3.438	D
Virola s./Virola k.	18.0	14.0	2.0	2.0	0.0	0.0	36.0	1.494	D
Vitex cooperii	0.0	0.0	2.0	0.0	0.0	0.0	2.0	0.227	D
Subtotal	50.0	28.0	10.0	6.0	6.0	2.0	102.0	5.820	
Percentages %	12.4	6.9	2.5	1.5	1.5	0.5	25.2	36.886	
Brosimum spp.	2.0	0.0	0.0	0.0	0.0	0.0	2.0	0.019	O
Casearia spp.	8.0	0.0	2.0	0.0	0.0	0.0	10.0	0.243	O
Cecropia spp.	2.0	2.0	0.0	0.0	0.0	0.0	4.0	0.084	O
Cespedesia m.	2.0	0.0	0.0	0.0	0.0	0.0	2.0	0.016	O
Faramea occidentalis	2.0	0.0	0.0	0.0	0.0	0.0	2.0	0.016	O
Guarea spp.	2.0	0.0	0.0	0.0	0.0	0.0	2.0	0.023	O
Heliocarpus spp.	2.0	0.0	0.0	0.0	0.0	0.0	2.0	0.051	O
Inga spp.	14.0	2.0	6.0	0.0	0.0	0.0	22.0	0.795	O
Naucleopsis naga	4.0	4.0	0.0	0.0	0.0	0.0	8.0	0.217	O
Nectandra nitida	6.0	2.0	0.0	0.0	0.0	0.0	8.0	0.157	O
Pouteria viridis	14.0	6.0	2.0	0.0	0.0	2.0	24.0	1.181	O
Protium glabrum	4.0	10.0	2.0	0.0	0.0	0.0	16.0	0.644	O
Protium spp.	2.0	0.0	0.0	2.0	0.0	0.0	4.0	0.308	O
Rapanoa spp.	4.0	0.0	0.0	0.0	0.0	0.0	4.0	0.091	O
Unknown	70.0	10.0	4.0	0.0	0.0	0.0	84.0	1.546	O
Subtotal	138.0	36.0	16.0	2.0	0.0	2.0	194.0	5.390	
Percentages %	34.2	8.9	4.0	0.5	0.0	0.5	48.0	34.164	
Palm	50.0	0.0	0.0	0.0	0.0	0.0	50.0	0.803	P
Subtotal	50.0	0.0	0.0	0.0	0.0	0.0	50.0	0.803	
Percentages %	12.4	0.0	0.0	0.0	0.0	0.0	12.4	5.087	
Total	268.0	72.0	34.0	12.0	14.0	4.0	404.0	15.778	
Percentages %	66.3	17.8	8.4	3.0	3.5	1.0	100.0	100.00	

APPENDIX XIb : Exposure, stem quality and lianas infection classes of trees of commercial species for the farmers woodlot

	DIAMETER RANGES (cm)[1]		
	10.0-39.9 (134)	>40.0 (26)	>10.0 (160)
CROWN EXPOSURE CLASS[2]			
Good (1+2)	31	84	40
Acceptable (3)	16	8	15
Poor (4+5)	53	8	45
STEM QUALITY CLASS[2]			
Exploitable (1)	-	69	11
Potential exploitable (2)	79	-	66
Damaged or deformed (3-5)	21	31	23
LIANAS INFECTION CLASS[2]			
Free of lianas (1)	58	31	53
Lianas on the stem (4+7)	25	38	28
<50% crown covered (2+5+8)	9	31	13
>50% crown covered (3+6+9)	8	-	6

1 the number of trees of commercial species per hectare between brackets
2 the codes between brackets are elaborated in appendix VII

APPENDIX XIc : Commercial volume of trees with dbh ≥ 50 cm on one hectare in the farmers woodlot

COMMERCIAL GROUP/SPECIES	FARMERS WOODLOT	
	Trees/ha No.	Comm. volume/ha m^3
acceptable species		
Apeiba menbranaceae	2	2.5
Dendropanax arboreus	2	2.1
Inga coruscans	2	2.8
Simarouba amara	2	3.4
desirable species		
Pentaclethra macroloba	4	3.5
total	12	14.3

APPENDIX XId : Results of Diagnostic Sampling in the farmers woodlot

Quadrates with LD and the exposure class and the lianas infection in the farmers woodlot (%), on 50 quadrates (= 0.5 ha)

TYPE OF LEADING DESIRABLE (LD)	CROWN EXPOSURE CLASS					LIANAS INFECTION CLASS			
	Good 1+2	Accept. 3	Poor 4+5	Undef.	Total	Crown	Stem	None	Undef.
Tree									
30-39cm dbh	2	4	-	-	6	2	-	4	-
20-29cm dbh	10	2	6	-	18	2	10	6	-
10-19cm dbh	2	2	10	-	14	2	4	8	-
Sapling									
5- 9cm dbh	2	-	8	-	10	-	-	10	-
Seedling									
< 5cm dbh	-	4	20	-	24	-	4	20	-
Quadrat with none	-	-	-	28	28	-	-	-	28
Total	16	12	44	28	100	6	18	48	28

APPENDIX XII : Diameter distribution of species per commercial group in the farmers grove, on 0.4 ha

Botanical species	0-4.5 No trees	5-9.9 No trees	10-19.9 No trees	20-29.9 No trees	30-39.9 No trees	40-49.9 No trees	50-59.9 No trees	Total No trees	Comm. Group
	DIAMETER CLASSES in (cm)								
Apeiba menbranaceae	0	1	1	0	0	0	0	2	A
Ceiba pentandra	0	0	0	1	0	0	0	1	A
Goethalsia meiantha	0	3	9	12	5	3	0	32	A
Rollinia pittieri	0	1	2	0	1	0	0	4	A
Simarouba amara	0	1	0	0	0	0	0	1	A
Sub-total	0	6	12	13	6	3	0	40	
Cordia alliodora	0	1	5	12	19	8	0	45	D
Hieronyma a.	0	0	6	1	0	0	0	7	D
Terminalia oblonga	1	0	1	0	0	0	0	2	D
Sub-total	1	1	12	13	19	8	0	54	
Bixa orellana	0	0	3	1	0	0	0	4	O
Carica c.	0	1	1	0	0	0	0	2	O
Cassia bicapsularis	0	0	3	0	0	0	0	3	O
Cecropia spp.	0	0	1	0	0	0	0	1	O
Colubrina ovalifolia	0	2	5	0	0	0	0	7	O
Genipa Americana	1	0	0	0	0	0	0	1	O
Hasseltia floribunda	0	3	6	0	1	0	0	10	O
Heliocarpus spp.	0	1	1	3	2	0	0	7	O
Inga spp.	0	1	1	1	1	0	0	4	O
Lonchocarpus c.	0	0	2	0	0	0	0	2	O
Luehea seemannii	0	6	2	0	0	0	0	8	O
Ochroma lagopus	0	0	0	0	1	0	0	1	O
Pterocarpus hayesii	0	0	1	0	0	0	0	1	O
Psidium guajava	0	0	0	0	1	0	0	1	O
Spondias mombin	0	8	11	2	1	1	1	24	O
Unknown	0	3	5	0	0	0	0	8	O
Zanthoxylum insulare	0	0	0	1	0	0	0	1	O
Sub-total	1	25	42	8	7	1	1	85	
Total	2	32	66	33	33	12	1	179	