Biophysical suitability classification of forest land in the Bipindi - Akom II - Lolodorf region, south Cameroon

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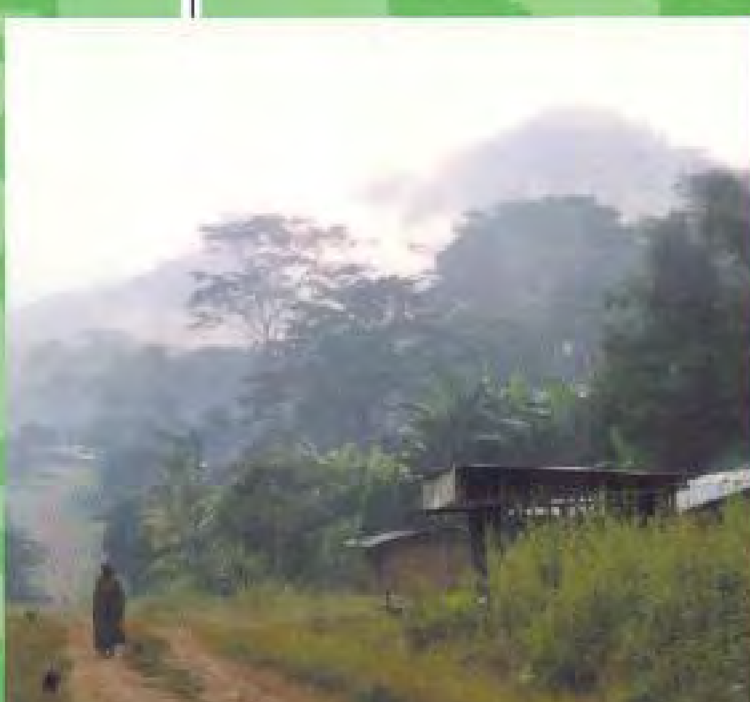

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BIOPHYSICAL SUITABILITY CLASSIFICATION OF FOREST LAND IN THE BIPINDI – AKOM II – LOLODORF REGION, SOUTH CAMEROON

G.W. Hazeu, B.S. van Gemerden, P.W.F.M. Hommel and A.J. van Kekem

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ABSTRACT

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A landscape ecological survey at reconnaissance scale (1:100,000) was conducted in the Bipindi – Akom II – Lolodorf region in south Cameroon. Seven landforms, four soil types and seven vegetation types are discerned and are integrated in one landscape ecological map. Subsequently a land evaluation study was carried out on the basis of the survey data. A total of five major land utilization types have been studied: conservation of biodiversity; extraction of non-timber forest products; timber production in natural stands; shifting cultivation and four types of plantation agriculture. Land suitability is evaluated by comparing the land use requirements with the land qualities. The results are presented as land suitability maps showing the physical potential of the area for each of the land uses. These maps provide a basis for sound land use planning in the area.

Keywords: land evaluation, nature conservation, non-timber forest products, forestry, agriculture, tropical rainforest, Cameroon

The Tropenbos-Cameroon Programme is a research programme executed under the joint responsibility of the Ministry of Environment and Forests of the Republic of Cameroon and the Tropenbos Foundation

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PREFACE

About Tropenbos

The Tropenbos Foundation was established in 1988 by the Government of the Netherlands with the objectives to contribute to the conservation and wise use of tropical rain forest by generating knowledge and developing methodologies, and to involve and strengthen local research institutions and capacity in relation to tropical rain forests.

The Tropenbos Programme carries out research on moist tropical forestland at various locations around the world. At present (semi-)permanent research sites are located in Colombia, Guyana, Indonesia, Ivory Coast and Cameroon. At the different locations, research programmes follow an interdisciplinary and common overall approach, with the aim to exchange data and to make results mutually comparable.

About the Tropenbos-Cameroon Programme and ITTO project PD 26/92

The present publication has been produced in the framework of ITTO project PD 26/92, which is an integral part of the Tropenbos-Cameroon Programme (TCP). The research on which this publication is based, was financed by the International Tropical Timber Organisation (ITTO), the Common Fund for Commodities (CfC), the Directorate General for International Co-operation of The Netherlands' Ministry of Foreign Affairs (DGIS), the Tropenbos Foundation and the implementing agencies mentioned below.

The Tropenbos-Cameroon Programme was established in 1992 by the Cameroonian Ministry of Environment and Forests (MINEF) and the Tropenbos Foundation. The general objective of the TCP is to develop methods and strategies for natural forest management directed at sustainable production of timber and other forest products and services. These methods have to be ecologically sound, socially acceptable and economically viable (Foahom and Jonkers, 1992). TCP consists of several interrelated projects in the fields of ecology, forestry, economy, social sciences, agronomy and soil science. In 1994, ITTO and CfC decided to co-finance six of these projects, which together form ITTO project PD 26/92. The 'Office National de Développement des Forêts' (ONADEF) is the agency responsible towards ITTO and CfC for the implementation of the Project PD 26/92.

The present study was carried out within the framework of one of the several TCP research projects, entitled 'Forest land inventory and land evaluation (Lu1)'. The implementing agencies involved are ALTERRA Green World Research (formerly the Winand Staring Centre for Integrated Land, Soil and Water Research; SC-DLO), the 'Institut de la Recherche Agricole pour le Développement' (IRAD) and Wageningen Agricultural University (WAU).

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We are grateful for the support from management team and technical staff of the Tropenbos-Cameroon Programme. Finally, we are indebted to the population of the research area for their permission to work in the area despite our sometimes confusing activities.

SUMMARY

This biophysical land evaluation study reports the results of the 'Forest land inventory and land evaluation project (Lu1)' of the Tropenbos-Cameroon Programme. It concerns the TCP research area in the South province of Cameroon, covering some 1700 km^2. Like in many tropical forest areas, land is becoming scarce in this area as the demands for arable land, forest land, property claims, wildlife etc. are becoming greater than the available sources. To avoid conflicts and, where possible, reconcile the interests of the different land user groups, sustainable land use planning is essential. The main objective of this biophysical land evaluation study is to provide a scientific framework for land use planning.

Method
The land evaluation methods used in this study are essentially based on the procedure and terminology described by FAO (1993). The following steps can be discerned:
- description of promising land use types ('land utilisation types' or LUTs);
- determination of requirements for each land use type ('land use requirements' or LURs);
- mapping of land units ('land inventory');
- description of their physical properties ('land qualities');
- land suitability classification by matching land use requirements with land qualities.

The chapters of this report broadly follow this operating procedure, the results of each step being described in one or more separate chapter(s) (Chapter 3 through 11). The methodology itself is described in detail in Chapter 2.

Land utilisation types
The five main land utilisation types (LUTs) dealt with in this study are:
- conservation of biodiversity;
- extraction of non-timber forest products (NTFP);
- timber production;
- shifting cultivation;
- plantation agriculture.

These five LUTs are shortly described in Chapter 3. For four of them, more than one suitability classification is carried out. Conservation of biodiversity is split up in a botanical and a faunistic aspect, plantation agriculture concerns the suitability for cocoa, oil palm, rubber and pineapple. For both NTFPs and timber production two scenarios are evaluated, directed at a narrow selection of highly valuable species, and a broad selection of species of varying value. For both LUTs (extraction of NTFPs and timber production) the transparency of the procedure should enable the reader to determine the suitability of land for any alternative selection of species, which may be considered relevant. Land evaluation for shifting cultivation is based on traditional technology only. However, information on alternative technologies is given in a distinct section (Section 10.3).

Land requirements
Land use requirements (LURs) are defined as the conditions needed for a successful implementation of the land use requirements. A distinction is made between requirements related to growth, management and conservation (Chapter 4). Examples are respectively nutrient availability, accessibility and tolerance to soil erosion. A summary of the LURs used in this study, grouped according to their relevance for the five land utilisation types, is given in Table 4.1 (p. 32).

Land inventory
Land inventory aims at the identification and delineation of tracts of land. These 'land mapping units' (LMUs) are described in terms of their specified land characteristics and they form the basis for spatial variation in the process of land evaluation. A land inventory of the TCP research area was executed in the first phase of the Lu1 project (van Gemerden and Hazeu,

1999). It resulted in an integrated landscape ecological map at reconnaissance scale (1 : 100 000). The various land mapping units are defined by:

- altitude range (ecological zone);
- a specific landform;
- the degree of forest disturbance by shifting cultivation;
- a specific combination of soil types;
- a specific combination of vegetation types.

The typologies for landform, soil and vegetation and the integrated map legend as compiled by van Gemerden and Hazeu are summarised in Chapter 5. In addition, this chapter lists the various land user groups of the area and discusses their specific land claims.

Land qualities

A land quality is defined as a complex of measurable properties of land (‘land characteristics’) which are relevant to a specific land use requirements. Like the land use requirements, land qualities may be related to growth, management or conservation. Chapter 6 enumerates all land qualities used in this study and gives the relevant data (either in classes or in real values) for all land mapping units. The results are summarised in Table 6.15 (p. 56). The land use planner may find the data presented in this table useful to compile maps showing the spatial variation of specific land qualities.

Suitability classification

Suitability classification is essentially done by confronting land use requirements and land qualities per land utilisation type and per land mapping unit. The results are presented in the Chapters 7 through 11. Each chapter includes one or more suitability maps, on which the spatial variation of suitability is indicated in four classes: suitable (S1), moderately suitable (S2), marginally suitable (S3) and not suitable (N). A summary of the suitability of the land for the different land utilisation types is given en Table 0.1.

Table 0.1 Summary of the suitability of the land for the various land utilisation types

LUT	Extent of suitability classes in % of total area						
	S1	S1+S2	S2	S2+S3	S3	S3+N	N
Conservation of flora	70%		20%		10%		
Conservation of fauna	5%		35%		30%		30%
NTFP, most important species	40%	8%	20%		25%		9%
NTFP, broad selection	75%	8%	7%		7%		
Timber, traditional selection			10%	25%	25%	10%	30%
Timber, broad selection		1%	25%	40%	10%	10%	20%
Shifting cultivation			7%	55%	0.5%	7%	30%
Cacao				75%		10%	15%
Oil palm				75%		10%	15%
Rubber				75%		10%	15%
Pineapple					7%	70%	25%

Conservation of biodiversity

Suitability of land for the conservation of biodiversity is described in Chapter 7. A distinction is made between conservation of flora (based on the whole spectrum of plant species) and conservation of fauna (based on four ‘umbrella species’: gorilla, mandrill, chimpanzee, and collared mangabey). The results for flora and fauna are deliberately not integrated. As for the flora aspect it proves that disturbance by shifting cultivation overrules all other factors influencing botanical conservation value. The one exception to this rule are the undisturbed valley bottoms which are only moderately valuable due to the relatively low species diversity of the primary forest on those sites.

As for fauna it is concluded that the vicinity of villages is not suitable for all species studies, whereas the vicinity of a major road clearly downgrades the suitability. Critical distances are species specific and range from 3 to 5 kilometres. It further proves that all species studied have a preference for undisturbed areas, which is at least partly due to a lesser availability of food plants in the shifting cultivation areas. When focussing on undisturbed areas at sufficient distance from roads and villages, suitability of land proves to vary from one species to another. For instance, the mountain area is suitable for gorillas only. On the other hand, the lowland area is to a large extent suitable for mandrill, but not so for the other species studied.

Extraction of non-timber forest products
Two variants of this land utilisation type were studied: one focussing on a small selection of very important NTFP species, and one focussing on a much wider range of species (Chapter 8). As for the broad selection, the whole area is considered suitable to moderately suitable; only the mountain area is but marginally suitable. However, when focussing on the most important species only, large tracts of land are judged considerably less suitable, especially in the upland areas between 350 and 500 m above sea level (asl), whereas the mountain area (> 700 m asl) is considered to be not suitable at all.

Timber production
Again, two variants were studied: one focussing on a small selection of very important, 'traditional' timber species, and one focussing on a much wider range of species (Chapter 9). As for suitability, the two variants do not differ dramatically. In the mountain area, the appreciation fully corresponds: not suitable due to unfavourable terrain conditions. In the zone between 500 and 700 m asl large tracts of land are considered moderately to marginally suitable for both variants, although in places suitability for the wide range variant is significantly higher. In the least elevated parts, the differences between variants are most pronounced. For the wide range variant the appreciation varies at short distances from suitable to not suitable. For the traditional timber species, the area is only marginally suitable to not suitable. This conclusion is striking since before commercial logging started the lowland area was part of the core area of Azobé distribution in Cameroon.

Shifting cultivation
Suitability for shifting cultivation was assessed by combining the requirements of various crops (banana, maize, groundnuts and macabo). The results are given in Chapter 10. It was a priori assumed that all land situated over 5 kilometres from a road is not suitable. Within this 5-km zone suitability for shifting cultivation is primarily limited by erosion risks (especially in the mountain areas: not suitable). However, in the dissected erosional plains of the lowland area insufficient drainage and high coarse fragment content of the topsoil are decisive: marginally suitable. The valley bottoms are even considered to be not suitable, due to very unfavourable drainage conditions.

Plantation agriculture
Suitability was assessed for four crops: cocoa, rubber, oil palm, and pineapple. The results were deliberately not integrated into one suitability classification for plantation agriculture as a whole. The suitability maps for cocoa, rubber and oil palm correspond very closely. Most parts of the research area are assessed moderately to marginally suitable; only the mountain area is considered to be not suitable, due to very high erosion risks. Conversely, for pineapple slope steepness is highly to strongly limiting in all parts. Only on valley bottoms, there are no serious erosion risks, but here drainage is strongly limiting. Thus, the whole research area is classified as marginally to not suitable for pineapple.

From land evaluation towards land use planning
A final 'Discussion' intends to bridge the gap between the scientific abstractions of a land evaluation procedure on one hand and the harsh reality of land use planning on the other. Chapter 12 summarises the main trends in suitability classification, it points to possible pitfalls (e.g. limitations related to size of the management area and to land use dynamics) and indicates ways to locate and solve conflicts between LUTs and the accompanying stakeholders. However,

the major message of this final chapter is that the results of a land evaluation procedure are no gospel truth. Land evaluation is more like a toolbox. This report provides a method and the relevant data to carry out sound suitability classifications. So, when views and priorities change, the land use planner will be able to carry out alternative suitability classifications easily and in an unbiased way.

LIST OF ABBREVIATIONS

asl	above sea level
CEC	Cation Exchange Capacity
CFC	Coarse Fragment Content
CfC	Common Fund for Commodities
FAO	Food and Agricultural Organisation of the United Nations
GIS	Geographic Information System
ITTO	International Tropical Timber Organisation
IUCN	International Union for the Conservation of Nature
IRAD	Institut de la Recherche Agricole pour le Développement
LC	Land Characteristic
LMU	Land Mapping Unit
LQ	Land Quality
LUR	Land Use Requirement
LUT	Land Use Type
MINEF	Ministry of Environment and Forests
NTFP	Non-Timber Forest Product
ONADEF	Office National de Développement des Forêts
TCP	Tropenbos-Cameroon Programme

1 INTRODUCTION

1.1 Forest land inventory and land evaluation project (Lu1)

The present study comprises part of a Tropenbos-Cameroon (TCP) research project entitled 'Forest land inventory and land evaluation' (Lu1). This project was carried out in two phases. The first phase implied a landscape ecological survey (1 : 100 000) of the TCP research area (van Gemerden and Hazeu, 1999). The second phase, of which this report gives the results, was aimed at land evaluation. This report, therefore, presents the results of the suitability classification of the forestland for various types of land use.

1.2 Research objectives

The forest land evaluation presented in this report concerns the TCP research area in the South province of Cameroon (Figure 1.1). The TCP research area is located between Bipindi, Akom II and Lolodorf and covers approximately 1700 km^2. In this part of Cameroon, land is becoming scarce as the demands for arable land, forestland, property claims, wildlife etc. are becoming greater than the available sources. As a result, conflicts might arise over land use between different land use groups (Bakola, Bantu tribes, Government, concession holders, etc.). Moreover, due to the slowly increasing intensification of the land use (shorter fallow periods), land degradation is looming around the corner.

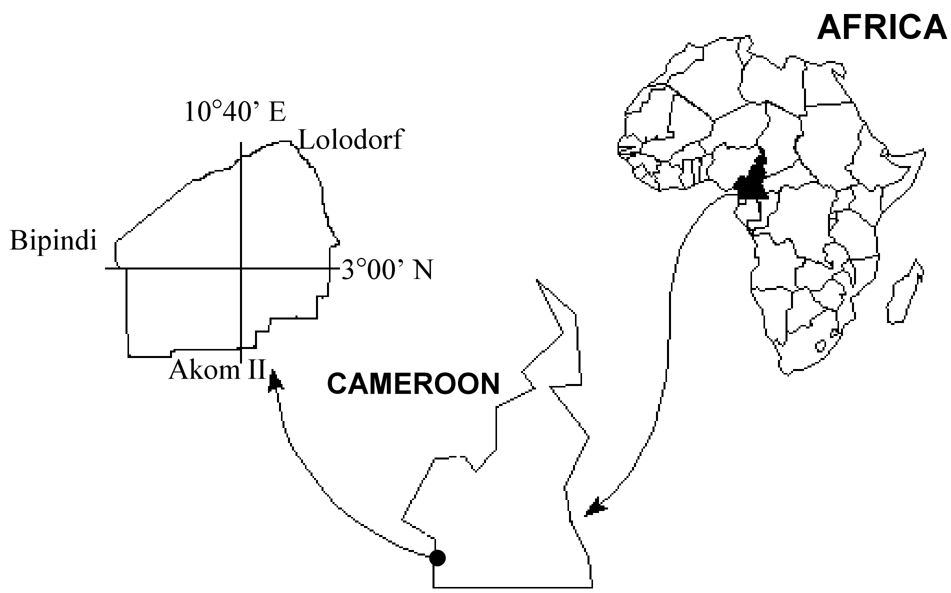


Fig 1.1 Location of the TCP research area in south Cameroon.

The general objective of Lu1 is to provide a scientific framework for sustainable land use planning for the TCP research area. This is realised through the development of a land evaluation methodology for tropical moist forests. Land evaluation indicates the suitability of land for different and well-specified, land uses. It is a tool in the elaboration of a land use plan which takes into account ecological sustainability, economic feasibility and social and political acceptability. The land use plan, in turn, forms a prerequisite for the forest management plan, which is an expected output of the Tropenbos-Cameroon Programme.

1.3 Course of the study

Two associate experts executed the project: Mr. G.W. Hazeu (soil scientist) and Mr. B.S. van Gemerden (vegetation scientist). Field work started in March 1995 and contracts expired in September, respectively December 1997. The associate experts were made available by the Directorate General for International Co-operation of the Netherlands' Ministry of Foreign Affairs (DGIS).

Overall supervision of the Lu1 project was provided by senior soil and vegetation experts of ALTERRA Green World Research (formerly DLO - Winand Staring Centre for Integrated Land, Soil and Water Research, SC-DLO). A senior GIS expert of the same institute gave additional assistance. A total of four backstopping missions were carried out (Bregt and van Kekem, 1995; Hommel, 1995; Hommel and van Kekem, 1996; van Kekem and Hommel, 1997).

1.4 Report outline

The structure of this report follows the steps taken in the course of the land evaluation study. Chapter 2 describes the principles and objectives of land evaluation and the methods used and developed in the 'forest' land evaluation concerning the TCP research area. The land utilisation types are discussed in Chapter 3. These are: conservation of biodiversity, gathering of non-timber forest products (NTFPs), timber production, shifting cultivation, and plantation agriculture. Chapter 4 deals with the land use requirements. The results of the landscape survey, which serve as an expedient for the land evaluation procedure, are summarised in Chapter 5. In addition, the social, cultural, economical and political setting is discussed. The different groups of stakeholders active in the area are described, including some major demographic aspects. Moreover, current land use types and land use dynamics in the TCP research area are briefly discussed. Chapter 6 discusses the land qualities.

In Chapters 7 through 11 the suitability of the land for the selected land utilisation types is described in detail. The matching of land use requirements with land qualities resulted for each land utilisation type in one or more land suitability classifications, which are presented in tables and on maps. Chapter 12 presents a discussion, including additional information relevant to land use planners.

2 METHODS

2.1 Introduction

Land use planning is the systematic assessment of land and water potential, and alternatives for land use and economic and social conditions, in order to select and adopt the best land-use options. Its purpose is to select and put into practice, the land uses which will best meet the needs of the local population and will also safeguard the resources for future use (FAO, 1993).

The land uses and their requirements selected have to take into account the attributes of three dimensions: ecological sustainability, economic feasibility, and social and political acceptability. *Ecological sustainability* is defined in terms of the continuous availability of resources, with minimal disturbance of biological diversity. *Economic feasibility* (efficiency) means that the cost-benefit balance is positive and that income and returns can compete favourably with other economic activities. *Social and political acceptability* (equity) implies (a) that the land use contributes to the welfare of the local community, (b) that it does not lead to cultural disruption or social instability and (c) that it is supported by local governments (Ros-Tonen *et al.*, 1995).

The land-use planning process is long and complex and involves land users and policy makers. Integration of information about the suitability of land and the knowledge about different technologies must take place. Demographic, social and economic aspects need to be incorporated into a policy supported by the government. Furthermore, the demands for alternative products or uses and the opportunities for satisfying those demands for available land, now and in the future, have to be taken into account.

Land evaluation is a tool for a strategic land-use planning. It predicts land performance, both in terms of the expected benefits from and constraints to productive land use, as well as the environmental degradation due to these uses (Rossiter, 1996). The land evaluation study provides a scientific basis for decisions regarding sustainable land use alternatives for the TCP study area. In other words: it is a specific contribution to land-use planning activities.

Land evaluation, in its broadest sense, includes the process of data gathering (i.e. inventory and mapping of natural resources), classification and identification of tracts of land, and interpretation of these tracts of land for a specified use (Touber *et al.*, 1989). Land evaluation may be defined as 'the process of land performance when [the land is] used for specified purposes' (FAO, 1985), or as 'all methods to explain or predict the use potential of land' (van Diepen *et al.*, 1991). Land evaluation *sensu stricto* encompasses only the interpretation of gathered data into suitability levels for actual or potential use.

Land evaluation entails the rating of land use options on a small-scale (reconnaissance scales, i.e. 1: 100,000 – 1: 250,000) in a setting of limited information on land characteristics. The challenge of land evaluation is to provide objective and transparent suitability ratings despite the restrictions posed by scale and information availability. The land evaluation (s.s.) gives indications of broad land use options. Management related questions concerning for instance ecological, economical, technical and social aspects can than be addressed.

2.2 Land evaluation procedure and terminology

The land evaluation procedure consists of the following steps (FAO, 1993):
- description of promising land-use types;
- determination of requirements for each land-use type;
- mapping of land units (land inventory);

- description of their physical and biotic properties (e.g. climate, relief, soils, vegetation) in terms of characteristics and qualities;
- land suitability classification based on a comparison of requirements of the land-use types with the properties of the land units.

Land utilisation types
Land is to be evaluated for a well-defined use. There is no 'suitable' or 'unsuitable' land as such, if no mention is made of the land use envisaged. The FAO makes a difference between major land use, being a major subdivision of rural land use and land utilisation types, which are defined in more detail. In this report we do not make that distinction and we use the term land utilisation type (LUT).

Land utilisation types are kinds of land uses described in terms of necessary inputs (management practices) and expected results (products) in a given physical, economic and social setting. Their standard description is based on a number of so-called key attributes, such as produce, capital input, labour input, farm size, land tenure, technical know-how, level of mechanisation etc. (Touber *et al.*, 1989). These descriptions of LUTs serve as the basis for determining the requirements of a land use. Moreover, the management specifications can be used as a basis for extension services and for planning necessary inputs (FAO, 1993).

Land use requirements and land attributes
The conditions for a successful implementation of the land utilisation types are described as land use requirements (LURs). The LURs are described by the land qualities needed for sustained production. A land quality (LQ) is a complex attribute of land that has a direct effect on land use. Most land qualities are determined by the interaction of several land characteristics (e.g. soil fertility can be expressed with the help of pH, CEC, available P, N and K). Only those land qualities that have a substantial effect on the costs of the production or on the 'performance' are to be selected. Moreover, critical values of the quality must occur within the TCP research area.
The land use requirements can be grouped as follows (FAO, 1984; Touber *et al.*, 1989):
- growth requirements refer to the land conditions necessary for survival and growth of trees and crops;
- management requirements are the conditions necessary or desirable for successful management of the defined land use;
- conservation requirements refer to the preservation of resources and natural values. They refer to the effects of management activities on soils, hydrology and vegetation.

Land inventory, land characteristics and land attributes
The identification and delineation of tracts of land is done in an overall land inventory. These land mapping units (LMUs) are described in terms of their specified land characteristics (LCs) and they form the basis for spatial variation in the process of land evaluation. The integrated/landscape ecological mapping units (soil, landform and vegetation characteristics are combined) are very useful in the land evaluation procedure for forestry (Bennema *et al.*, 1981). A land characteristic is defined as an attribute of land that can be measured or estimated (e.g. slope gradient, vegetation structure) and which can be employed as a means of describing or distinguishing between land mapping units (FAO, 1976).

Suitability classification
To facilitate comparisons between competing land use alternatives, FAO (1976) developed a land suitability classification system, for rainfed and irrigated agriculture, for forestry, and for extensive grazing (FAO, 1983; 1984; 1985; 1987). The critical phase of land evaluation is the identification of relevant land qualities and the establishment of factor ratings (FAO, 1983). A factor rating is a set of critical values, which indicate the extent (minimum and maximum) to which a particular condition of a land quality meets the corresponding land use requirement.

In the matching process that follows, the factor ratings are compared with the measured values of a land characteristic or quality for a given land mapping unit. The results are suitability classes for each land use type for each land unit. The outputs are land suitability maps, showing the suitability of each land unit for each land-use type.

The limitation classes established for the relevant LURs/LQs of a certain land utilisation type need to be combined to one overall rating for the land unit. Four methods to combine ratings within one group of requirements (crop, management and sustainability/conservation) may be used according to circumstances:
– subjective combination;
– most limiting conditions;
– arithmetic procedures;
– modelling.

Overall ratings for each group of requirements need to be combined with the limiting conditions method. This method is simple as it takes the least favourable assessment to determine the final suitability. This method is a broadening of the well-known 'law of the minimum', which states that suitability is determined by the most limiting factor. The level of suitability of land for a certain land use will be grouped in four classes: suitable, moderately suitable, marginally suitable and not suitable (Table 2.1). The suitability classification presents the potential suitability of land for different land utilisation types. This suitability is based on nearly constant (physical/ecological) qualities of the land.

Table 2.1. Land suitability definitions (After FAO, 1976)

Class	Designation	Definition
S1	Suitable	Land having no significant limitations to sustained application of a given use, or only minor limitations that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level.
S2	Moderately suitable	Land having limitations which, in aggregate, are moderately severe for sustained application of a given use; the limitations will reduce productivity or benefits, and increase required inputs to the extent that the overall advantage to be gained from the use, although still attractive, will be appreciably inferior to that expected on class S1 land.
S3	Marginally suitable	Land having limitations which, in aggregate, are severe for sustained application of a given use and will so reduce productivity or benefits, or increase required inputs, that this expenditure will be only marginally justified
N	Not suitable	Land having limitations that appear so severe as to preclude any possibility of successful sustained use of the land in the given manner

2.3 Land evaluation for the TCP area

The level of detail of the forest land evaluation is determined by the scale of the land inventory. In the case of the TCP land evaluation this is 1 : 100 000. The TCP land evaluation method, which has a general organisation level (ecological zone, landscape) related to the scale of the land inventory, predicts to a minimum legible delineation of 40 ha at scale 1 : 100 000 (Forbes *et al.*, 1982; Hoosbeek and Bryant, 1992; Rossiter, 1996). The land evaluation of the TCP research area will be qualitative as sufficient quantitative data are lacking.

The TCP land evaluation is a physical and ecological forest land evaluation. The landscape ecological map (1 : 100 000) is the basis for this land evaluation (Annex I, van Gemerden and Hazeu, 1999). Areas which are actually or potentially suitable for a specific land utilisation type are indicated. Land use planners use these potential suitability maps together with political, social and economic aspects in the elaboration of a land use plan that is directed to indicate zones for specific (actual) land uses. Prioritisation is done in consultation with the different stakeholder and facilitated by scenario studies and an ecological impact assessment (Lescuyer, unpublished project proposal; Lescuyer and Fines, in press). Once land use plans have been agreed upon research should be aimed at answering relevant management questions.

Land use planning for the TCP research area is needed to solve or to prevent land use conflicts. Different interests and perceptions concerning the environment (nature conservation), economy (commercial logging, agriculture) and welfare (community development) by the stakeholders will result/results in conflicts. With the selection of land utilisation types makes, care is taken of the social and political setting. Information on actual land use and population distribution is incorporated as much as possible in this land evaluation study. The suitability classification is not a-priory socially or politically acceptable and/or economically feasible as this will be determined during the land use planning process, which follows the land evaluation. Within the setting of the TCP scenario studies will be developed and discussed with the different stakeholders (Lescuyer, unpublished project proposal; Lescuyer and Fines, in prep.). The present biophysical land evaluation is used as starting point for these studies.

The description of land utilisation types for the TCP research area was given special attention, as the formulation is one of the most important steps in land evaluation. Van Berkum (1996) formulated 14 land utilisation types, five of which were retained for further study. Several meetings and discussions were held to incorporate the ideas of all the TCP researchers in the final LUT and LUR descriptions. Data delivered by other researchers concerning timber logging, non-timber forest products, wildlife, shifting cultivation and social aspects of land use are used. Only presently occurring or realistically possible land utilisation types are taken into account. For instance, industry or large-scale cattle breeding are not considered.

The land utilisation types are identified on the basis of studies on the present and potential land uses in the area (e.g. van Berkum, 1996; van Gemerden and Hazeu, 1999). The LUTs can be divided by the main activities conducted but also by the main actors linked with that particular type of land use (e.g. forest dwellers, logging companies, nature conservationists). The list of LUTs is by no means exhaustive but reflects the most important demands on land in the Tropenbos-Cameroon research area. The LUTs are treated as if they have one type of land use only. In reality the land use is often combined. The following LUTs are taken into account (given in order of increasing human influence on the forest ecosystem):

- conservation of biodiversity, separately for flora and fauna;
- collection of non-timber forest products (NTFPs), both for common species and a wider array of species;
- production of timber in natural forest, both for the traditional species as well as for a wider selection of species;
- shifting cultivation;
- plantation agriculture; specified for cacao, oil palm, rubber and pineapple.

The systematic description of the LUTs includes: objective, output, markets, labour and capital input, technology involved, infrastructure needs and scale of operations. In the next chapter the LUTs are described in more detail.

The land qualities as well as the requirements are grouped into three groups: land qualities concerning growth and yield, land qualities concerning management and land qualities concerning sustainability and conservation.

3 LAND UTILISATION TYPES

3.1 Conservation of biodiversity

Tropical rain forests are the species richest and structurally the most complex terrestrial ecosystems in the world. The variety and uniqueness of their genetic reserves (both floral and faunal) are determining their value for biodiversity conservation. Conservation of diversity within species, between species and of ecosystems is internationally recognised as a high priority (Lammerts van Bueren and Duivenvoorden, 1996). Human actions have strongly affected tropical rain forests and generally have a severe negative impact on biodiversity. The need for and the importance of biodiversity conservation in protected zones within the TCP area also depends on the presence of similar ecosystems in other parts of south Cameroon.

Objective
The objective is "to protect the ecological integrity of one or more ecosystems for future generations, to exclude exploitation or occupation inimical to the purposes of designation of the area and to provide foundation for spiritual, scientific, recreational and visitor opportunities, all of which must be environmentally compatible" (IUCN Protected Area Category II; Stolton and Dudley, 1999). The livelihood of local populations is so much intertwined with the surrounding forests that access to the conservation areas and limited use of its resources is permitted. Nonetheless, priority is given to conservation purposes.

Output
Conservation of biodiversity contributes to the preservation of the genetic variation of the flora and fauna species of the forest ecosystems and more particularly contributes to the survival of rare and endangered species. The main benefits of conservation of biodiversity are not directly tangible but may have far reaching (positive) effects. Biodiversity reserves contribute to regulation and maintenance of many ecological, physical and chemical processes and cycles (e.g. microclimate, hydrological and nutrient cycles, oxygen-carbondioxide balance, and protection against erosion). The areas designated as biodiversity reserves play an important role in scientific research on forest ecosystem functioning. Additionally, it may serve educational, cultural and spiritual functions. The scenic beauty of these forests could, in time, attract tourists.

Markets
The beneficiaries of the conservation of biodiversity are the international community (conservation of biodiversity, endangered species, science, etc.) and to a lesser extent the local population (regulatory functions, low intensity gathering of NTFPs). The benefits of (eco) tourism could eventually contribute to the local economy.

Labour input
Overall labour input for the conservation of biodiversity is low. Demarcation of the protected areas will require unskilled labour for a relative short period. Well-trained personnel (forest guards) are needed to control illegal incursions. Monitoring of endemic, endangered and keystone species as indicators for the effectiveness of management requires university-trained staff.

Capital input
Overall capital input for biodiversity conservation forest is low to medium (e.g. maintenance of infrastructure).

Level of technology
Measures to be taken are aimed at protection of the conservation forest against illegal incursions and (over)exploitation of its components by the local population. Law enforcement requires

well-organised structures. Monitoring the biodiversity is the work of university trained specialists.

Infrastructure
Infrastructure needs consists of offices, boundary demarcation and provision of access for guarding and monitoring purposes.

Scale of operations
The minimal area needed for viable populations of flora and fauna species is difficult to estimate. Species with low population densities (e.g. many plant species of the primary forest) and large home ranges (e.g. large mammals) or with seasonal dependence on other ecosystems (migratory species) are likely to be the most critical groups. The scale of operations should also reflect the landscape diversity and the relative importance in terms of conservation needs of the species or ecosystems.

3.2 Collection of non-timber forest products

The people living in the Tropenbos-Cameroon research area depend for their livelihood to a large extent on forest products. The forest in their direct surrounding provides food, construction materials, agricultural and household utensils, medicines, and other products. Nearly the complete protein uptake by these households is derived from forest products. The majority of the NTFPs are collected for subsistence needs and for the local market. A few products are sold at the national, and even international, markets (van Dijk, 1997; 1999). Moreover, the social and cultural perception of the local population is intertwined with the forest.

In the Tropenbos-Cameroon research area, two population groups can be discerned that depend on the extraction of NTFPs. The first group, about 98% of the population in the area, consists of Bantu villagers belonging to the Bulu, Fang, Bassa and Ngoumba tribes. They live in villages along the main roads and their mainstay is shifting cultivation. NTFP extraction is complementary to agriculture. The second population group consists of the forest dwelling Bagyeli (or Bakola) pygmies. They constitute approximately 2 – 4% of the population in the Tropenbos-Cameroon area. These forest dwelling hunters and gatherers are still rather mobile, despite processes of sedentarization (Biesbrouck, 1999a). They practise some shifting cultivation but the scale is limited compared to that of their Bantu neighbours. Forest products and services are essential to Bagyeli survival, but their availability is seriously threatened by the expansion of the area under cultivation and particularly by logging activities (Biesbrouck, 1999b; Booijink, 2000). The Bakola collect NTFP for subsistence and for trading agricultural products with Bantu farmers. Some NTFPs, e.g. the seeds of the liana *Strophanthus gratus*, find their way to the national markets through intermediates.

Actual situation
Hunting, fishing and gathering are practised in all parts of the TCP area; within the agricultural zone along the main roads but also extending deeper into the forest. The importance of these activities increases from the road onwards (Ngoma and Giasson, 1996). Van Dijk (1999) indicates that secondary forests and cacao plantations are also important collection areas for several NTFPs. The hunting season is from April to December. Almost two third of the households practise hunting. Often, Bakola rent their services to certain Bulu households. Both guns and traps are used. The most frequently hunted animal species are Gambian rat, Brush-tailed porcupine, Cane rat, several species of pangolins, Blue duiker, cusimanse and venomous snake like the Gaboon viper (van Dijk, 1999). Hunting as a new revenue source is stimulated by the low cocoa price and the high unemployment rate under youths. The hunting pressure in the area has become so high (large mammals are hardly seen anymore) that some species may become extinct.

Fishing is practised by one third of all farmers in the region. It is a seasonal activity, which usually takes places within 5 km of the village. The species, which are most frequently caught, are shrimps, carps and sheat-fish. Sometimes, fishing is delegated to the Bakola. Due to a lack of data of sufficient detail, hunting and fishing are not included in this land evaluation study.

Gathering of NTFPs is practised by less than fifty percent of the households. Surveys on NTFP collection have been carried out in the nearby Campo-Ma'an area and the TCP research area. Some 500 plant species were recorded in the TCP area alone, providing a total of nearly 1200 different uses. The trade in NTFPs is an important source of income for the local population. For the Bantu population the most commonly traded NTFPs in the TCP area are (wild) oil palm (*Elaeis guineensis*), bush mango (*Irvingia gabonensis*) and 'njansang' (*Ricinodendron heudelotii*). The Bakola collect and trade the fruits of the liana *Strophanthus gratus*, honey and several oil containing nuts (e.g. *Panda oleosa* and *Poga oleosa*). At present most of the commercialised NTFPs are sold at local markets (Dounias, 1993; van Dijk, 1999).

Objective
The primary objective is sustainable extraction of NTFPs by local population for subsistence and cash revenues (IUCN protected area category VI; Stolton and Dudely, 1999). The use and control of the area is devolved to the local communities. The sustainable extraction of NTFPs contributes to the continued presence of a (slightly) modified forest. Forest conservation may thus be a secondary objective. Commercialising a small number of NTFPs, as proposed by Ros-Tonen *et al*. (1995), could be an interesting option and as such contribute to forest conservation.

Output
The main tangible benefits are food, construction materials, medicine, agricultural, household utensils and cash. The major non-tangible benefit is the well-being of the local population who depends on the forest. As sustainable extraction of NTFPs may contribute to forest conservation, this LUT also contributes to biodiversity maintenance and thus to regulation and maintenance of ecological, physical and chemical processes and cycles.

Markets
The extraction of NTFPs is mainly for subsistence and local market. A few highly valued products are sold on the national and international markets. In the latter case intermediates intervene in the trade.

Labour input
The collection, transport and processing of NTFPs are relatively labour-intensive. The quantity of labour required depends on the type of NTFPs collected and the distance to be covered. Local knowledge of species and ecology is required. The traditional divisions in tasks by gender and age classes make that nearly the complete household participates in the collection of NTFPs.

Capital input
In general, the extraction of NTFPs requires hardly any capital input.

Level of technology
The level of technology is low. Hardly any tools are needed for collecting and techniques for processing are simple. Local techniques are applied for selection, extraction and storage of NTFPs.

Infrastructure
Infrastructural needs for the extraction of NTFPs for subsistence and local markets are low. A well-developed infrastructure creates possibilities for merchandising NTFPs beyond the local level.

Scale of operations

The scale of operations depends on the type of NTFPs collected and the abundance of NTFP species. In general the extraction of a wide array of NTFPs requires relatively large areas and is ideally situated within reasonable distance of the homesteads. Specialists (often Bakola) are prepared to cover larger distances.

3.3 Production of timber in natural forest

Timber is an economically important product. The annual production is estimated at 2.8 million cubic meters. It represents one fifth of Cameroon's export revenues, i.e. 320 million US Dollars (Eba'a, 2000). The forests provide timber for local and export markets. Approximately 55% of it are processed in Cameroon.

Forest exploitation has been the main economic activity in the TCP area, although not the most widespread one. (Note: logging stopped in 1998, after the fieldwork for this research had been carried out). Temporal exploitation roads have been constructed to enable the logging of the forest lands. In general, the area used for exploitation does not interfere with the area used for shifting cultivation. In fact in some locations forest land was only cleared after the exploitation roads had been constructed. On a small scale the logging company has negotiated with farmers in order to obtain the timber located in cultivation areas.

The logged-over forest areas are still used for hunting, fishing and gathering of other NTFPs. The present zone of agricultural fields and plantations has usually been logged in the past. Although most of the forests in the TCP area have been logged, they still hold a large potential for timber production.

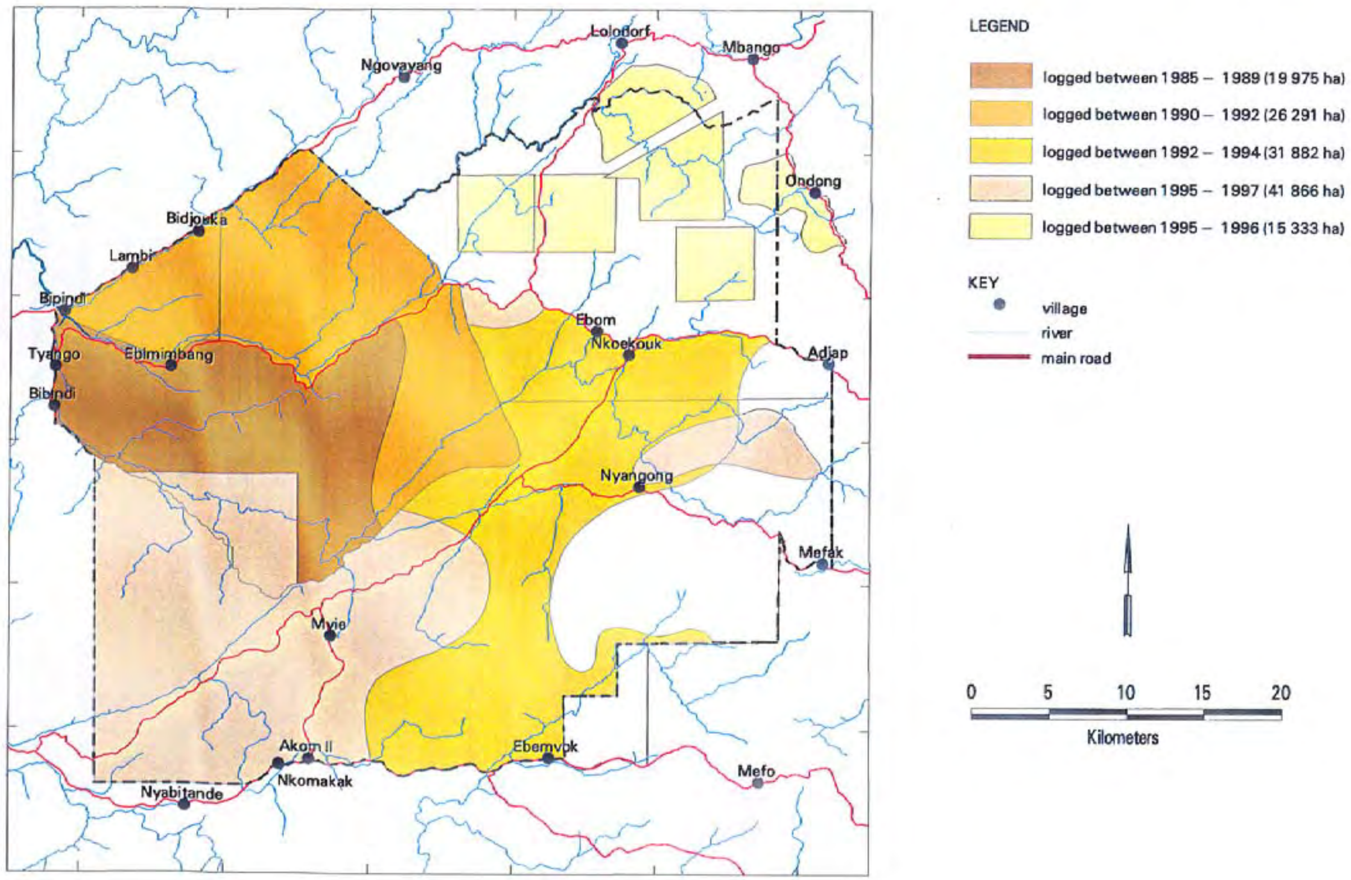
National and international companies, among them the Dutch GWZ, exploit the forest selectively. Logging concessions have sizes up to 150 000 – 200 000 ha and time spans of 15 years. Within these concessions the logging companies have to ask the government for permission to log in small sections. These 'assiettes de coupe' have a size of 2500 ha and are granted for a period of one to three years. The logging company could, if granted, also log in 'ventes de coupe gré-à-gré' of 2500 ha which were not parts of the concession. With the introduction of the revised forest legislation, however, these practices stopped. The logging of the forest involves the construction of logging roads with bulldozers and graders.

Log extraction from the forest is done by wheeled skidders and crawler tractors. Present logging activities focus on three main species: Azobé (*Lophira alata*), Tali (*Erythrophleum ivorense*) and Padouk (*Pterocarpus soyauxii*), as well as the usually easy to market redwood package (Sipo, Kosipo, Ngollon, Tiama, etc.). Azobé is by far the most important species, representing 60% of the total extracted volume. Only trees surpassing a minimum diameter, which is fixed by the government and species specific, and straight boles of at least six meters length are considered worthwhile. The resulting average logging intensity is low, compared to other tropical regions: 10 m^3 (i.e. 0.7 trees) ha^{-1}. The felling and extraction of the logs from the stand are estimated to affect less than 10% of the surface area (G.J.R. van Leersum, pers. comm. 1997). Since logging started, large parts of the TCP research area have been selectively logged, with the exception of the mountainous and hilly regions in the eastern parts. Map 3.1 shows the spatial and temporal distribution of the logging concessions over the last fifteen years. Sufficiently detailed records of areas logged before 1985 could not be obtained.

The production of timber, as described in this LUT, covers the exploitation as well as the regeneration period of the forests. The management is aimed at both presently traded timber species and species that provide timber with good technical properties but are at present lesser known on the national and international markets.

SPATIAL AND TEMPORAL DISTRIBUTION OF LOGGING CONCESSIONS

Bipindi– Akom II– Lolodorf region, South Cameroon



Map 3.1

Objective
The primary objective is sustainable production of timber for the national and export markets. Timber production will take place in a polycyclic system with a felling cycle of about 30 years. Logging activities are concentrated on timber species already being exploited in West Africa and a number of lesser known but technically good timber species.

Output
The timber production required for economically sustainable exploitation is 7 - 12 $m^3ha^{-1}y^{-1}$ (R.A. Eba'a, pers. comm. 1997). Due to the relatively low logging intensity the forest cover of the production forest remains more or less permanent. Thus the production forest contributes to conservation of biodiversity and the regulation and maintenance of many ecological, physical and chemical processes and cycles (e.g. microclimate, hydrological and nutrient cycles, oxygen-carbondioxide balance and protection against erosion). Likewise the forest will continue to be a source of NTFPs.

Markets
The production of timber is directed at national and export markets. Cameroon's forest policy aims at an internal processing rate of 70% (FAO/PNUD, 1988). At present, however, only 55% of the timber volume are sawn in Cameroon (Eba'a, 1998). The nearest harbours are Kribi (100 km) and Douala (280 km). Saw mills are located in Ebolowa and Bidou, both about 70 km from the TCP area.

Labour input
Labour requirements vary with time and are high during silvicultural treatments and exploitation and low in the regeneration period. The labour is semi-skilled under skilled foremen. For overall management and monitoring a small number of highly skilled personnel is required.

Capital input
Level of capital investment is high.

Level of technology
The level of technology is high. Silvicultural treatments may include climber cutting, poisoning of undesirable trees and enrichment planting. Directional felling and reduced impact harvesting techniques are applied. Road construction, log extraction and log transport requires heavy machinery.

Infrastructure
Infrastructural needs are relatively high. Roads are needed to transport logs from the concession to the markets and saw mills. Forest access roads are of dry weather type. These will be used for exploitation, but also for monitoring purposes and should therefore be maintained during the whole management period.

Scale of operations
For a small forestry enterprise an annual yield of about 1000 m^3 is required (Eba'a, 2000). Based on a felling cycle of thirty years and an estimated extractable log volume of 10 m^3 ha^{-1}, the forest management unit for such an enterprise is 30 000 ha. A forest management unit should cover at least 60 000 ha to support a small to medium-sized sawmill (R.A. Eba'a, pers. comm. 1997).

3.4 Shifting cultivation

Shifting cultivation is the most widespread agricultural land use in the TCP research area. It is practised on both sides of the main roads within a belt of about 5 km width (locally wider). Map 3.2 and Table 3.1 present the actual distribution and extent of the shifting cultivation areas.

The shifting cultivation system involves the clearing and burning of primary and old secondary forest just before the rainy season, and the planting of cucumber or `ngôn' *(Cucumeropsis mannii*), groundnut (*Arachis hypogeae*), maize (*Zea mays*), cassava (*Manihot esculenta*), macabo or `tannia' (*Xanthosoma sagittifolium*), cocoyam (*Colocasia antiquorum*), yams (*Dioscorea spec*.) and plantain (*Musa spec*.). When the productivity decreases, the tending and harvesting of a field gradually stops. The land is left fallow after a maximum of three years, allowing the forest to re-establish. Problems related to shifting cultivation as perceived by the farmers are (in decreasing order of importance): damage by animals, diseases, lack of technical assistance, low soil fertility, and absence of equipment, marketing and transport (Ngoma and Giasson, 1996).

Table 3.1. Extent of the areas influenced by shifting cultivation (after van Gemerden and Hazeu, 1999)

Intensity of shifting cultivation*	Extent (ha)	% of total
No to hardly any (u)	116 170	69.4
Low intensity (l)	29 820	17.8
High intensity (h)	21 360	12.8

* u = (near complete) absence of agricultural fields; l = actual and recently abandoned fields cover maximally 20% of the area and young secondary vegetation covers about 20%; h = actual and recently abandoned fields cover over 40% and young secondary vegetation covers over 20% (less than 40% of the area is covered by old secondary and primary forest).

Nowadays, the traditional shifting cultivation cycle is gradually changing, due to the use of chain saws, the limited amount of available labour, and the scarcity of new land in the vicinity of the village. More and more farmers are clearing young fallows where they plant groundnut in association with macabo, cassava and maize. Ngôn and yams are restricted to forest fallow.

Table 3.2 presents production figures and the percentage used for home consumption of some crops cultivated in the TCP research area. The most important food crop is cassava. Besides cassava, ngôn is becoming an important crop for revenues. In the Bidjouka region, crops like plantain and macabo are also becoming important revenue sources (Tiayon, 1997a). Less important crops such as gombo (*Abelmoschus esculentus*), taro (*Colocasia esculenta*) and sweet potatoes (*Ipomoea batatas*) are not presented in Table 3.2. They are mainly cultivated for home consumption and by less than 25% of the farmers. Unfortunately data concerning groundnut, which is another important crop, are not available.

Table 3.2. Production of some important food crops in the TCP research area[1]

Crops	Percentage of farmers[2]	Production[3] (bags)	Total per household[3] (bags)	Production Production for home consumption (%)
Cassava	100 (62)	3707	60	56
Maize	84 (55)	288	5.2	70
Plantain	86 (56)	4918	88	65
Cucumber	78 (52)	165	3.2	56
Macabo	77 (49)	389	7.9	68
Yam	54 (31)	91	2.9	80

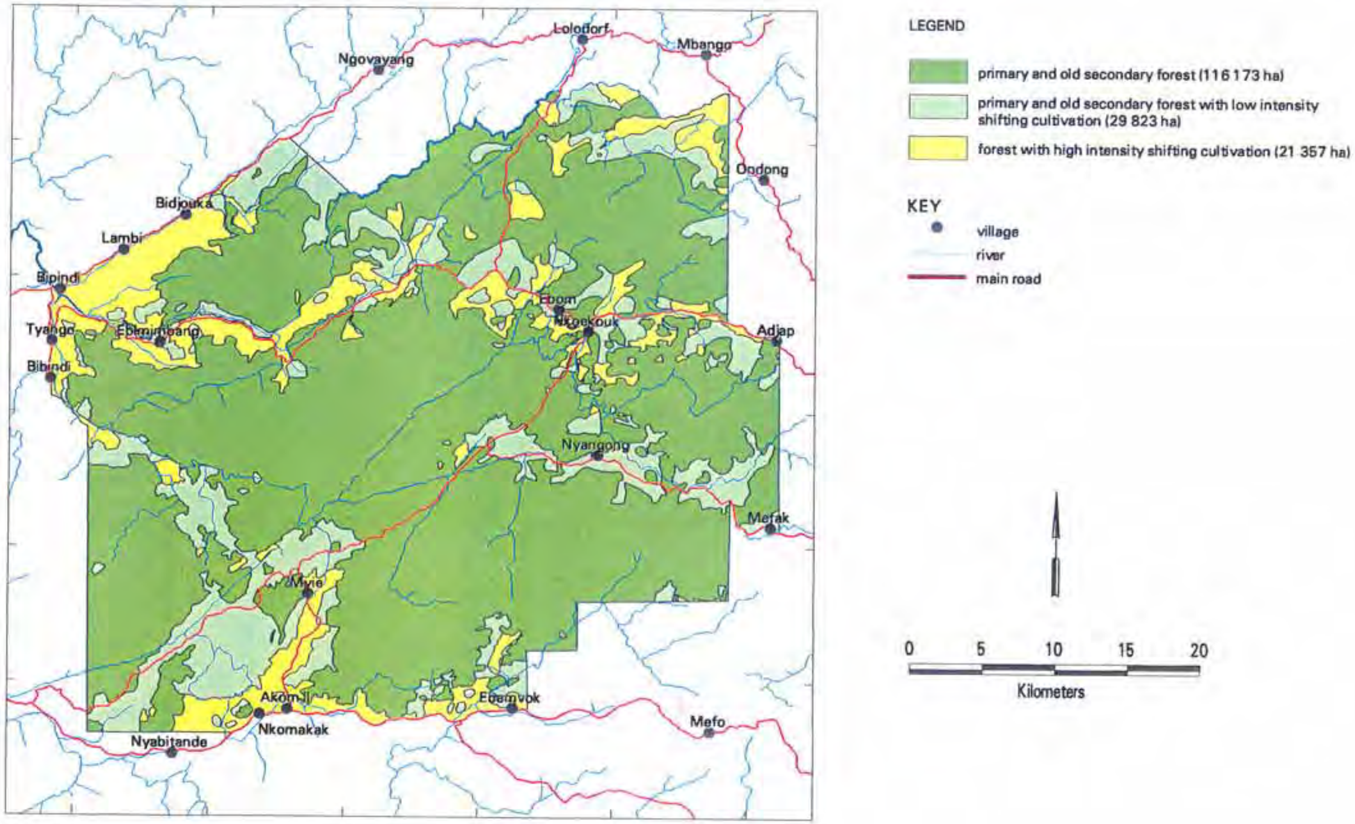
[1] Data concern eleven villages in the Bulu sector in the southern part of the TCP research area (Ngoma and Giasson, 1996).

[2] The total number of farmers interviewed is 70; the number of farms from which the production was calculated is given in parenthesis.

[3] One bag weighs approximately 90 kg; production figures for plantain are given by bunch.

MAIN VEGETATION AND LAND USE ZONES

Bipindi– Akom II– Lolodorf region, South Cameroon



Map 3.2

The total area used in the rotational fallow system is less than ten hectares per farmer (Ngoma and Giasson, 1996; M. Yemefack, pers. comm. 1996) and consists of 5 to 6 fields of 0.5 to 1.5 ha each. During the last five years, the majority of farmers have enlarged their cultivate area because of an increase in nourishment needs and possibly decreasing soil fertility. Moreover, they wish to increase their revenues and to secure claims on land. After the cocoa price fell, the number of farmers cultivating food crops for revenues has increased as well (Tiayon, 1997a; 1997b).

The system of shifting cultivation is adapted to the local environment and can be a sustainable land use option. Problems may, however, arise when changes occur in the socio-economic environment. The LUT shifting cultivation, as treated in the present land evaluation study, is adapted to low land pressures. This type is similar to the shifting cultivation systems already in use in the Tropenbos-Cameroon region.

Nounamo and Yemefack (1997) studied the shifting cultivation system in the TCP area. They recognised three subtypes based on the length of the fallow period. These three subtypes have differences in the (mixed) cropping systems, which may well be related to the initial (regeneration time) and diminishing soil fertility after burning. These subtypes are:

1. Shifting cultivation with forest fallow. This system is characterised by long fallow periods (>15 years fallow) during which the forest regenerates.
2. Shifting cultivation with bush fallow. The fallow period is 7 to 9 years which results is a bush type of vegetation.
3. High intensity shifting cultivation. With an increasing pressure on the land available for shifting cultivation, the fallow period becomes shorter: 3 to 5 years. This is the so-called Chromolaena type of shifting cultivation. The name is related to the Chromolaena plant, which dominates the land cover after 3 to 5 years. Research is needed to look into the sustainability of this type of shifting cultivation.

In this land evaluation study, these sub-types are not treated separately as not sufficient data are available to justify that.

Objective
The primary objective of shifting cultivation is the sustainable production of agricultural food and cash crops by the local population. The agricultural produce is for subsistence and cash revenues from local markets.

Cropping system and output
After clearing the main crops planted in association are ngôn, cassava, macabo, plantain and maize. In the second year groundnuts are added to the crop association. Crops are cultivated for approximately three years on forest fields and for two years on bush fields, after which the tending gradually stops. Specific yield data are not available.

Markets
The major part of the crops grown (55 - 80%) is consumed within the family; surpluses are sold at local markets. Transport to the somewhat more distant markets is often problematic, as no regular transport services are available.

Labour input
Clearing (felling, burning) of a forest fallow or a bush fallow is traditionally done by men, using axes and machetes. Occasionally chain saws are hired. Clearing a forest fallow takes more time than clearing a bush fallow. The preparation of new fields is generally carried out by men but women may take part in it as well. Traditionally, tilling, planting, weeding and harvesting is a woman's job.

Capital input
Capital input is very low.

Level of technology
The level of technology is low; only hand-held tools are used for clearing and cultivation (hoe, axe, machete, hand weeding). An exception may be the use of a (hired) chain saw. Seeds are local varieties and not especially cultivated for that purpose. Occasionally seeds are bought. Pesticides and fertilisers are hardly used.

Infrastructure
Roads in the area are poor. Due to this and the lack of organised transport services, access to markets outside the village of production is poor. Access to improved seeds, fertilisers, extension services is poor.

Scale of operations
Field size is 0.5 to 1 ha, depending on the availability of labour. Households open 3 to 4 fields yearly.

3.5 Plantation agriculture

Plantation agriculture is practised in the TCP area but does not cover large surfaces as yet. The main product is cocoa, which is cultivated for cash revenues, mostly by Bantu farmers. Small cocoa plantations are found throughout the area: almost every household has one or more plantations, which are generally smaller than 1 ha, yielding only 1-5 sacks of beans. The cocoa plantations are located near home-gardens and, more often, at the far end of the shifting cultivation fields. In general, the plantations are not well maintained due to low world market prices. The devaluation of the FCFA in 1994 was some incentive for the production, but still more than 50% of the cocoa plantations remain abandoned (Ngoma and Giasson, 1996).

Recently, few large-size oil palm, pineapple and banana plantations have been established in the TCP area. So-called 'élites', comparatively rich villagers who work and live in towns, appear to be the initiators of this development (van den Berg, pers. comm. 1996). Especially, the surface of oil palm plantations seems to be expanding during the last years.

Plantation agriculture is subdivided for the different crops: cocoa (*Theobroma cacao*), rubber (*Hevea brasiliensis*), oil palm (*Elaeis guineensis*) and pineapple (*Ananas comosus*).

Objective
The objective of plantation agriculture is the (relatively) large-scale production of marketable agricultural goods.

Output and market
Outputs are the products of the plantations. For cocoa these are the dried beans. The beans are sold to local traders. The oil palm plantations produce bunches of palm nuts, which mainly go to processing factories but some of which also go to local markets. Rubber trees are tapped and the dried products sold to local traders. Pineapples are sold as fresh fruits on the local markets. Export markets could be explored as well as the possibilities for canning of the fruits and or juice.

Labour input
All commercially oriented plantations need high and hired labour inputs.

Capital input
Capital inputs are initially high, especially for clearing the land and buying planting materials. For established plantations, capital inputs depend on the intensity of the cultivation. Next to costs for labour, inputs for fertilisers, especially for pineapples, and for pesticides are recurrent.

Level of technology
Medium to high levels of technology are needed to successfully manage plantations.

Infrastructure
A good road infrastructure is needed to transport products of the plantations to the markets.

Scale of operations
Scale of operations varies from a few hectares to in some cases over a hundred hectares.

3.6 Other land use types

Other land use types are present in the area. They are briefly mentioned hereafter but not treated in the land suitability classification as they are either having a very limited spatial extent or may be temporary only.

Villages and home-gardening/animal husbandry
At short distance of the village, some of the wild growing plants are treated with special care, while several other species are planted to produce fruits or legumes (home-gardening). The following fruit trees are encountered (in order of decreasing importance): avocado, plum, mango and citrus (Ngoma and Giasson, 1996). Small-scale animal husbandry (chickens, pigs and goats) is also taking place in and around the villages. The transition from this zone to the agricultural zone is diffuse.

Sacred places
Sacred places are places in the forest where spiritual or religious ceremonies take place. A sacred place can be a hill, a rock, a tree, a valley, etc. They are dispersed all over the TCP area, but identification and mapping of these places is difficult. The sacred places are only accessible for selected people. The forest as a whole is considered as the residence of the ancestors, a place of knowledge and comfort. In this way it is important to the total population.

Research
Most current scientific research in the area takes place within the framework of the Tropenbos-Cameroon Programme (TCP). Permanent sample plots and detailed survey areas occupy small areas of 25 km^2 at the most. Up to now four detailed surveys areas have been established in which research is concentrated. The main fields of research are forestry, ecology, hydrology and sociology. The distribution of the plots and survey areas is related to the major landscape gradients described by van Gemerden and Hazeu (1999).

4 LAND USE REQUIREMENTS

An overview of the most important land use requirements and their relative importance for the different land utilisation types in the TCP area is given in Table 4.1.

Table 4.1. Relative importance of land use requirements for the land utilisation types in the Tropenbos-Cameroon area.

Land use requirements (LURs)	Land utilisation types (LUTs)				
	biodiversity conservation	NTFP extraction	timber production	shifting cultivation	plantation agriculture
(1) related to growth					
Drainage condition	-	-	-	++	++
Rooting conditions	-	-	-	++	++
Nutrient availability	-	-	-	++	++
Timber species	-	-	++	-	-
Non-timber forest products (NTFPs)	+	++	-	+	-
Conservation value flora and vegetation	++	-	-	-	-
Food plants for wildlife	++	++	-	-	-
Habitat quality	++	++	-	-	-
(2) related to management					
Workability	-	-	-	++	++
Terrain condition	-	+	++	+	++
Size of management unit	++	++	++	-	+
Accessibility	-/+	++	+	++	+
(3) related to conservation					
Tolerance to soil erosion	-	-	++	++	++

- = not important; + = important; ++ = very important

4.1 Requirements related to growth

In the FAO land evaluation terminology growth requirements refer to the land conditions necessary for survival and growth of trees and crops (FAO, 1984; Touber *et al.*, 1989). To include nature conservation as land use, the method needs to be adjusted. The suitability for nature conservation means the priority of an area to be protected on the basis of its intrinsic conservation value. The "growth" requirements can consequently be interpreted as criteria to assess this conservation value.

Growth requirements considered relevant in this land evaluation study are drainage condition, soil depth, nutrient availability, timber species, non-timber forest products, conservation value of flora and vegetation, and habitat quality. Moisture availability is not included, as the length of the growing period is not a limiting factor in the Tropenbos-Cameroon region.

Drainage condition is important for the availability of oxygen and moisture to plants. In the Tropenbos-Cameroon area lower topographical positions (valley bottoms) have imperfectly to very poorly drained soils, whereas on the slopes soils are well and moderately well drained.
The LUR drainage is of most importance for the LUTs shifting cultivation and plantation agriculture.

Rooting condition is expressed as the rootable depth whereby the percentage gravel or stones in the soil is taken into consideration (Touber *et al.*, 1989). The soil depth determines the soil volume available for roots for water extraction and nutrient uptake. This land use requirement is relevant for the LUTs shifting cultivation and plantation agriculture.

Nutrient availability is mainly determined by, Cation Exchange Capacity (CEC), pH and/or base saturation (the latter two are related) and organic matter content. The organic matter content of the topsoil is one of the most important characteristics determining the fertility of soils in the humid tropics. The LUR nutrient availability is important for the LUTs shifting cultivation and plantation agriculture. In light of intensification of agriculture as a result of increasing population or demands for agricultural produce, nutrient availability becomes more important. It can, however, be influenced by management practices.

The LUR *timber species* refers to the potential of land to produce timber. It is expressed by abundance of specific timber species, growth rates and predicted yields. The LUR timber species is important for the LUT production of timber in natural forest and for NTFP collection.

The LUR *non-timber forest products* (NTFPs) refers to the abundance and diversity of non-timber forest commodities. The requirement is relevant for the LUTs extraction of NTFPs by local population. It may also serve as secondary objective in the LUTs biodiversity conservation, production of timber in natural forest and shifting cultivation

Conservation value flora and vegetation defines the need for conservation of flora and vegetation. Criteria to determine the conservation value are (among others) species diversity, occurrence of rare species (uniqueness), and naturalness (absence of human interference) (cf. de Groot, 1992; Hawthorne, 1996). This LUR is especially important for the LUT protection of biodiversity.

Food plants for wildlife refers to the presence of food resources for four selected species. This requirement is in the present land evaluation study estimated on the basis of the requirements of large mammals. This group of species has low population densities and large home ranges and safeguarding their needs is assumed to cover the habitat requirements of many forest dependant species. Gorilla, chimpanzee, mandrill and collared mangabey are used as such 'umbrella' species. The LUR habitat quality is especially important for the LUTs protection of biodiversity and extraction of NTFPs by the local population.

The LUR *habitat quality* has two aspects. One refers to the availability of water, resting places, and the distance to human settlements and activities (e.g. roads). As such it is an indication of the potential for fauna conservation. The other aspect is related to NTFP species and reflects the heterogeneity of the landscape. The more divers the landscape is the more (ecologically specific) NTFP species are found.

4.2 Requirements related to management

Management requirements are the conditions necessary or desirable for successful management of the defined land use (FAO, 1984; Touber *et al.*, 1989). Management requirements considered relevant in this land evaluation study are workability, terrain conditions, size of potential management unit, and accessibility.

Workability refers to the texture, structure and consistence of the soil. Workability expresses the ease to work the land and the suitability to cultivate certain crop types, e.g. tubers. In the Tropenbos-Cameroon region only soil texture varies significantly and the workability in the present study is therefore based on this characteristic. This requirement is especially relevant for the LUTs shifting cultivation and plantation agriculture.

The LUR *terrain condition* reflects the suitability of the land for mechanised operations. It is valued by the absence of steep slopes, of swampy areas and of rock outcrops. This requirement is especially important for the LUTs production of timber in natural forest and plantation agriculture. For shifting cultivation and extraction of NTFPs by local population the terrain conditions play a role as well but are less crucial.

The LUR *size of management unit* is defined by area needed for 'economic' management of a LUT. In land uses with mainly production-oriented objectives, the size of the management unit is primarily based on an economic optimisation of the management system. For conservation purposes the management unit should be sufficient to support viable populations of species. The viability of populations depends on the genetic diversity within the population, and the availability of sufficient food, water and resting places in the management unit. Horizontal relationships in the landscape are important in this respect

Accessibility of the land is an important management requirement. It is determined by the possibilities for linkage with the present road network. Also the distance to (potential) markets is included. The LUR accessibility is relevant for the LUTs NTFP collection by local population, shifting cultivation and plantation agriculture. For biodiversity conservation, accessibility is needed for safeguarding and monitoring only. For the LUTs production of timber in natural forest and most forms of large scale plantation agriculture, the distance to existing roads and markets is only of limited importance as roads can be constructed and more heavy means of transport are available.

4.3 Requirements related to conservation

Conservation requirements refer to the effects of management activities on soils, hydrology and vegetation (FAO, 1984; Touber *et al.*, 1989). The only conservation requirement treated in this biophysical land evaluation study is tolerance to soil erosion.

Tolerance to soil erosion refers to the texture, slope, susceptibility to surface sealing and crusting, and land cover of an area. The land use requirement tolerance to erosion is relevant for the land utilisation types production of timber in natural forest, shifting cultivation and plantation agriculture.

Conservation requirements in the FAO terminology often refer to sustainability aspects of land use. Sustainability of land use depends on the balance between biophysical setting and the LUT specific management activities. In Section 12.5 (Sustainability of land use) further aspects of sustainability are treated at management level.

5 LAND INVENTORY

5.1 The physical environment

The TCP study area in south Cameroon measures some 1700 km^2. It is situated on the transition of the coastal plain and the more elevated area of the Precambrian shield in the interior. The climate is equatorial with an approximate mean annual temperature of 24°C. Although rainfall occurs throughout the year, two relatively wet seasons can be distinguished: September – November, and April – May. The mean annual rainfall is some 2000 mm. The rainfall is not evenly distributed over the area: annual rainfall totals tend to decrease with increasing distance from the coast.

The hydrology of the study area is characterised by a high drainage density as a result of the humid climate and the low permeability of the crystalline rock formations. The flow direction of the major rivers is NNE-SSW; smaller streams have a flow direction essentially perpendicular to the main rivers. The discharge patterns of the rivers correspond to the seasonal rainfall pattern (Waterloo *et al*., 1997). Swamp areas are largely restricted to the valleys of the smaller rivers.

The geomorphology of the study area is quite divers, landforms range from low dissected plains in the NW to relatively high mountains in the SE. The altitudinal range is 40 to 1000 m. Four ecological zones related to altitude are discerned (van Gemerden and Hazeu, 1999):
- zone A: altitude 700 – 1000 m.; mountains; hills;
- zone B: altitude 500 – 700 m.; hills, uplands;
- zone C: altitude 350 – 500; hills, uplands;
- zone D: altitude 40 –350 m; hills, uplands, plains.

A fifth ecological zone, not related to altitude, consists of relatively extensive valley bottoms. As indicated above all zones (except E) consist of several landforms. The landforms discerned with their relief characteristics are given in Table 5.1.

Table 5.1 Relief characteristics of the different landforms (after van Gemerden and Hazeu, 1999)

Landform units	Slope length (m)	Slope (%)	Relief intensity (m)	Altitude range (m)	Extent (km^2)
Dissected erosional plains (pd)	50 – 200	5 – 15	20 – 30	40 – 280	110
Uplands (u1)	100 – 200	10 – 20	10 – 50	120 - 700	480
Uplands (u2)	150 – 300	10 – 30	30 – 80	120 – 700	690
Isolated hills (h1)	250 – 500	> 30	120 – 300	200 – 900	116
Complex of hills (h2)	200 – 350	20 – 40	80 – 200	350 – 700	139
Mountains (m)					
- outside slopes	> 400	> 30	> 250	> 500	100
- inside slopes	250 – 400	30 – 60	120 – 250		
Valley bottoms (v)		0- 2	< 10	40 – 700	15

The soils of the Bipindi - Akom II – Lolodorf area may be subdivided into four main types. This subdivision is based on drainage characteristics and the texture of both topsoil and subsoil. The soils within the study area also vary in depth, stoniness, and in the occurrence of phlinthite in the subsoil. These characteristics, however, are not systematically related to the position in the landscape and are therefore not used as determining criteria in the soil typology. The main soil types and their diagnostic criteria are listed in Table 5.2.

Table 5.2 Soil types of the TCP research area and their diagnostic criteria (after van Gemerden and Hazeu, 1999).

Soil type	Drainage	Texture (% clay topsoil)	Texture (% clay subsoil)
Nyangong	Well drained	40-70% (heavy clay)	50-80%
Ebom	Well drained	20-40% (sandy loam to sandy clay)	35-60%
Ebimimbang	Moderately well to well drained	9-25% (sand to sandy loam)	20-45%
Valley Bottom	Poorly to very poorly drained	5-30% (loamy sand to sandy clay loam)	Variable

topsoil = 0-25 cm; subsoil = 25-100 cm

5.2 Vegetation and wildlife

South Cameroon forms part of the Guineo-Congolian domain of which the primary vegetation mainly consists of dense humid evergreen forests, and which is subdivided into a submontane zone (altitudes > 800 m) and a zone with low and medium altitudes. The lower zone is subdivided into four districts which reflect ecologically relevant differences in climate (Letouzey, 1985).

The TCP research area is situated within the Biafran Atlantic district that is characterised by an evergreen rainforest rich in *Caesalpiniaceae*. Only the higher parts of the southeastern area reach into the submontane zone, whereas the lowest parts of the northwestern area (near Bipindi) can be considered as a transition zone towards the Littoral Atlantic forest with (formerly) an abundance of *Lophira alata* (azobé). The actual vegetation of the TCP research area, however, not only includes primary rainforest, but also various types of secondary growth. Based on their floristic composition seven distinct vegetation types ('plant communities') can be discerned which reflect major differences in altitude, disturbance and drainage (van Gemerden and Hazeu, 1999). Denomination and ecological interpretation of the 7 vegetation types are given in Table 5.3.

Table 5.3 Vegetation types of the TCP research area (after van Gemerden and Hazeu, 1999)

Denomination		**Interpretation**
I.	*Maranthes-Anisophyllea* community	submontane primary and old secondary forest; altitude > 700 m asl; well drained soils
II.	*Polyalthia* community group	primary and old secondary lowland forest; altitude < 700 m asl; well drained soils
IIa.	*Podococcus - Polyalthia* community	as above: altitude 500 - 700 m asl; well drained soils
IIb.	*Strombosia - Polyalthia* community	as above: altitude 350 - 500 m asl; well drained soils
IIc.	*Diospyros - Polyalthia* community	as above: altitude < 350 m asl; moderately well drained soils
III.	*Carapa-Mitragyna* community	swamp forest; most common on low altitudes; valley bottoms
IV.	*Xylopia-Musanga* community	young secondary forest; throughout area but most common on low altitudes
V.	*Macaranga-Chromolaena* community	thicket on recently abandoned fields and cacao plantations; throughout the area, but most common on low altitudes

During the reconnaissance survey of the TCP research area, some 490 plant species, belonging to 76 families, were recorded (van Gemerden and Hazeu, 1999). Annex 2 gives an estimate of the distribution of each of these species over the 7 vegetation types. A concise version of this summary table is given in Table 5.4, listing twenty of the most important differentiating species. The results of the reconnaissance survey allow for a reliable comparison of the vegetation types discerned with regards to species number, rarity and endemism.

Table 5.4 Summary table of plant communities in TCP research area with some of the most important differentiating species (after van Gemerden and Hazeu, 1999)

Plant communities:	I	IIa	IIb	IIc	III	IV	V
Differentiating species:							
Anisophyllea polyneura	5	2	1	r	.	+	r
Scorodophloeus zenkeri	4	1	+	+	.	.	r
Maranthes glabra	3	.	.	.	.	.	.
Raphia cf regalis	3	3	1	-	-	-	-
Polyalthia suaveolens	2	4	4	4	2	1	.
Scaphopetalum blackii	2	4	4	2	2	+	1
Hymenostegia afzelii	+	3	1	r	r	.	.
Podococcus barteri	.	2	1	+	1	+	.
Grewia coriacea	+	.	1	1	+	1	.
Cola cordifolia	.	r	2	+	+	.	.
Diospyros suaveolens	+	1	1	4	3	r	r
Buchholzia coriacea	r	r	+	2	+	.	.
Mitragyna stipulosa	.	.	r	.	5	.	+
Carapa spec	.	.	.	.	3	.	.
Xylopia aethiopica	2	1	2	1	2	4	2
Thaumantococcus daniellii	.	.	+	+	+	3	2
Musanga cecropioides	r	2	.	1	2	5	4
Funtumia elastica	.	+	r	+	+	2	3
Macaranga barteri	.	r	.	.	r	2	4
Chromolaena odorata	.	.	.	.	.	+	4
Milicia excelsa	.	.	.	+	.	.	3

Frequency classes: . = absent; r = occurring once; + = present in 1-9% of the relevés; 1 = 10-19%; 2 = 20-39%; 3 = 40-59%; 4 = 60-79% and 5 = 80-100%.

The tropical moist forest area of Cameroon possesses high levels of endemic flora and fauna (Gartlan, 1989). As for mammals, some 132 species are found in the humid forests of Cameroon (Vivien, 1991), among which endangered species like elephant (*Loxodonta africana cyclotis*), western lowland gorilla (*Gorilla gorilla gorilla*), chimpanzee (*Pan troglodytes troglodytes*), mandrill (*Mandrillus sphinx*), African leopard (*Panthera pardus*), forest buffalo (*Synceras caffer nanus*) and bongo (*Tragelaphus eurycerus*) (IUCN, 1988). No systematic census of the mammals of the TCP area has taken place. Van Dijk (1997), in her study on non-timber forest products, interviewed villagers on the use and presence of 'bush meat'. Her survey reveals that, although the elephant has become extinct, the TCP research area still harbours gorillas, chimpanzees and mandrills. Bekhuis (1997) studied, within the framework of the Lu1 project, the habitat requirements of some larger mammal species.

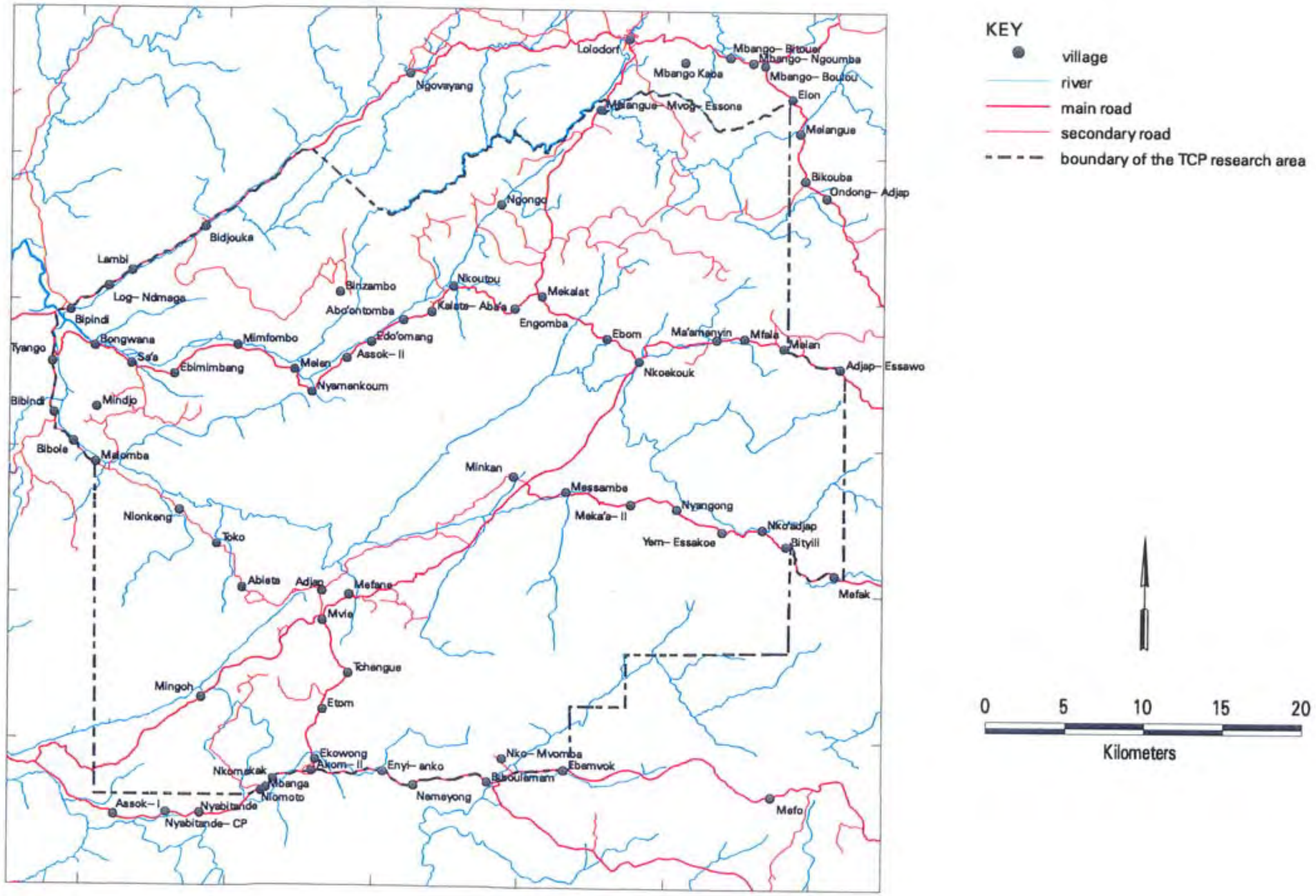
Other fauna groups are not included in the land evaluation procedure due to lack of systematic observations. The available data on the avifauna may serve as an example. Some 849 species of birds are found in Cameroon (Louette, 1981) and at least 390 species are known to occur in the Korup National park and its surroundings in the Southwest Province (Rodewald *et al.*, 1994). As for the TCP research area, the legacy of a few individuals has resulted in the drafting of a preliminary bird species list which includes until now 'only' 125 species of which the distribution over the various land units is hardly known (van Gemerden, in prep.).

5.3 Land users

In 1966-67 a number of 15 000 to 18 000 inhabitants was recorded in the area, which is less than 10 inhabitants per km^2 (Franqueville, 1973). The population growth was estimated to be within the range of 0 and 4% per year. In 1987 the population density was assumed to be within the range of 15 to 30 inhabitants per km^2 (MINPAT, 1991). A study covering some villages in the Akom II area indicated that the population increased fourfold since 1966-67 (Ngoma and Giasson, 1996). The same study proves the population to be very young (only 25% older than 30 years) and increasing rapidly due to immigration from the cities. This study, however, is not representative for the TCP area.

LOCATION OF VILLAGES

Bipindi– Akom II– Lolodorf region, South Cameroon



Map 5.1

A recent study by Lescuyer *et al*. (1999) came to a total of 14 370 habitants in the TCP area. Children who are schooling outside the area have not been counted but can not be more than 6000 (2 per household). Biesbrouck (pers. comm. 2000) indicated that al least some 200 Bakola pygmies have not been included in that survey. Nevertheless, compared to 1966-67, the population has hardly increased in number.

The location of the villages in the TCP research area is shown in Map 5.1. Most villages are situated along the main roads, at places with drinkable water nearby. The roads are preferably constructed in relatively accessible land (flat, gradual slopes, no swamps). They give connection to other villages and towns in which schools, health facilities, etc. can be found. Only the Bakola villages are not situated along the roads.

The relative importance of economic, social and ecological sustainability for the different stakeholders in the TCP area, as estimated by the researchers of the TCP project, is indicated in Table 5.5.

Table 5.5. Relative importance of economic, social and ecological sustainability for the different stakeholders in the TCP area

	Fields of Sustainability[1)]		
Stakeholders	Economic	Social	Ecological
Government	+++	++	+
Concession holders	+++		
Bantus	+++	++	+
Bakola	+	+++	++
Tropenbos	+	++	+++
Tourists		++	+++

[1)] Plusses indicate relative importance: + slightly important, ++ moderately important, +++ very important

The land user groups, which can be discerned in the TCP area, are described hereafter. The Bantu and Bakola are the two main ethnic groups actually living in the area.

Bantu

A large majority of the TCP area's inhabitants (98%) belong to the Bantu people. In 1966-67, Franqueville (1973) found the following tribal composition: Bulu 45%, Ngoumba 30%, Fang 15%, and Bassa 7%. Recent data indicate that of the 66 villages 47 (71%) have mainly Bulu inhabitants, 4 (6%) have mainly Fang people and 2 (3%) are dominated by the Bassa tribe.

The Bantus have an economic and socio-cultural interest in the forestland. The forest provides them with food (bushmeat and NTFPs), water, medicines, construction material, fuel wood, income through commercialisation, and areas for agriculture. Originally, the Bantus were nomads who sedentarised and became farmers with fields for subsistence agriculture and cocoa plantations to make some cash income. Nowadays, agricultural activities consume about 70% of their time and hunting and gathering take about 20% (Tiayon, 1997b). Agricultural activities imply shifting cultivation and/or plantation agriculture. The larger plantations, of which there are only a few in the area, are owned by the so-called 'élites': natives working and living outside the area. The plantations provide them with additional income. Yet another group of Bantu people gets an income as contract labourers in the commercial logging industry.

Bakola

The Bakola pygmies are the indigenous population of the TCP research area. In 1966-67, they made up only 3% of the population of the TCP area (Franqueville, 1973). Recent data come to 286 (2%) Bakola people in the area (Lescuyer *et al*., 1999) but according to Biesbrouck (pers. comm. 2000) could amount to some 4%. The Bakola are mostly self-subsistent and live in close harmony with their environment, the tropical rainforest, on which their cultural and social life depends. Their main activities are hunting, fishing and gathering of NTFPs. These provide them with food, water, medicines, fuel wood, construction material and income. They exchange products and services with the Bantu farmers. They also use the forest as habitat and in spiritual rites (sacred places).

Loung (1992) distinguished three types of pygmy life-style, according to their main activities: (i) hunting as main and gathering as side activity, (ii) hunting and gathering as main activities and agriculture as side activity, and (iii) agriculture as main activity. Currently, the Bakola culture seems to be in transition from pure forest dwelling to incorporation in a (local) market economy (Biesbrouck, 1999a).

Concession holders
The concession holders can be divided into national and international companies. They both have an economic interest in the forest. The extraction of tropical hardwood is regulated by national and international laws.

The international logging companies are directed to the export of tropical hardwood. Only small amounts are sold at national level. They are extracting specific species depending on the 'niche' in the international market to which the company is directed. The width of the 'niche' determines the number of species extracted and consequently the extent of logging damage. Their logging equipment is expensive, well maintained and has high redemption costs. To optimise the use of the logging equipment, deep penetrations into the forest take place in relatively short periods of time. The international companies construct exploitation roads and can exploit relative difficult accessible tracts of land. They exploit larger areas in a relative short period when compared to the national logging companies (van Leersum, pers. comm. 1997).

The national concession holders produce for local sale or for international companies. In the latter case they may operate as contractors. Their production is determined by sale contracts they have obtained beforehand. This implies that the trees, which are logged, are already sold. In general, their equipment is old and has low redemption costs. As a consequence, they stay longer in a certain tract of forest land. The national companies exploit only relatively flat areas in the surroundings of roads as a consequence of the low maintenance level of their material (van Leersum, pers. comm. 1997).

Tropenbos
The Tropenbos-Cameroon Programme is a NGO, which uses certain parts of the TCP research area for permanent research on the development of methods for sustainable use of the tropical rainforest. Their use of the forest is temporary and aims to contribute to a management plan of the region. Long-term plots for monitoring and research have been established and can be taken over by national research organisations.

Tourists
Tourists are mentioned as an optional land utilisation group. Up to now, tourism is of no significance in the region but there certainly is some potential. Development of tourism, however, depends on conservation of flora, fauna, and landscapes, but also on the lifestyle and culture of the local people.

Administration
The administration or government is responsible for the planning and control on the use of the land and has the right to issue rules and laws concerning land use. This group of stakeholders acts at different levels: government ministries, provinces, departments and municipalities.

The *'Loi N° 94/01 du 20 janvier 1994, portant régime des forêts, de la faune et de la pêche'* (Anonymous, 1994b), the '*Décret N° 94/436 du 23 août, fixant les modalités d'application du régime des forêts'* (Anonymous, 1994a) and the zonation plan (Côté, 1993) are part of the political setting in which land evaluation and land use planning have to take place. The forest law defines in general terms the legal conditions. Definitions of different forest types are presented which can be grouped under two main types: permanent and non-permanent forest. These are indicated in a 'zonation plan' (Côté, 1993). Two types of permanent forest are discerned: production forest ('forêt domaniale') and protection forest. Production forest is planned just north of the Lokoundjé river in the western part of TCP research area, whereas the protection forest is situated in the Bingalanda mountain range in the eastern part. The largest part of the TCP area (over 60%), however, is marked as a zone influenced by local population. This zone is not classified as national forest domain (Anonymous, 1994a). Habitation and agro-forestry are given as the main land uses and are situated along the main roads. The area allocated to this zone is based on the estimated needs of the local population up to the year 2020 (Côté, 1993).

5.4 Land mapping units

The landscape ecological mapping units discerned by van Gemerden and Hazeu (1999), which serve as an expedient for the land evaluation procedure, are listed hereafter. The descriptions given are based on the reconnaissance survey report. More detailed data on land qualities are provided in the next chapter.

The spatial distribution of the land mapping units is presented on the landscape ecological map, scale 1 : 100 000 (van Gemerden and Hazeu, 1999; annex I). The various land mapping units are defined by:

- altitudinal range (ecological zone);
- a specific landform;
- the degree of forest disturbance by shifting cultivation;
- a specific combination of soil types;
- a specific combination of vegetation types.

The four altitude zones A (700 - 1000 m asl), B (500 - 700 m asl), C (350 - 500 m asl) and D (< 350 m asl) which are discerned by van Gemerden and Hazeu (1999) reflect differences in land characteristics such as radiation regime, temperature, air humidity, and rainfall. Mean monthly temperatures are between 22 and 28^{o} C. The yearly rainfall in the TCP research area is around 2000 mm and falls throughout the year. Two short dry seasons are recognised. The variation of these characteristics within the TCP research area is small. In combination with other biophysical factors, however, these small differences have resulted in different vegetation types. Vegetation type is therefore an important land quality in case of the land utilisation types timber production and protection forest.

The altitudinal range (ecological zone), landform and degree of disturbance can be deducted from the codes used. For instance, Ah1(u) refers to undisturbed (u) isolated hills (h1) in ecological zone A (700 – 1000 m asl). The specific combination of both soil types and vegetation types, and the surface area of the various land mapping units is given in Table 5.6.

Am: mountains above 700 m asl, well drained soils
The Am land mapping units coincide with the Bingalanda mountain range in the eastern part of the TCP area, with altitudes between 700 and 1000 m asl. The mountainous area is strongly dissected and has very steep slopes (>30%). Rock outcrops or (very) shallow soils occur on upper slopes. Valley bottoms are narrow and cover only very limited areas.
Soils, mainly Nyangong soils, are variable in depth, well drained and very clayey. The dominant colour is strong brown. They have high organic carbon contents, low CECs - clay, low pHs and a low base saturation; therefore the fertility of these soils is low.
The predominant forest type is the submontane *Maranthes-Anisophyllea* community (I). In general, the vegetation is not affected by human activity (logging or shifting cultivation). Human activities are restricted to low intensity hunting and gathering.

Table 5.6. Soil types, vegetation types and surface area of the land mapping units.

LMU	Soil				Vegetation							area	
	Ny.	Eb.	Em.	Vb.	I	IIa	ÍIb	IIc	III	IV	V	ha	%
Am (u)	5	+			5	+						10064	6.0
Ah1 (u)	5	+			5	+						879	0.5
Bh1 (u)	5					5						3043	1.8
Bh1 (l)	5					3				1	1	772	0.5
Bh2 (u)	5	+				5						12329	7.4
Bh2 (l)	5	+				3				1	1	721	0.4
Bh2 (h)	5	+				1				2	3	847	0.5
Bu2 (u)	3	2		+		5			+			14594	8.7
Bu2 (l)	3	2		+		3			+	1	1	3350	2.0
Bu2 (h)	3	2		+		1			+	2	3	1755	1.0
Bu1 (u)	3	2		1		5			1			2484	1.5
Bu1 (l)	3	2		1		2			1	1	1	2831	1.7
Bu1 (h)	3	2		1		1			1	2	3	88	0.1
Ch1 (u)		5					5					3920	2.3
Ch1 (l)		5					3			1	1	596	0.4
Cu2 (u)		5		+			5		+			20785	12.4
Cu2 (l)		5		+			3		+	1	1	3110	1.9
Cu2 (h)		5		+			1		+	2	3	1179	0.7
Cu1 (u)		5		1			5		1			16936	10.1
Cu1 (l)		5		1			3		1	1	1	7163	4.3
Cu1 (h)		5		1			1		1	2	3	7171	4.3
Dh1 (u)		1	5					5				2543	1.5
Dh1 (l)		1	5					3		1	1	770	0.5
Du2 (u)		+	5	+				5	+			17222	10.3
Du2 (l)		+	5	+				3	+	1	1	4691	2.8
Du2 (h)		+	5	+				1	+	2	3	2033	1.2
Du1 (u)			5	1				5	1			7896	4.7
Du1 (l)			5	1				3	1	1	1	3650	2.2
Du1 (h)			5	1				1	1	2	3	1078	0.6
Dpd (u)			4	1				4	1			2246	1.3
Dpd (l)			4	1				3	1	1	1	1835	1.1
Dpd (h)			4	1				1	1	2	3	7179	4.3
Ev (u)				5					5			1261	0.8
Ev (l)				5					3	1	1	334	0.2

LMU: land mapping unit (descriptions given hereafter); Ny: Nyangong soil type; Eb: Ebom soil type; Em: Ebimimbang soil type; Vb: Valley bottom soil type. I to V: vegetation communities (descriptions given hereafter). Coverage classes: +: 5-9%, 1: 10-19%, 2: 20-39%, 3: 40-59%, 4: 60-79%, 5: 80-100%.

Ah1: isolated hills above 700 m asl, well drained soils

These mapping units are found along the fringes of the Bingalanda massive in the eastern part of the TCP area. The altitude of the isolated hills vary from 700 to 900 m asl. They have very steep (>30%) and long slopes (250-500 m). The summit areas are relatively small. Rock outcrops may occur at the upper slopes. Valley bottoms are not included in this unit.
The predominant forest type is the submontane *Maranthes-Anisophyllea* community (I). Human activities have not altered the vegetation in these units.

Bh1: isolated hills between 500 and 700 m asl, well drained soils

These mapping units are found scattered as small patches in the eastern part of the TCP area. The soils are very clayey and belong to the Nyangong type. They have very steep (>30%) long slopes (250 - 500m). The summit areas are relatively flat and small. Valley bottoms are absent.
The vegetation is predominantly primary and old secondary lowland forest of the *Podococcus-Polyalthia* community (IIa). Human activities have not, or only locally, altered the vegetation of these units.

Bh2: complex of hills between 500 and 700 m asl, well drained soils

These complexes of hills are found in the strongly dissected eastern part of the TCP research area. They cover large areas just west of the Bingalanda mountain range and have a general SW-NE orientation. In addition, Bh2 units are found in the southwestern part of the TCP research area, where they form the foothills of the mountain range that is situated west of the

TCP research area. Bh2 units are strongly dissected with moderate to steep slopes (20 - 40%). Valley bottoms are narrow and cover only limited areas. At a larger scale the complexes can be disentangled into individual hills in a rolling to hilly landscape.
The dominant soils are the deep to very deep, well drained, strong brown to yellowish brown, very clayey Nyangong soils. The soil fertility is low.
The vegetation is predominantly primary and old secondary lowland forest of the *Podococcus-Polyalthia* community (IIa). Human activities are largely restricted to hunting and gathering. Shifting cultivation has locally altered the vegetation composition.

Bu1: rolling uplands between 500 and 700 m asl; well drained soils
Bu1 units are only found in the most eastern part of the TCP area. These rolling uplands are moderately dissected with moderately steep (10-20%), 100 - 200 m long slopes. Valley bottoms are estimated to cover 10 to 15% of these mapping units. In places, these valley bottoms are sufficiently large to be mapped individually. The soils form an association of Nyangong and Ebom types. The valley bottoms are typically poorly to very poorly drained.
The Bu1 units are partly affected by human activities. Near the village of Nyangong a large area with low intensity shifting cultivation is present. Primary and old secondary lowland forest of the *Podococcus-Polyalthia* (IIa) community is the predominant vegetation of the relatively undisturbed areas. The shifting cultivation areas are characterised by a vegetation mosaic that contains disturbed lowland forest of the *Podococcus-Polyalthia* community, young secondary forest of the *Xylopia-Musanga* community (IV) and thicket of the *Macaranga-Chromolaena* community (V). The valley bottoms are covered by swamp forest of the *Carapa-Mitragyna* community (III).

Bu2: hilly uplands between 500 and 700 m asl; well drained soils
The hilly uplands of the Bu2 units are located at the foothills of the Bingalanda mountain range in the eastern part of the TCP area and extend up to the northeastern part of the area. The uplands are strongly dissected with moderately steep (10-30%), 150 - 300 m long slopes. Valley bottoms are estimated to cover some 5 to 10% of the surface.
The soils are an association of very clayey Nyangong soils and the clayey Ebom ones. Generally, these soils are moderately deep to very deep, well drained, yellowish to strong brown clay soils. The valley bottoms are characterised by poorly drained soils.
The dominant vegetation type is the primary and old secondary forest of the *Podococcus-Polyalthia* community (IIa). The units are to a limited extent affected by agricultural practices as only along the roads some low intensity encroachment is visible. In these areas, the lowland forest of the *Podococcus-Polyalthia* community (IIa) has gradually changed into a mosaic of thicket of the *Macaranga-Chromolaena* community (V), with young secondary forest of the *Xylopia-Musanga* community (IV), and. The swamp forest of the Carapa-Mitragyna community (III) covers the valley bottoms.

Ch1: isolated hills between 350 and 500 m asl, well drained soils
The isolated hills form a characteristic aspect of the central and northern region of the TCP area, which is mainly composed of uplands. They have very steep (>30%) and long slopes (250-500 m). The summit areas are relatively small. Rock outcrops may occur at the upper slopes. No valley bottoms are found.
The soils are predominantly clayey and classified as Ebom soils. These soils are well drained and yellowish brown.
The vegetation is primary and old secondary forest of the *Strombosia-Polyalthia* community (IIb). Human activities have hardly affected the vegetation of these units, most likely because of the steep slopes.

Cu1: rolling uplands between 350 and 500 m asl; well drained soils
Cu1 units are situated in the central and northern regions of the TCP area. With the hilly uplands in the ecological zones C (Cu2) and D (Du2), they form the major land mapping units of these regions. Together they cover almost half of the total area. The rolling uplands are

moderately dissected, having moderately steep (10 - 20%) and 100 - 200 m long slopes. Some 10 to 15% of the rolling uplands consist of valley bottoms.
The dominating soils of the slope and summit areas are clayey Ebom soils, which are moderately deep to very deep, well drained and yellowish to strong brown. Soil fertility of these soils is intermediate. The soils of the valley bottoms are typically poorly to very poorly drained.
The vegetation of the valley bottoms belongs to the *Carapa-Mitragyna* community (III), whereas the well drained areas are for the greater part covered by primary and old secondary lowland forest of the *Strombosia-Polyalthia* community (IIb). Near villages and roads, however, considerable parts of the rolling uplands of Cu1 are occupied by high intensity shifting cultivation. The vegetation in these areas consists of a mosaic of actual fields, recently abandoned fields with secondary shrubland (*Macaranga-Chromolaena)* community; V), young secondary forest (*Xylopia-Musanga* community; IV), and remnants of obviously disturbed lowland forest of the *Strombosia-Polyalthia* community (IIb). According to the aerial photographs, the vegetation outside the shifting cultivation areas units is relatively undisturbed. Field observations, however, suggest that considerable parts of the forest have been exploited for timber. Due to the lack of recent remote sensing material the extent of logging could not be mapped.

Cu2: hilly uplands between 350 and 500 m asl; well drained soils
These mapping units occupy considerable areas in the central and northern regions of the TCP area. The general orientation of these mapping units is SW-NE. The uplands are strongly dissected and an estimated 5 to 10% consists of valley bottoms.
The predominant vegetation of the well drained part of the Cu2 units is primary and old secondary lowland of the *Strombosia-Polyalthia* community (IIb). Swamp forest of the *Carapa-Mitragyna* community (III) covers the valley bottoms. Shifting cultivation covers limited areas and occurs in the southern part of the unit near the villages of Adjap and Akom II and in the northern parts and is generally of low intensity. The vegetation in these areas is a mosaic of disturbed lowland forest of the *Strombosia-Polyalthia* community (IIb), and young secondary vegetation of the *Xylopia-Musanga* community (IV), and the *Macaranga-Chromolaena* community (V). Furthermore it is observed that most of the forest has been logged in the recent past.

Dh1: isolated hills below 350 m asl, moderately well to well drained soils
These isolated hills are restricted to the western part of the TCP area. They have very steep (>30%) and 250 - 500 m long slopes. The small summit areas are relatively flat. Valley bottoms do not form part of this unit. The soils (Ebimimbang type) are moderately deep to very deep, moderately well to well drained, yellowish brown sandy clay loam to (sandy) clay soils with a sandy to sandy loam topsoil. Subsoils may contain up to 40% clay. These Ebimimbang soils have a relatively high CEC-clay, pH and base saturation.
The predominant vegetation of these units is primary and old secondary lowland forest of the *Diospyros-Polyalthia* community (IIc). The vegetation of the isolated hills with their steep slopes has hardly been affected by recent human activities.

Dpd: dissected erosional plains below 350 m asl; moderately well to well drained soils
The dissected erosional plains are found in the northwest of the TCP area. The low relief intensity and low altitude are characteristic features of the landscape. The relief is undulating to rolling with short slopes of 5 - 15%. An estimated 10-15% of the plains consist of valley bottoms.
The dominant soil type is the Ebimimbang soil. The soils are moderately deep to deep, moderately well drained, yellowish brown sandy clay loams to (sandy) clays with sand to sandy loam topsoils. The CEC - clay, pH and base saturation are relatively high, indicating a relative high soil fertility.
Shifting cultivation has largely affected the Dpd mapping units. Favourable soils and landforms have resulted in a long tradition of agricultural practice, especially near the village of Bipindi. Moreover, the area has at least three times been logged for commercial timber. The vegetation forms a mosaic of actual fields, recently abandoned fields with the *Macaranga-Chromolaena*

community (V), young secondary forest (*Xylopia-Musanga* community; IV) and remnants of obviously disturbed lowland forest (*Diospyros-Polyalthia* community; IIc).

Du1: rolling uplands below 350 m asl; moderately well to well drained soils
Rolling uplands below 350 m asl are restricted to the western part of the TCP area. They are moderately dissected with slopes of 10 - 20%. Valley bottoms occupy some 10 to 15% of the rolling uplands.
The slope and summit areas of the rolling uplands have predominately Ebimimbang soils, which are comparable to those of the Du2 mapping unit (see below). The valley bottom soils are typically poorly to very poorly drained.
About 30% of the Du1 units are affected by shifting cultivation. In addition, repeated logging for commercial timber has taken place in the last decennia. The primary forest vegetation in these units, where not disturbed, consists of the *Diospyros-Polyalthia* community (IIc). Within the shifting cultivation areas, the vegetation is a mosaic of actual fields, thickets of the *Macaranga-Chromolaena* community (V) on recently abandoned fields, young secondary forest of the *Xylopia-Musanga* community (IV), and remaining patches of lowland forest mentioned above. The predominant vegetation type of the valley bottoms is the *Carapa-Mitragyna* community (III).

Du2: hilly uplands below 350 m asl; moderately well to well drained soils
This is the major landscape type of the western lowlands of the TCP area. It is a strongly dissected hilly upland with slopes of 10 - 30%. An estimated 5 to 10% of it is covered by valley bottoms.
The predominant soils of the slope and summit areas are of the Ebimimbang type, i.e. moderately deep to (very) deep, moderately well drained, yellowish brown sandy clay loams to (sandy) clays. The clay content of the subsoils is less than 40%. The valley bottoms are typically poorly to very poorly drained. The soils are comparable in chemical and physical characteristics with those of the other mapping units of the landscape ecological zone D.
The vegetation consists of *Diospyros-Polyalthia* forest (IIc) in different stages of disturbance. The swamp forest of the *Carapa-Mitragyna* community (III) covers the valley bottoms. Shifting cultivation has affected these hilly uplands only to a limited extent (about 25%). The vegetation in the shifting cultivation areas is a mosaic of forest of the *Diospyros-Polyalthia* community (IIc), with young secondary vegetation of the *Xylopia-Musanga* community (IV), and the *Macaranga-Chromolaena* community (V). Field observations suggest that most of the forest in these units have undergone commercial logging activities in the recent past.

Ev: valley bottom; poorly to very poorly drained soils
Valley bottoms occur throughout the TCP research area. The majority however is too small to be mapped individually at reconnaissance scale. They appear as inclusions in the other mapping units, locally covering up to 15%.
The soils are imperfectly to very poorly drained with clayey to gravely/stony textures. The soils are developed in unconsolidated and often stratified alluvium. The groundwater table is permanently high and water stagnation is common.
The swamp forest is classified as the *Carapa-Mitragyna* (III) community. The Ev units are hardly affected by human activities.

6 LAND QUALITIES

6.1 Land qualities related to growth

Drainage condition

The soil drainage class reflects the combined effects of climate, landscape and soil. Drainage class is determined by internal and external drainage, rainfall, seepage, soil permeability and surface infiltration rate. The drainage condition determines the *oxygen* and *moisture availability* for plant roots. During the survey not all the characteristics related to drainage condition were measured or estimated separately, but drainage condition was assessed directly using the FAO-classification system (1990) which discerns seven drainage classes. The four major soil types of the TCP research area can be allotted to four of these classes (Table 6.1). The well drained (Nyangong and Ebom) and the well to moderately well drained (Ebimimbang) soils are the most extended drainage classes. Poorly and very poorly drained soils are restricted to the valley bottoms. The classification values per land mapping unit are given in the summary table (Table 6.15).

Table 6.1. Soil types and drainage condition (after van Gemerden and Hazeu, 1999)

Soil type	Drainage condition
Nyangong	well drained
Ebom	well drained
Ebimimbang	well to moderately well drained
Valley bottom	poorly to very poorly drained

Rooting conditions

Two land characteristics are of importance: *effective soil depth* and the *percentage of coarse fragments* at the surface or in the soil profile. The effective soil depth is defined as the soil depth at which root growth is strongly inhibited (FAO, 1990). The presence of hard rock, permanent high groundwater table and/or compacted or indurated layers govern the effective soil depth. The effective soil depth classes used in the land evaluation procedure are the slightly adapted FAO (1990) ones. Five classes are discerned (Table 6.2). In the TCP research area shallow to very shallow soils (class 4 and 5) cover only very small areas.

Table 6.2. Soil depth classes and soil type (after van Gemerden and Hazeu, 1999)

Class	Depth (cm)	Denomination	Soil type*			
			Ny.	Eb.	Em.	Vb.
1	> 150	very deep	+	+	+	+
2	100 – 150	deep	+	+	+	+
3	50 – 100	moderately deep	-	-	+	+
4	25 – 50	shallow	-	-	-	-
5	0 – 25	very shallow	-	-	-	-

* Ny.: Nyangong; Eb.: Ebom; Em.: Ebimimbang; Vb.: Valley bottom.

For the coarse fragment contents (CFC) five classes are discerned (Table 6.3). For some types of land use the CFC of the topsoil (0 – 25 cm) is of importance, for others the CFC of both topsoil and subsoil. Therefore, in the land evaluation procedure CFC of topsoil and subsoil are treated as two separate land characteristics.

Table 6.3. Soil types and coarse fragment contents (modified after van Gemerden and Hazeu, 1999)

Class	%	Denomination	Topsoil (0 –25cm)*				Subsoil (25 –100cm)*			
			Ny.	Eb.	Em.	Vb.	Ny.	Eb.	Em.	Vb.
1	0 –3	very low to nil	+	+	-	+	+	-	-	-
2	3 – 15	low	-	-	+	-	+	+	-	+
3	15 – 35	moderately high	-	-	-	-	-	-	+	+
4	35 – 55	high	-	-	-	-	-	-	+	+
5	> 55	very high	-	-	-	-	-	-	-	+

* Ny.: Nyangong; Eb.: Ebom; Em.: Ebimimbang; Vb.: Valley bottom.

Effective soil depth and coarse fragment content vary in the TCP research area, even at short distances. The steep upper slopes of the hills and mountains may be very shallow to shallow, whereas the summit areas have deep to very deep soils. The middle and lower slopes have an intermediate position (moderately deep to (very) deep). Coarse fragment contents show the same trends. The uplands generally have deep to very deep soils. The uplands in the landscape ecological zone D have moderately deep to deep soils and have higher coarse fragment contents in topsoil and subsoil. The valley bottoms may have high coarse fragment contents in the subsoil and effective soil depth is limited by permanent high groundwater tables. The summary table gives a generalised overview of these land characteristics for soil types covering > 10% (Table 6.15).

Nutrient availability
Nutrient availability is determined by four land characteristics, i.e. pH, Cation Exchange Capacity (CEC), base saturation, and organic carbon content. The pH and the base saturation are related: low pH is correlated to low base saturation and high base saturation to near neutral pH. The CEC is largely determined by the organic carbon content and partly by the clay content (van Gemerden and Hazeu, 1999). The base saturation is the CEC accounted for by exchangeable bases (Ca, Mg, K, and Na). It is an important indication of soil fertility (Landon, 1991). The various land utilisation types have different requirements regarding soil fertility.

Table 6.4 gives measured values and *ad hoc* classifications of the four major soil types of the TCP research for all four fertility related land characteristics. The figures presented refer to the topsoils (0-25 cm) only, as plants take the bulk of nutrients from this layer. The values per soil type are extrapolated to land mapping units (neglecting coverages < 10% and borderline cases in the classification) and are transferred to the summary table (Table 6.15).

Table 6.4. Measured values and classification of fertility related land qualities for the four major soil types (topsoils only; modified after van Gemerden and Hazeu, 1999)

Soil type	pH		CEC		base saturation		organic carbon content	
	value	class*	value	class*	value	class*	value	class*
Nyangong	3.5-4.5	3-4	10-20	1-2	10-20	4	4-9	1-3
Ebom	3.5-5	2-4	12-25	1	10-50	2-4	4-8	2-3
Ebimimbang	5-6	1	4-12	2-3	50-100	1	2-3.5	4
Valley bottom	5-6	1	7-17	1-2(3)	15-50	2-4	2.5-6.5	(2)3-4

* Classification pH: 1: 5-6.5, 2: 4.5-5, 3: 4-4.5, 4: <4; CEC: 1: >12, 2: 8-12, 3: 4-8, 4: <4; base saturation: 1: 50-100, 2: 35-50, 3: 20-35, 4: <20; organic carbon content: 1: >8, 2: 6-8, 3: 4-6, 4: 2-4.

Timber species
The land quality timber species is (ideally) determined by the number of valuable timber species in an area, the frequency of occurrence, the diameters of these species, and the predicted growth rates and yields. In the present land evaluation, for practical reasons, only the frequency with which timber species are found is considered. No data are available on diameter distribution, growth and yield. Insight in the logging history will only give some indication what areas are likely to produce timber in the short term.

On the basis of the annotated list of plant species in the TCP research area (see Annex 2) the availability of the various classes was calculated for each vegetation type. The score per vegetation type is the number of timber species present in the vegetation type multiplied by the specific frequency with which the species occur. Frequencies less than 10% were omitted. The frequency figures are presented in the annotated list of plant species (Annex 2). Vegetation type IV (young secondary forest) and V (recently abandoned fields and plantations) were not included in the analysis; their significance for timber production is assumed to be zero in the management type considered here, due to the lack of mature trees. The results are given in Table 6.5, including an estimate of the relative availability of timber per vegetation type in four categories (quality classes). A total number of 146 species is included in the analysis. Two variants for timber production are evaluated: one focussing on the ‘traditional’ superior grade species, and one lumping all four classes together, not using any factor rating. However, the data presented in Table 6.5 enable any alternative approach of land evaluation directed on a specific class of timber species. The average classifications per land mapping unit for both variants are transferred to the summary table (Table 6.15).

Table 6.5. Availability of timber species per vegetation type (adjusted for the frequency of occurrence)

	Scores per vegetation type*						
category**	I	IIa	IIb	IIc	III	IV	V
1	2	10	11	5	4	-	-
2	9	14	8	10	10	-	-
3	12	14	16	17	14	-	-
4	18	22	18	27	23	-	-
Total scores	41	60	63	69	61	-	-
Classification:***							
category 1 only	4	1	1	3	4	4	4
category 1- 4	3	1	1	1	1	4	4

* Category (see Annex 3 for categories of species)
1 superior grade pers. comm. G.J.R. van Leersum (species presently exploited)
2 high grade list of state forestry service; code 11 (ONADEF, 1992)
3 medium grade list of state forestry service; code 12
4 low grade list of state forestry service; code 13 and/or list of potential timber species by Zijp *et al.* (2000) (identified by the TCP project on lesser-known timber species as potential timber species: good technical qualities but not yet widely marketed).
** Score is the sum of the frequency classes with which the timber species occur per vegetation type. Frequency classes and species distribution per vegetation type are given in Annex 2.
*** Classification: relative scaling based on the percentage of the maximum score: 1: 80-100% (high), 2: 60-80% (moderately high), 3: 40-60%, (low) and 4: 0-40% (very low).

The availability of superior grade timber is high in the primary and old secondary forests of ecological zone B and C (vegetation types IIa and IIb), and (very) low in the mountain forests (I), swamp forests (III) and the primary and old secondary forests of ecological zone D (IIc). When the other timber categories are taken into account as well, the availability of timber in the mountain forests is still low, but the availability of timber in swamp forests and the primary and old secondary forests of ecological zone D is high. The young secondary forests (IV) and *Chromolaena* shrublands (V) are not included in these calculations (see above); their importance for timber production is considered to be negligible in both cases.

Non-timber forest products

Non-timber forest products are all the forest products which are or could be extracted by local people, excluding the exploitation of industrial timber and its derivates (after Falconer, 1990). The suitability classification for NTFPs as presented here is only based on products derived from plants due to the scarcity of information on fauna. The availability of NTFPs was determined per vegetation type on the basis of the 'Annotated list of plant species in the TCP research area' (Annex 2) and a list of NTFPs in the TCP research area compiled by van Dijk (1999). This list is based on 29 interviews with villagers, mainly in the Ebom area, and on literature data. Only species that occur in at least one vegetation type with a frequency of 10% or more are used. A total number of 157 species is included in the analysis.

Five categories of NTFP species are discerned, according to their importance for the local population. Table 6.6 gives the relative availability of NTFPs per vegetation type. The scores reflect the frequency with which the NTFP species occur. Two variants for the collection of non-timber forest products are evaluated: one focussing on the most important species (category 1) only, and one lumping all five categories together (broad selection), not using any factor rating. However, the data presented in Table 6.6 and the method described enable any alternative approach of land evaluation directed on a specific class of NTFPs. The resulting relative abundance of NTFPs per land mapping unit is given in the summary table (Table 6.15).

Table 6.6. Availability of non-timber forest products per vegetation type (adjusted for the frequency of occurrence)

Cat.	Importance	Frequency use*	Scores per vegetation type** I	IIa	IIb	IIc	III	IV	V
1	high	>40	6	14	8	9	9	14	13
2	moderately high	20-40	17	25	25	23	22	29	17
3	low	5-20	22	35	35	32	31	48	36
4	very low	<5	33	54	44	44	38	32	22
5	potential	-***	56	44	61	46	37	25	13
	Total scores		134	172	173	154	137	148	101
Classification****									
category 1 only			3	1	3	2	2	1	1
category 1 – 5			2	1	1	1	2	1	3

* Number of times a species (for any of its products) was mentioned in 29 interviews (van Dijk, 1999)

** Score is the sum of the frequency classes with which the non-timber forest species occur per vegetation type. Frequency classes and species distribution per vegetation type are given in Annex 2.

*** Based on literature data only

**** Classification: relative scaling based on the percentage of the maximum score: 1: 80-100% (high), 2: 60-80% (moderately high), 3: 40-60%, (low) and 4: 0-40% (very low).

Regardless the selection of NTFPs, the availability is high in the primary and secondary forests of ecological zone B (vegetation type IIa) and in the young secondary forests (IV), and moderately high in the swamp forests (III). For the other vegetation types, the selection of NTFP species determines the relative abundance, but generally speaking the differences between the various vegetation types are not very pronounced.

Conservation value flora and vegetation

Two aspects (characteristics) are taken into consideration: species diversity, and occurrence of rare species. As for species diversity, it is hard to give an accurate estimate for the various vegetation types, based on the results of a reconnaissance survey only. Still, the results of a reconnaissance survey (van Gemerden and Hazeu, 1999; annex Vb) are likely to show trends in species diversity correctly, if a sufficient number of plots are available and incidentally occur-ring species are omitted. For each vegetation type, all species that occur with a frequency of 10% or more are counted (Annex 2). A total of 277 species was used in the calculations. The totals per vegetation type reflect the relative species diversity (Table 6.7). The average classification per land mapping unit was transferred to the summary table (Table 6.15), omitting vegetation types covering less than 10% of the unit.

Table 6.7. Diversity of plant species per vegetation type (frequency 10% or more).

Vegetation type	I	IIa	IIb	IIc	III	IV	V
number of species	109	127	124	114	100	133	77
classification*	1	1	1	1	2	1	3

* Classification: relative scaling based on the percentage of the maximum score: 1: 80-100% (high), 2: 60-80% (moderately high), 3: 40-60% (low) and 4: 0-40% (very low).

It proves that species numbers in the various types of both primary and secondary forests do not vary strongly. Species numbers are highest in the primary and old secondary forests of zone B and C, and (which is rather unexpected) in the younger secondary forests of vegetation type IV. Swamp forests (type III) have a somewhat lower species number and younger secondary shrublands (type V; *Macaranga-Chromolaena* community) are the poorest in species diversity and differ strongly from young secondary forests (type IV; *Xylopia-Musanga* community).

As for the occurrence of rare species, rareness is defined on a global scale: rareness reflects the geographical distribution of the species encountered. Species with a very limited distribution, i.e. endemics, have a higher conservation value than common species. All species that occur with sufficient frequency have been classified according to their geographical distribution. Six categories are discerned (Table 6.8). The geographical distribution of plant species is given in Annex 5. The information on the geographical distribution of species was derived primarily from various regional floras; additional information was gathered from Hawthorne (1996). A total of 200 species, occurring with sufficient frequency (>10% belonging to the type), could be classified.

Table 6.8. Occurrence of rare plant species based on their geographical distribution.

Species category	Distribution area	Vegetation types I		IIa		IIb		IIc		III		IV		V		Total	
		N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
1.	Cameroon	1	1	2	2	2	2	2	2	1	1	2	2	1	2	3	2
2.	Region*	23	32	34	34	28	28	24	28	21	27	17	19	6	10	49	25
3.	Central Africa	14	19	14	14	17	17	13	15	12	15	11	12	2	3	28	14
4.	W. and C. Africa	28	39	43	43	42	42	35	40	36	46	45	50	33	55	81	41
5.	Tropical Africa	4	6	7	7	9	9	10	11	7	9	14	16	11	18	27	14
6.	Tropics / World	2	3	1	1	2	2	3	3	2	3	1	1	7	12	11	6
Classification**		1		1		1		1		1		3		4			

* South Nigeria, Gabon, Equatorial Guinea, Congo (Zaire), and Cameroon);
** Classification based on percentage rare species: 1 (high): > 75% west and central African species (s.l.); > 25% regional species (s.l.); 2 (moderately high): > 75% West and Central African species (s.l.); < 25% regional species (s.l.), 3 (low): < 75% West and Central African species (s.l.); < 25% African species (s.l.); 4 (very low): < 75% West and Central African species (s.l.); > 25% African species (s.l.); s.l. (sensu lato) implies that the class at issue includes all higher ranked classes; e.g. regional (s.l.) includes both regional and endemic species.

The phytogeographical spectra given in Table 6.8 show a large difference between the primary or old secondary forests (types I, IIa, IIb, IIc and III), and types of young secondary growth (IV and V). Primary and old secondary forests are rich in both regional, and West-Central African species. By contrast, young secondary vegetation is relatively rich in species that can be found all over tropical Africa. In the *Macaranga-Chromolaena* shrublands many pantropical species are present. Truly endemic species (restricted to Cameroon) are of little significance in all vegetation types, but this may be due to the fact that the data are derived from a reconnaissance survey, in which aberrant micro-habitats (not seldom harbouring rare species) are neglected.

For an appreciation of the vegetation types based on the phytogeographical spectra, a simple ad-hoc classification system was used. However, the data presented in Table 6.1 enable any alternative approach of land evaluation directed on a specific phytogeographical class of plant species. For classification unweighed figures were used, since once a rare species is more than incidentally present in a given vegetation type, its exact frequency is of minor importance. However, using values weighted according to the frequency of occurrence proved to produce very similar results. The average results per land mapping unit are transferred to the summary table (Table 6.15), omitting vegetation types covering less than 10% of the unit.

Food plants for wildlife

Bekhuis (1997) studied the habitat requirements of gorilla, mandrill, chimpanzee and collared mangabey in the context of the present land evaluation study. The food plants of these animals are summarised in annex 6. Based on the annotated list of plant species in the TCP research area (Annex 2), the scores per vegetation type are calculated (Table 6.9). The scores reflect the frequency with which food plants occur in the different vegetation types. Species with a frequency of less than 10% are omitted. The average classification for the four species of monkey per land mapping unit studied was transferred to the summary table (Table 6.15).

Table 6.9 shows that in general the food availability is highest in the primary to old secondary forests of ecological zone B, C and D (vegetation types IIa, IIb and IIc), and lowest in the *Chromolaena* shrublands (V). The mountain forests (I), swamp forests (III) and young secondary forests (IV) have a more or less intermediate position.

Habitat quality

Land characteristics related to habitat quality are relevant for the LUTs non-timber forest products, conservation of flora and fauna. As for non-timber forest products, habitat quality is here defined as landscape diversity. A simple *ad hoc* classification system was used, based on the number of vegetation types (covering at least 10%) of the land mapping units (Table 6.10). The results per land mapping unit are given in the summary table (Table 6.15).

Table 6.9. Availability of food plants for gorilla, mandrill, chimpanzee and collared mangabey per vegetation type (weighed according to frequency; modified after Bekhuis, 1997).

Vegetation	Gorilla			Mandrill			Chimpanzee			Coll. mangabey		
type	N	score#	class*	N	score#	class*	N	score#	class*	N	score#	class*
I	7	16	3	13	26	3	9	20	3	9	21	2
IIa	10	27	1	18	44	1	12	32	1	11	30	1
IIb	10	22	1	17	41	1	12	27	2	11	29	1
IIc	11	21	2	16	35	1	15	33	1	10	26	1
III	8	17	2	15	29	2	12	24	2	9	21	2
IV	7	19	2	11	26	3	15	35	1	6	16	3
V	5	13	3	6	12	4	9	23	2	2	4	4

Score is the sum of the frequency classes with which the food plant species occur per vegetation type. Frequency classes and species distribution per vegetation type are given in Annex 2.
* Classification: relative scaling based on the percentage of the maximum score: 1: 80-100% (high), 2: 60-80% (moderately high), 3: 40-60%, (low) and 4: 0-40% (very low).

Table 6.10. Landscape diversity based on the number of vegetation types per land mapping unit

Class	Number of vegetation types per LMU*	Landscape diversity
1	4	high
2	3	moderately high
3	2	low
4	1	none

* Covering at least 10% of the area.

Habitat quality for the conservation of flora and fauna implies the degree of *disturbance*, which is estimated per vegetation type. The estimation is based on the 'ecological' spectra of the vegetation types. Therefore, an attempt was made to classify all species, which occur with sufficient frequency (> 10%) according to their indication for disturbance (see Annex 7: Habitat preference of plant species). Five categories are discerned (Table 6.11). These categories are broad and partly overlapping, since relevant information in literature does not allow for a more accurate classification. The information on the ecology of species was derived from the same sources as were used for the geographical spectra (occurrence of rare species).

For an appreciation of the vegetation types based on the ecological spectra, a simple ad-hoc classification system was used. However, the data presented in Table 6.11 enable any alternative approach of land evaluation directed on a specific 'ecological' class of plant species. The average results per land mapping unit are transferred to the summary table (Table 6.15), neglecting vegetation types covering less than 10% of the unit.

Table 6.11. Classification of plant species and vegetation types based on indication for disturbance.

Cat.	Denomination	Scores vegetation types*													
		I		IIa		IIb		IIc		III		IV		V	
		N	%	N	%	N	%	N	%	N	%	N	%	N	%
Species of:															
1	primary forest	42	30	48	25	47	25	30	18	20	14	7	4	2	2
2	forest**	87	63	119	61	116	62	102	61	91	62	70	44	23	20
3	secondary forest	8	6	15	8	15	8	17	10	21	14	36	23	22	19
4	sec. vegetation**	1	1	11	7	6	3	15	9	9	6	36	23	37	32
5	secondary shrublands	0	0	1	1	2	1	2	1	6	4	10	6	31	27
Classification***		1		1		1		2		2		3		4	

* Weighed according to frequency
** Not specified
*** Classification disturbance: 1 (low): > 75% forest species (s.l.) and > 25% species of the primary forest; 2 (moderately low): > 75% forest species (s.l.) and < 25% species of the primary forest; 3 (high): < 75% forest species (s.l.) and < 25% species of secondary shrubland; 4 (very high): < 75% forest species (s.l.) and > 25% species of secondary shrubland; forest species s.l. (sensu lato) include: species of the primary forest, forest species (not-specified) and species of the secondary forest.

The main trend in Table 6.11 is a decrease of (primary) forest species and increase of secondary species from vegetation type I (*Maranthes-Anisophyllea* community; primary submontane forest) towards vegetation type V (*Macaranga-Chromolaena* community). Types IIa and IIb (*Podococcus-Polyalthia* community and *Strombosia-Polyalthia* community) resemble the submontane forest (I), both in the high percentage of (primary) forest species, and in the low percentage of secondary species. The *Diospyros-Polyalthia* community (type IIc), a comparable forest type which occurs on still lower altitudes, and the *Carapa-Mitragyna* community (type III; valley bottoms) are still rich in forest species, but contain already many secondary elements. Finally, the *Xylopia-Musanga* community (type IV) is a typical young secondary forest, in which both primary forest and shrubland species are scarce.

Habitat quality for the conservation of wildlife implies three land qualities: availability of drinking water, availability of resting-places, and acceptable distance from human activities. All these qualities are species specific. Availability of drinking water, however, is not a limiting factor in any land mapping unit for all four species considered (Bekhuis, 1997) and is therefore omitted in the further land evaluation procedure. Acceptable distance from human activities (villages, roads) is differentiating, but not related to land mapping units; more specific information is given Chapter 7. Availability of resting places (differs for each animal considered) is a differentiating factor for all four species considered. Only two classes are discerned: present (+) and not or insufficiently present (-). In general, availability of resting places is related to landform (Table 6.12). Only in the case of the Collared mangabey vegetation is primarily differentiating, but extrapolation to ecological zones is easy since only the primary forests of zone A and B, and the *Chromolaena* shrublands are not used for resting. Shortage of resting places is assumed only if a LMU is covered for more than 50% by (one of) these vegetation types. The species specific data are combined into one gross factor using a simple *ad hoc* model (see also Table 6.12). The results are included in the summary table (Table 6.15).

Table 6.12. Availability of resting-places (modified after Bekhuis, 1997).

Landform (per zone)	Gorilla	Mandrill	Chimpanzee	Collared mangabey	class*
Am	+	+	+	-	2
Ah1	+	+	+	-	2
Bh1	+	+	+	-	2
Bh2	+	+	+	-	2
Bu2	-	-	-	-	4
Bu1	-	-	-	-	4
Ch1	+	+	+	+	1
Cu2	-	-	-	+	3
Cu1	-	-	-	+	3
Dh1	+	+	+	+	1
Du2	-	-	-	+	3
Du1	-	-	-	+	3
Dpd	-	-	-	+	3
Ev	-	-	-	+	3

* Classification: 1: high (++++); 2: moderately high (++ or +++); 3: low (+); 4: very low (-).

6.2 Land qualities related to management

Workability

The workability land quality expresses the ease of tillage. Only the land characteristic texture is taken into account, as consistency and structure are not differentiating in the TCP research area. The texture of the topsoil (0 - 25cm) is of major importance (Sys, 1985). Four texture classes are discerned (Table 6.13). The Ebimimbang soils have a sandier soil profile than the Ebom and Nyangong soils; their topsoils have loamy sand to sandy loam texture. The texture classes per LMU, based on the occurring soil types (neglecting coverages of < 10%) are transferred to the summary table (Table 6.15).

Table 6.13. Texture of soil types (topsoils only; after van Gemerden and Hazeu, 1999).

Code	Soil type	Texture (0 - 25cm) % clay	Description	Class*
Ny	Nyangong	40-70	heavy clay	4
Eb	Ebom	20-40	sandy loam to sandy clay	2-3
Em	Ebimimbang	9-25	sand to sandy loam	1-2
Vb	Valley bottom	5-30	loamy sand to sandy clay loam**	2-3

* classification: 1: sand; 2: loamy sand, sandy loam, loam; 3: sandy clay loam, sandy clay; 4: clay loam, clay and heavy clay;

** locally peaty.

Terrain conditions

The terrain conditions are determined by the characteristics slope percentage, percentages of areas covered with swamp or rock outcrops. All these characteristics determine the accessibility and the potential of an area for mechanised operations. The terrain conditions within the TCP research area are related to the landforms. For slope and coverage of swamps, measured values and classifications are given in Table 6.14. Dissected erosional plains and undulating to rolling uplands have a less strong relief and few rock outcrops. A relative large area is occupied by swamp areas (10-15%). The hills and mountains are steep to very steep, have generally more rock outcrops (at slope ruptures mainly upper slopes) and only small surface areas are occupied by swamps. The rolling to hilly uplands and the complex of hills have an intermediate position.
Coverage of rock outcrops is not included in Table 6.14, since this characteristic is in none of the landforms a significant factor (coverage < 2%). The scores per LMU are transferred to the summary table (Table 6.15).

Table 6.14. Slope percentage and coverage of swamps per landform (after van Gemerden and Hazeu, 1999)

Code:	Landform	Slope %	Class*	Swamps %	Class**
M	mountains	30->60	4	< 5	1
H1	isolated hills	>30	4	< 5	1
H2	complexes of hills	20-40	3-4	< 5	1
U1	rolling uplands	10-20	2-3	10-20	3
U2	hilly uplands	10-30	2-3	5-10	2
PD	dissected erosional plains	5-15	1-2	10-20	3
V	valley bottoms	0-2	1	40-60	4

* Slope classes: 1: < 8 %; 2: 8-16 %; 3: 16-30 %; 4: >30 %.

** Classes swamp coverage: 1: < 5 %; 2: 5-10%; 3: 10–20 %; 4: > 20 %.

6.3 Land qualities related to conservation

Resistance to erosion

Resistance to erosion is determined by a relatively large number of land characteristics, such as topsoil texture and structure, slope percentage, slope length, land cover, and susceptibility to surface sealing and crusting. In the TCP research area the most important characteristic is slope percentage as this varies considerably. Slope length does not contribute to erosion since it is common practice in the TCP area to cultivate only small parts of the slopes. Longer slopes are covered with forest. Susceptibility to surface sealing and crusting is of minor importance as well, given the high organic carbon content of all soil types. Original land cover does not favour erosion either, since all LMUs are primarily covered by forest. Future land cover depends on the kind of envisaged land use and undoubtedly exerts influence on erosion. Therefore the class limits of resistance to erosion depend heavily on the LUT. As far as resistance to erosion is concerned only slope percentage is taken as determining characteristic. For a classification, see terrain conditions (Table 6.14).

Table 6.15. Classification of land qualities related to growth, management and conservation for the various land mapping units (LMU).

LMU	Land Qualities																				
	DR	SD	CF (a)	CF (b)	pH	CE	BS	OC	TI (a)	TI (b)	NT (a)	NT (b)	DI	RP	FP	LD	DS	RS	TX	SL	SW
Am (u)	1	1-2	1	1-2	3-4	1-2	4	1-3	4	3	3	2	1	1	3	4	1	2	4	4	1
Ah1 (u)	1	1-2	1	1-2	3-4	1-2	4	1-3	4	3	3	2	1	1	3	4	1	2	4	4	1
Bh1 (u)	1	1-2	1	1-2	3-4	1-2	4	1-3	1	1	1	1	1	1	1	4	1	2	4	4	1
Bh1 (l)	1	1-2	1	1-2	3-4	1-2	4	1-3	2	2	1	1	1	2	2	2	2	2	4	4	1
Bh2 (u)	1	1-2	1	1-2	3-4	1-2	4	1-3	1	1	1	1	1	1	1	4	1	2	4	3-4	1
Bh2 (l)	1	1-2	1	1-2	3-4	1-2	4	1-3	2	2	1	1	1	2	2	2	2	2	4	3-4	1
Bh2 (h)	1	1-2	1	1-2	3-4	1-2	4	1-3	4	4	1	2	2	3	3	2	3	2	4	3-4	1
Bu2 (u)	1	1-2	1	1-2	2-4	1-2	2-4	1-3	1	1	1	1	1	1	1	4	1	4	2-4	2-3	2
Bu2 (l)	1	1-2	1	1-2	2-4	1-2	2-4	1-3	2	2	1	1	1	2	2	2	2	4	2-4	2-3	2
Bu2 (h)	1	1-2	1	1-2	2-4	1-2	2-4	1-3	4	4	1	2	2	3	3	2	3	4	2-4	2-3	2
Bu1 (u)	2	1-3	1	1-5	1-4	1-2	2-4	1-4	2	1	1	1	1	1	1	3	1	4	2-4	2-3	3
Bu1 (l)	2	1-3	1	1-5	1-4	1-2	2-4	1-4	3	2	1	2	2	2	2	1	2	4	2-4	2-3	3
Bu1 (h)	2	1-3	1	1-5	1-4	1-2	2-4	1-4	3	3	1	2	2	3	3	1	3	4	2-4	2-3	3
Ch1 (u)	1	1-2	1	2	2-4	1	2-4	2-3	1	1	3	1	1	1	1	4	1	1	2-3	4	1
Ch1 (l)	1	1-2	1	2	2-4	1	2-4	2-3	2	2	2	1	1	2	2	2	2	1	2-3	4	1
Cu2 (u)	1	1-2	1	2	2-4	1	2-4	2-3	1	1	3	1	1	1	1	4	1	3	2-3	2-3	2
Cu2 (l)	1	1-2	1	2	2-4	1	2-4	2-3	2	2	2	1	1	2	2	2	2	3	2-3	2-3	2
Cu2 (h)	1	1-2	1	2	2-4	1	2-4	2-3	4	4	1	2	2	3	3	2	3	3	2-3	2-3	2
Cu1 (u)	2	1-3	1	2-5	1-4	1-2	2-4	2-4	2	1	3	1	1	1	1	3	1	3	2-3	2-3	3
Cu1 (l)	2	1-3	1	2-5	1-4	1-2	2-4	2-4	3	2	2	2	2	2	2	1	2	3	2-3	2-3	3
Cu1 (h)	2	1-3	1	2-5	1-4	1-2	2-4	2-4	4	3	1	2	2	3	3	1	3	3	2-3	2-3	3
Dh1 (u)	3	1-3	1-2	2-4	1-4	1-3	1-4	2-4	3	1	2	1	1	1	2	4	2	1	1-3	4	1
Dh1 (l)	3	1-3	1-2	2-4	1-4	1-3	1-4	2-4	3	2	2	1	1	2	2	2	3	1	1-3	4	1
Du2 (u)	3	1-3	2	3-4	1	2-3	1	4	3	1	2	1	1	1	2	4	2	3	1-2	2-3	2
Du2 (l)	3	1-3	2	3-4	1	2-3	1	4	3	2	2	1	1	2	2	2	3	3	1-2	2-3	2
Du2 (h)	3	1-3	2	3-4	1	2-3	1	4	4	4	1	2	2	3	3	2	3	3	1-2	2-3	2
Du1 (u)	4	1-3	1-2	2-5	1	1-3	1-4	3-4	3	1	2	1	1	1	2	3	2	3	1-3	2-3	3
Du1 (l)	4	1-3	1-2	2-5	1	1-3	1-4	3-4	4	2	2	2	2	2	2	1	3	3	1-3	2-3	3
Du1 (h)	4	1-3	1-2	2-5	1	1-3	1-4	3-4	4	3	1	2	2	3	3	1	3	3	1-3	2-3	3
Dpd (u)	4	1-3	1-2	2-5	1	1-3	1-4	3-4	3	1	2	1	1	1	2	3	2	3	1-3	1-2	3
Dpd (l)	4	1-3	1-2	2-5	1	1-3	1-4	3-4	4	2	2	2	2	2	2	1	3	3	1-3	1-2	3
Dpd (h)	4	1-3	1-2	2-5	1	1-3	1-4	3-4	4	3	1	2	2	3	3	1	3	3	1-3	1-2	3
Ev (u)	5	1-3	1	2-5	1	1-2	2-4	3-4	4	1	2	2	2	1	2	4	2	3	2-3	1	4
Ev (l)	5	1-3	1	2-5	1	1-2	2-4	3-4	4	2	2	2	2	2	2	2	3	3	2-3	1	4

DR: Drainage condition. 1: well; 2: well, incl. 10-20% (very) poorly; 3: moderately well; 4: moderately well, incl. 10-20% (very) poorly; 5: poorly to very poorly.

SD: Effective soil depth. 1: very deep (> 150 cm); 2: deep (100–150 cm); 3: moderately deep (50–100 cm); 4: shallow (25-50 cm); 5: very shallow (0 – 25 cm).

CF: Coarse fragment content (a) 0-25 cm; (b) 25: 100 cm. 1: very low (0-3 %); 2: low (3–15 %); 3: moderately high (15-35 %); 4: high (35-55 %); 5: very high (> 55 %).

pH: Soil pH. 1: high (5-6.5); moderately high (4.5-5.5); 3: low (4-4.5); 4: very low (< 4).

CE: Cation exchange capacity (0-25 cm). 1: high (>12 meq/100g clay); moderately high (8-12 meq/100g clay); 3: low (4-8 meq/100g clay); 4: very low (< 4 meq/100g clay).

BS: Base saturation (0-25 cm). 1: high (50-100 %); moderately high (35-50 %); 3: low (20-35 %); 4: very low (<20%).

OC: Organic carbon content (0-25 cm). 1: high (> 8 % C); moderately high (6-8 % C); 3: low (4-6 % C); 4: very low (2-4 % C).

TI: Availability of timber species (a) superior grade only, (b) superior to low grade. 1: high; 2: moderately high; 3: low; 4: very low (relative scaling).

NT: Availability of non-timber forest products. (a) most important species only; (b) all species; 1: high; 2: moderately high; 3: low; 4: very low (relative scaling).

DI: Average species diversity of vegetation types. 1: high; 2: moderately high; 3: low; 4: very low (relative scaling).

RP: Occurrence of rare plant species. 1: high; 2: moderately high; 3: low; 4: very low (relative scaling).

FP: Availability of food plants for wildlife (based on data for gorilla, mandrill, chimpanzee and collared mangabey). 1: high; 2: moderately high; 3: low; 4: very low (relative scaling).

LD: Landscape diversity (based on the number of vegetation types per LMU). 1: high (N = 4); 2: moderately high (N = 3); 3: low (N = 2); 4: very low (N = 1).

DS: Disturbance (based on ecological spectra of vegetation types). 1: low; 2: moderately low; 3: high; 4: very high (relative scaling).

RS: Availability of resting-places (based on data for gorilla, mandrill, chimpanzee and collared mangabey). 1: high; 2: moderately high; 3: low; 4: very low (relative scaling).

TX: Texture (0-25 cm): 1: sand; 2: loamy sand, sandy loam, loam; 3: sandy clay loam, sandy clay; 4: clay loam, clay and heavy clay.

SL: Slope: 1: < 8 %; 2: 8-16 %; 3: 16-30 %; 4: >30 %.

SW: Swamps: 1: < 5 %; 2: 5-10%; 3: 10–20 %; 4: > 20 %.

7 SUITABILITY FOR CONSERVATION OF BIODIVERSITY

7.1 Classification procedure

The requirements used are in fact criteria to assess the conservation value of the mapping units discerned. In this context conservation value means: priority (‘suitability') of land to be set aside as protection forest. The LUT conservation of biodiversity is divided into the value for the conservation of the flora and the suitability for the conservation of the fauna (directed in first instance at large mammals).

The assessment of the botanical conservation value of the TCP research area is based on the complete floristic composition as described by van Gemerden and Hazeu (1999). However, no systematic data on faunistic diversity in the TCP research area are available. Therefore, the conservation value of the various land mapping units was assessed on the basis of the potential habitat of four endangered species (gorilla, mandrill, chimpanzee, and collared mangabey), which may serve as ‘umbrella species’ for the fauna as a whole. The data were (slightly modified) derived from Bekhuis (1997). The same author also collected data on the present status of the forest elephant within the area. It proved that actually the elephant does not occur within the research area and only a very small part of the area (some 2%) may be classified as potentially suitable. The main limiting factor for the forest elephant is the distance to human occupation: the critical distance is taken as 8 km. Therefore, the potential suitability for elephants is not further discussed here.

Classification procedures for flora on the one hand, and fauna on the other differ considerably. In short, the procedures can be described as follows:

Flora

- suitability classification of the land mapping units is based on the assessed conservation value of the various vegetation types within the LMU (excluding the ones covering less than 10%);
- three criteria (‘requirements’) are used: (1) integrity (vs. disturbance), (2) occurrence of rare species, and (3) species diversity; these criteria are considered to be equivalent (have similar weight);
- conservation values per vegetation type are extrapolated to LMUs using the frequency classes of the vegetation types as weighing factors.

Fauna

- for all four species concerned suitability classification is primarily based on the availability of food plants per LMU;
- limitations of the habitat quality due to lack of resting places downgrade the classification with one scale;
- the same applies for limitations of the habitat quality due to the vicinity of major roads;
- the vicinity of major villages (tentatively set as villages with over 320 inhabitants) is classified as not suitable, irrespective of other land characteristics;
- the critical distance (to roads and villages) is species specific: 3 km for gorilla, chimpanzee and collared mangabey, and 5 km for mandrill.

As for flora and vegetation, landscape diversity was deliberately not used as a criterion to assess botanical diversity. Landscape diversity is defined in this study as diversity of vegetation types within the LMUs (see Chapter 6) and is in practice strongly related to agricultural activities around the villages. Although the presence of secondary vegetation types undoubtedly implies the occurrence of several plant species, which are absent in the primary forest, this effect is assumed to be inferior to the reduction of the species number in the primary forest. This assumption is based on the practical experience that the minimum area in tropical forests needed for survival of species is exceedingly large due to the relatively high number of species, which occur in very low densities.

Both availability of drinking water and accessibility are not used as criteria for fauna, as none of the land mapping units provides serious limitations for any of the species concerned. Conversely, size of management unit is of great importance for the conservation value of land, both for flora and vegetation, and for fauna. However, this factor should be dealt with in the process of land use planning, rather than be included in the land evaluation procedure (see also Chapter 12).

7.2 Flora

An assessment of the overall botanical value of the seven main vegetation types is given in Table 7.1. The assessment is based on three equivalent criteria: integrity (measure of naturalness, lack of disturbance), occurrence of rare species, and species diversity.

Table 7.1. Overall botanical value of the vegetation types.

Vegetation type	Value*			
	integrity	rare species	species diversity	overall conservation value
I	1	1	1	1
IIa	1	1	1	1
IIb	1	1	1	1
IIc	2	1	1	1
III	2	1	2	2
IV	3	3	1	2
V	4	4	3	4

* 1 = high; 2 = moderately high; 3 = low; 4 = very low

Extrapolation of this value from vegetation types to land mapping units is done by calculating the average botanical conservation value per LMU (using the frequency classes as weighing factors). The resulting values are used as an expedient for the suitability classification following the procedure described in Section 7.1. The results are given in Table 7.2 and on Map 7.1. It should be stressed that, although the procedure followed for the definition of 'requirements' and the description of 'qualities' are more widely applicable, this final suitability classification system leads to an appreciation of the relative conservation value within the TCP area only.

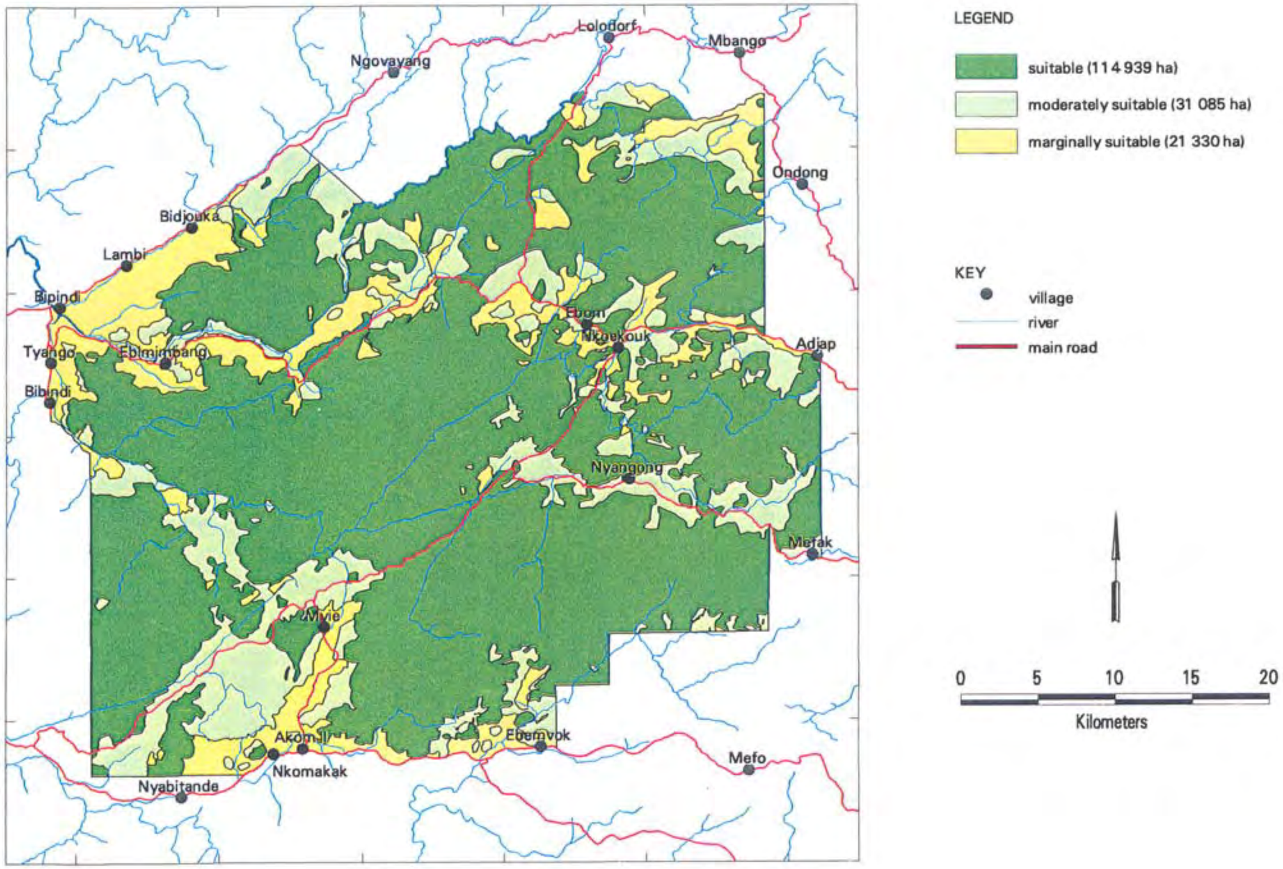
Table 7.2. Suitability classification for conservation of biodiversity (flora).

LMU	Suitability	LMU	suitability
Am (u)	S1	Cu2 (h)	S3
Ah1 (u)	S1	Cu1 (u)	S1
Bh1 (u)	S1	Cu1 (l)	S2
Bh1 (l)	S2	Cu1 (h)	S3
Bh2 (u)	S1	Dh1 (u)	S1
Bh2 (l)	S2	Dh1 (l)	S2
Bh2 (h)	S3	Du2 (u)	S1
Bu2 (u)	S1	Du2 (l)	S2
Bu2 (l)	S2	Du2 (h)	S3
Bu2 (h)	S3	Du1 (u)	S1
Bu1 (u)	S1	Du1 (l)	S2
Bu1 (l)	S2	Du1 (h)	S3
Bu1 (h)	S3	Dpd (u)	S1
Ch1 (u)	S1	Dpd (l)	S2
Ch1 (l)	S2	Dpd (h)	S3
Cu2 (u)	S1	Ev (u)	S2
Cu2 (l)	S2	Ev (l)	S2

Suitability: S1: suitable; S2: moderately suitable; S3: marginally suitable; N: not suitable.

SUITABILITY FOR FLORA CONSERVATION

Bipindi– Akom II– Lolodorf region, South Cameroon



Map 7.1

Interpretation of Table 7.2 leads to two conclusions. First, it is most obvious that there is a strict relation between disturbance (by shifting cultivation practices) and conservation value. Apparently, in the TCP research area disturbance by shifting cultivation overrules all other factors influencing botanical conservation value: the undisturbed areas are highly variable, the low intensity shifting cultivation areas are moderately valuable, and the high intensity shifting cultivation areas have a low value. There is but one exception to this rule: the undisturbed valley bottoms are only moderately valuable, mainly because the primary swamp forest has a lesser species diversity than the other primary forest types.
A second conclusion from Table 7.2 is that not one land mapping unit was classified as not suitable for conservation of flora and vegetation. This is because currently no LMUs are fully dominated by *Chromolaena* shrublands (vegetation type V; very low value), and that the secondary *Musanga* forests which cover 20-40% of the most disturbed areas, still represent a moderately high conservation value.

7.3 Fauna

Following the procedure described above (Section 7.1) the suitability for gorilla, mandrill, chimpanzee, and collared mangabey was assessed. The results are given in Table 7.3.

Table 7.3. Suitability classification for conservation of biodiversity (fauna)

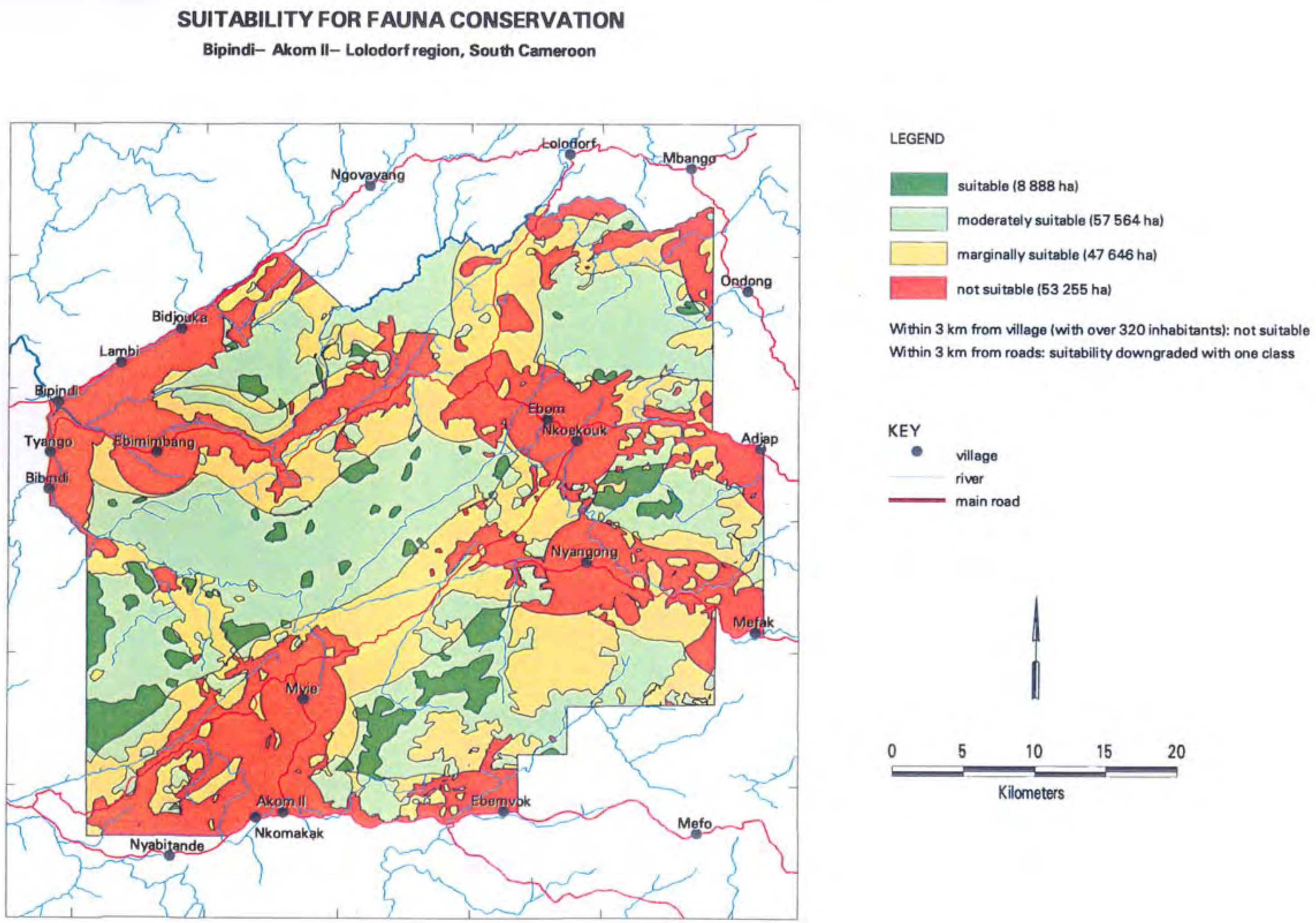
LMU	Gorilla				Mandrill				Chimpanzee				Coll. Mangabey				All	Overall
	FP	RP	Su (a)	Su (b)	FP	RP	Su (a)	Su (b)	FP	RP	Su (a)	Su (b)	FP	RP	Su (a)	Su (b)	Su (c)	Su (a)
Am (u)	3	+	S3	N	3	+	S3	N	3	+	S3	N	2	-	S3	N	N	S3
Ah1 (u)	3	+	S3	N	3	+	S3	N	3	+	S3	N	2	-	S3	N	N	S3
Bh1 (u)	1	+	S1	S2	1	+	S1	S2	1	+	S1	S2	1	-	S2	S3	N	S1
Bh1 (l)	2	+	S2	S3	2	+	S2	S3	1	+	S1	S2	2	-	S3	N	N	S2
Bh2 (u)	1	+	S1	S2	1	+	S1	S2	1	+	S1	S2	1	-	S2	S3	N	S1
Bh2 (l)	2	+	S2	S3	2	+	S2	S3	1	+	S1	S2	2	-	S3	N	N	S2
Bh2 (h)	3	+	S3	N	4	+	N	N	2	+	S2	S2	4	-	N	N	N	S3
Bu2 (u)	1	-	S2	S3	1	-	S2	S3	1	-	S2	S3	1	-	S2	S3	N	S2
Bu2 (l)	2	-	S3	N	2	-	S3	N	1	-	S2	S3	2	-	S3	N	N	S3
Bu2 (h)	3	-	N	N	4	-	N	N	2	-	S3	S3	4	-	N	N	N	N
Bu1 (u)	1	-	S2	S3	1	-	S2	S3	1	-	S2	S3	1	-	S2	S3	N	S2
Bu1 (l)	2	-	S3	N	2	-	S3	N	1	-	S2	S3	2	-	S3	N	N	S3
Bu1 (h)	3	-	N	N	4	-	N	N	2	-	S3	S3	4	-	N	N	N	N
Ch1 (u)	1	+	S1	S2	1	+	S1	S2	2	+	S2	S3	1	+	S1	S2	N	S1
Ch1 (l)	2	+	S2	S3	2	+	S2	S3	2	+	S2	S3	2	+	S2	S3	N	S2
Cu2 (u)	1	-	S2	S3	1	-	S2	S3	2	-	S3	N	1	+	S1	S2	N	S2
Cu2 (l)	2	-	S3	N	2	-	S3	N	2	-	S3	N	2	+	S2	S3	N	S3
Cu2 (h)	3	-	N	N	4	-	N	N	2	-	S3	N	4	+	N	N	N	N
Cu1 (u)	1	-	S2	S3	1	-	S2	S3	2	-	S3	N	1	+	S1	S2	N	S2
Cu1 (l)	2	-	S3	N	2	-	S3	N	2	-	S3	N	2	+	S2	S3	N	S3
Cu1 (h)	3	-	N	N	4	-	N	N	2	-	S3	N	4	+	N	N	N	N
Dh1 (u)	2	+	S2	S3	1	+	S1	S2	1	+	S1	S2	1	+	S1	S2	N	S1
Dh1 (l)	2	+	S2	S3	2	+	S2	S3	1	+	S1	S2	2	+	S2	S3	N	S2
Du2 (u)	2	-	S3	N	1	-	S2	S3	1	-	S2	S3	1	+	S1	S2	N	S2
Du2 (l)	2	-	S3	N	2	-	S3	N	1	-	S2	S3	2	+	S2	S3	N	S3
Du2 (h)	3	-	N	N	4	-	N	N	2	-	S3	N	4	+	N	N	N	N
Du1 (u)	2	-	S3	N	1	-	S2	S3	1	-	S2	S3	1	+	S1	S2	N	S2
Du1 (l)	2	-	S3	N	2	-	S3	N	1	-	S2	S3	2	+	S2	S3	N	S3
Du1 (h)	3	-	N	N	4	-	N	N	2	-	S3	N	4	+	N	N	N	N
Dpd (u)	2	-	S3	N	1	-	S2	S3	1	-	S2	S3	1	+	S1	S2	N	S2
Dpd (l)	2	-	S3	N	2	-	S3	N	1	-	S2	S3	2	+	S2	S3	N	S3
Dpd (h)	3	-	N	N	4	-	N	N	2	-	S3	N	4	+	N	N	N	N
Ev (u)	2	-	S3	N	2	-	S3	N	2	-	S3	N	2	+	S2	S3	N	S3
Ev (l)	2	-	S3	N	3	-	N	N	2	-	S3	N	3	+	S3	N	N	S3

FP: Availability food plants: relative scaling based on the percentage of the maximum score: 1: 80-100%, 2: 60-80%, 3: 40-60% and 4: 0-40%. RP: Availability resting places: +: no limitations; -: serious limitations. Su: Suitability: S1: suitable; S2: moderately suitable; S3: marginally suitable; N: not suitable; (a): > critical distance from both roads and villages; (b) < c.d. from roads and > c.d. from village; c: < c.d. from village (c.d. is species specific critical distance). Overall suitability is calculated as the average of the four others and the c.d. is taken as 3 km.

Interpretation of the classification scores presented in Table 7.3 leads to several conclusions. The main trends become clear if one focuses on the zone outside the vicinity of roads and villages (suitability given in Table 7.3 under (a)). First, it proves that, like botanical conservation value, the value of the land for wildlife is clearly related to disturbance by shifting cultivation: all species studied have a preference for undisturbed areas, which is at least partly due to a lesser availability of food plants in the shifting cultivation areas. High intensity shifting cultivation leads to unsuitable areas for all species except chimpanzee (marginally suitable). Low intensity shifting cultivation has also the least negative effects for chimpanzee. All mapping units are suitable to moderately suitable for chimpanzee except for the uplands in ecological zone C and swamps (marginally suitable). All other species react less favourable to low intensity shifting cultivation. Especially the flatter areas are less suitable because, in addition to reduced quantity of food plants, resting-places are scarce.

In general, when focussing on the undisturbed areas, the following trends may be discerned. The mountain areas (ecological zone A) are only marginally suitable for all four species if we take food plants and resting places into account. Field observations indicate that these areas harbour at present the largest quantity of wildlife. This is probably the result of logging activities and relentless hunting in the more flat and accessible areas elsewhere. The mountains serve as a refuge but are strictly speaking not the most ideal area for fauna conservation. Ecological zone B is suitable (hills) to moderately suitable (uplands) for all species. In ecological zone C the collared mangabey thrives in all landforms, whereas the upland areas are only marginally suitable for chimpanzee. Mandrill and gorilla also show a preference for the steeper parts (moderately suitable). Ecological zone D is suitable for collared mangabey. Its hills are also suitable for chimpanzee and mandrill. The uplands score moderately to marginally suitable for the larger monkeys. The valley bottoms (Ev), finally, are marginally suitable for all species but collared mangabey (moderately suitable).

An overall suitability for fauna conservation is calculated from the suitability of the four mammals. The method used was to take the average of the four values (outside the critical distance from roads, taken as 3 km, and villages). Within the critical distance from roads the suitability is downgraded with one class. The area within 3 km from the main villages remains not suitable. The results of the overall suitability classification are presented on Map 7.2.


SUITABILITY FOR FAUNA CONSERVATION
Bipindi– Akom II– Lolodorf region, South Cameroon
Lolodorf
Mbango
Ngovayang
Ondong
Bidjouka
Lambi
Bipindi
Ebom
Nkoekouk
Adjap
Tyango
Ebimimbang
Bibindi
Nyangong
Mefak
Mvie
Akom II
Ebemvok
Nkomakak
Mefo
Nyabitande
LEGEND
suitable (8 888 ha)
moderately suitable (57 564 ha)
marginally suitable (47 646 ha)
not suitable (53 255 ha)
Within 3 km from village (with over 320 inhabitants): not suitable
Within 3 km from roads: suitability downgraded with one class
KEY
village
river
main road
0
5
10
15
20
Kilometers

Map 7.2

8 SUITABILITY FOR COLLECTION OF NON-TIMBER FOREST PRODUCTS

8.1 Classification procedure

The suitability of land units for extraction of NTFPs by the local population is based on the availability of NTFP species and terrain conditions (slope percentage). Availability of NTFPs per LMU depends both on the availability of NTFPs per vegetation type and on the number of vegetation types per LMU (landscape diversity). LMUs with high landscape diversity are assumed to heighten the available quantity of NTFPs. In short, the procedure can be described as follows:

- the availability of NTFP species of a LMU is primarily based on the average quantity of NTFP species in the vegetation types present (weighed according to their coverage; see Section 6.1)
- a high landscape diversity of the LMU (3 or 4 vegetation types per LMU, excluding coverages < 10%) upgrade S2 and S3 classification with one scale (respectively to S1 and S2);
- steep slopes (> 30%) downgrade the classification with one scale (difficult access).

Distance to roads and villages is included implicitly in the model, since complex LMUs are in practice bound to the vicinity of roads and villages (due to shifting cultivation activities).

In this land evaluation study, two variants of NTFP extraction are considered: one focussing on a small selection of very important NTFP species (variant a) and one focussing on a much wider range of species (variant b). The procedure described, however, enables any alternative approach of land evaluation directed on a specific (category of) NTFP species (see Chapter 6). The results of the suitability classification are given in Sections 8.2 and 8.3.

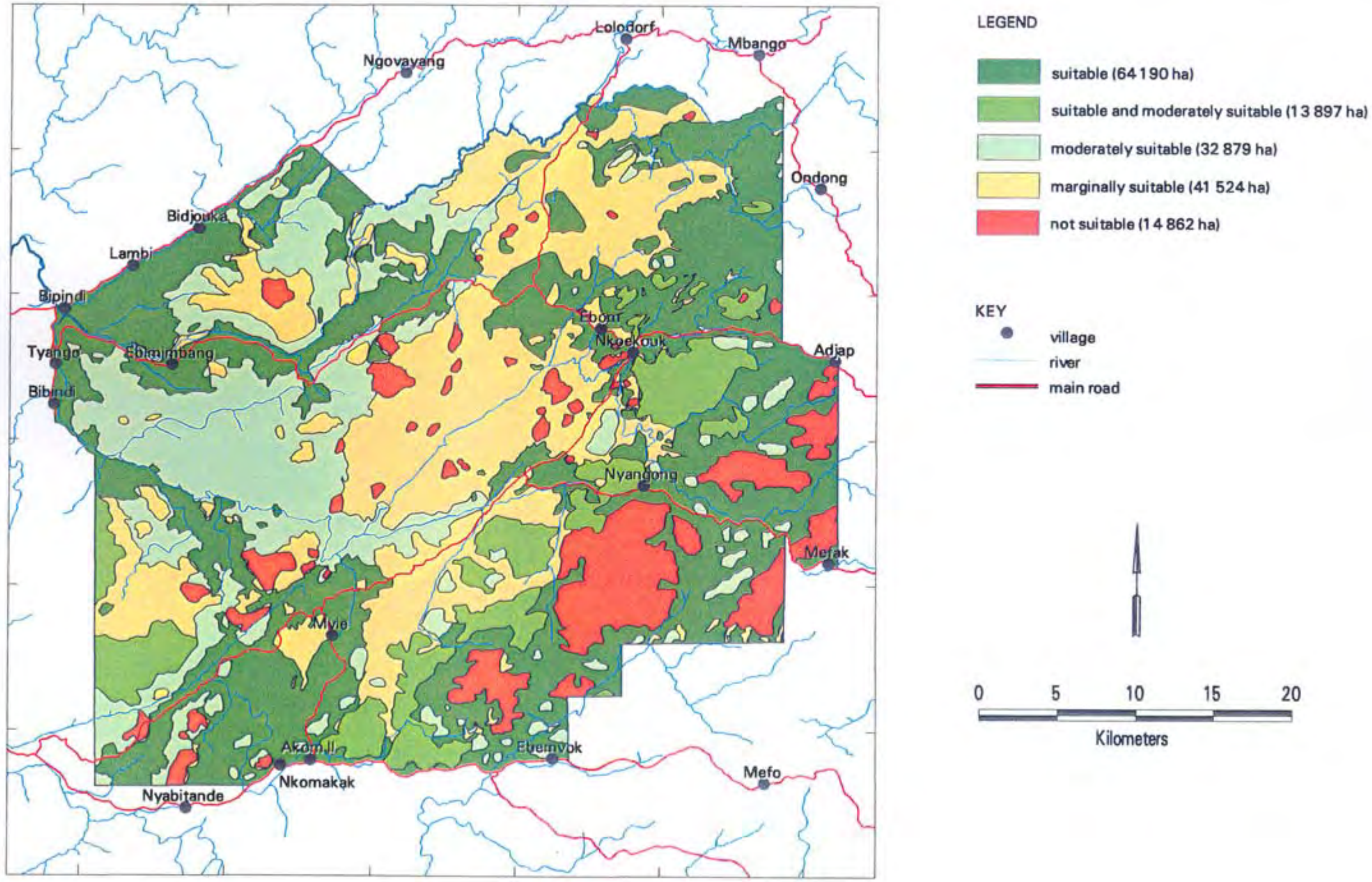
8.2 Most important species

In this ‘traditional’ variant, only the most frequently used species used (Annex 4, Category 1). Although not exclusively, the majority of the most widely commercialised NTFP species of the TCP area are found in this category (van Dijk, 1999). Following the procedure described above (Section 8.1), the final suitability classification of the land mapping units for NTFP extraction can be calculated. The results are given in Table 8.1 and shown on Map 8.1.

The classification given in Table 8.1 indicates that most LMUs are suitable to moderately suitable for the extraction of NTFPs. Not suitable are the mountain areas (Am), and the (undisturbed parts of the) hilly areas of ecological zones A and C. In areas without steep slopes there is a positive relation between shifting cultivation activities and suitability for NTFP extraction (due to a higher landscape diversity). If we focus on the relatively undisturbed landscapes without steep slopes, it proves that ecological zone B is more suitable than zones C and D. This is striking since the list of important NTFP species is based on interviews with villagers of whom a majority was living in the Ebom area, i.e. in ecological zone C.

SUITABILITY FOR NON– TIMBER FOREST PRODUCTS (NTFP); most important species

Bipindi– Akom II– Lolodorf region, South Cameroon



Map 8.1

Table 8.1. Suitability classification for the extraction of NTFPs (most important species).

LMU	Availability species `)	Landscape diversity	Limitations slope	Suitability (a)	notes
Am (u)	3	-	+	N	
Ah1 (u)	3	-	+	N	
Bh1 (u)	1	-	+	S2	
Bh1 (l)	1	+	+	S2	
Bh2 (u)	1	-	+/-	S1-2	1
Bh2 (l)	1	+	+/-	S1-2	1
Bh2 (h)	1	+	+/-	S1-2	1
Bu2 (u)	1	-	-	S1	
Bu2 (l)	1	+	-	S1	
Bu2 (h)	1	+	-	S1	
Bu1 (u)	1	-	-	S1	
Bu1 (l)	1	+	-	S1	
Bu1 (h)	1	+	-	S1	
Ch1 (u)	3	-	+	N	
Ch1 (l)	2	+	+	S2	
Cu2 (u)	3	-	-	S3	
Cu2 (l)	2	+	-	S1	
Cu2 (h)	1	+	-	S1	
Cu1 (u)	3	-	-	S3	
Cu1 (l)	2	+	-	S1	
Cu1 (h)	1	+	-	S1	
Dh1 (u)	2	-	+	S3	
Dh1 (l)	2	+	+	S2	
Du2 (u)	2	-	-	S2	
Du2 (l)	2	+	-	S1	
Du2 (h)	1	-	-	S1	
Du1 (u)	2	-	-	S2	
Du1 (l)	2	+	-	S1	
Du1 (h)	1	+	-	S1	
Dpd (u)	2	-	-	S2	
Dpd (l)	2	+	-	S1	
Dpd (h)	1	+	-	S1	
Ev (u)	2	-	-	S2	
Ev (l)	2	+	-	S1	

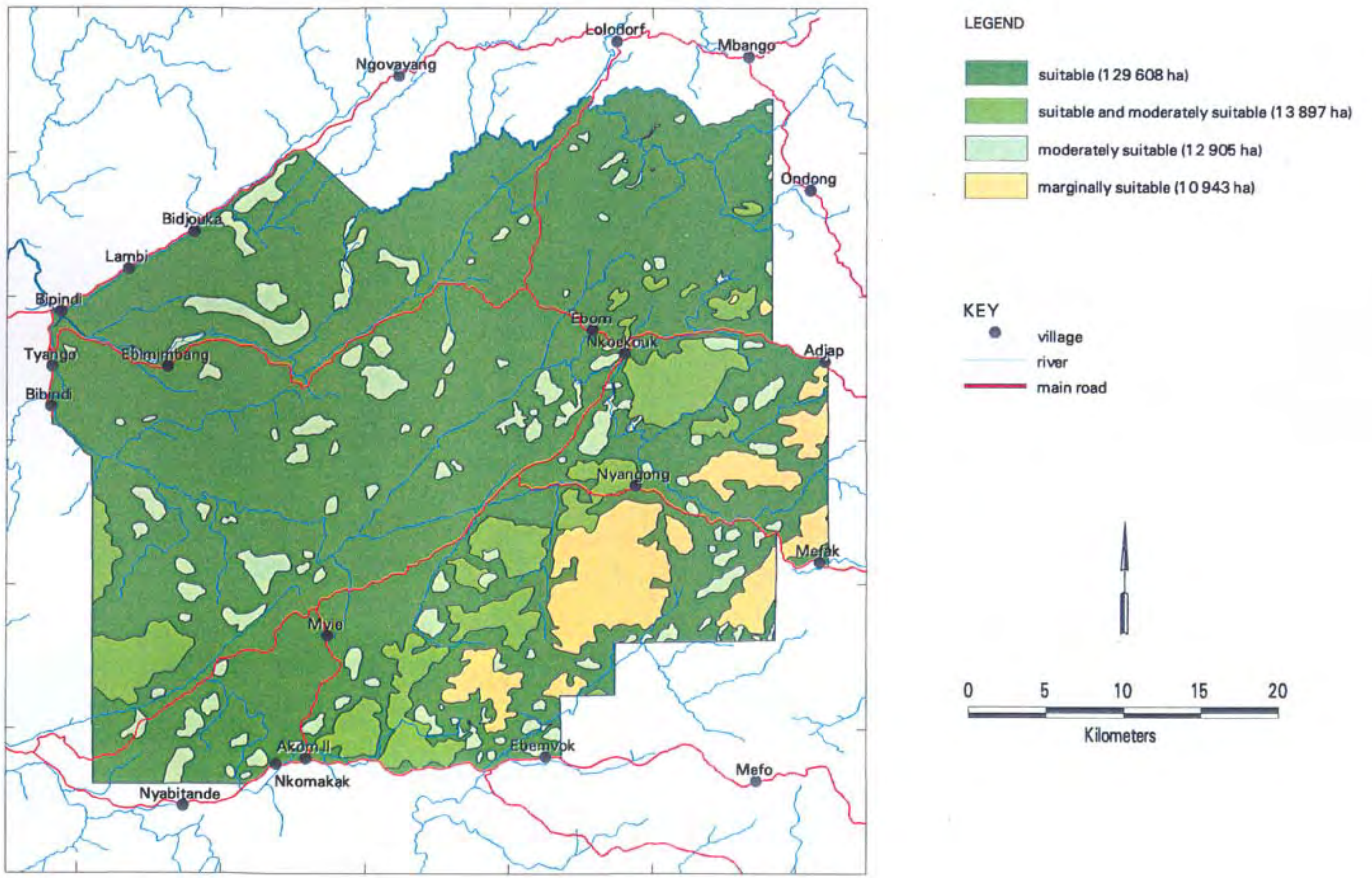
Notes: (1) N: where slopes > 30%. `) Availability NTFP species (weighed average per vegetation type): relative scaling based on the percentage of the maximum score: 1: 80-100%, 2: 60-80%, 3: 40-60% and 4: 0-40%. Landscape diversity: +: 3 or 4 vegetation types per LMU; -: 1 or 2 vegetation types per LMU. Limitations slope: +: > 30%; -: < 30%. Suitability: S1: suitable; S2: moderately suitable; S3: marginally suitable; N: not suitable.

8.3 Broad selection of species.

This variant refers to a much wider selection of NTFP species including less frequently used and lesser known ones (Annex 4, Categories 1 – 5). The results of the suitability classification are given in Table 8.2 and shown on Map 8.2.

SUITABILITY FOR NON– TIMBER FOREST PRODUCTS (NTFP); broad selection of species

Bipindi– Akom II– Lolodorf region, South Cameroon



Map 8.2

Table 8.2. Suitability classification for the extraction of NTFPs (broad selection of species).

LMU	Availability NTFP	Landscape diversity	Limitations slope	Suitability	notes
Am (u)	2	-	+	S3	
Ah1 (u)	2	-	+	S3	
Bh1 (u)	1	-	+	S2	
Bh1 (l)	1	+	+	S2	
Bh2 (u)	1	-	+/-	S1-2	1
Bh2 (l)	1	+	+/-	S1-2	1
Bh2 (h)	2	+	+/-	S1-2	1
Bu2 (u)	1	-	-	S1	
Bu2 (l)	1	+	-	S1	
Bu2 (h)	2	+	-	S1	
Bu1 (u)	1	-	-	S1	
Bu1 (l)	2	+	-	S1	
Bu1 (h)	2	+	-	S1	
Ch1 (u)	1	-	+	S2	
Ch1 (l)	1	+	+	S2	
Cu2 (u)	1	-	-	S1	
Cu2 (l)	1	+	-	S1	
Cu2 (h)	2	+	-	S1	
Cu1 (u)	1	-	-	S1	
Cu1 (l)	2	+	-	S1	
Cu1 (h)	2	+	-	S1	
Dh1 (u)	1	-	+	S2	
Dh1 (l)	1	+	+	S2	
Du2 (u)	1	-	-	S1	
Du2 (l)	1	+	-	S1	
Du2 (h)	2	-	-	S1	
Du1 (u)	1	-	-	S1	
Du1 (l)	2	+	-	S1	
Du1 (h)	2	+	-	S1	
Dpd (u)	1	-	-	S1	
Dpd (l)	2	+	-	S1	
Dpd (h)	2	+	-	S1	
Ev (u)	2	-	-	S2	
Ev (l)	2	+	-	S1	

Notes: (1) N: where slopes > 30%.. Availability NTFP species (weighed average per vegetation type): relative scaling based on the percentage of the maximum score: 1: 80-100%, 2: 60-80%, 3: 40-60% and 4: 0-40%. Landscape diversity: +: 3 or 4 vegetation types per LMU; -: 1 or 2 vegetation types per LMU. Limitations slope: +: > 30%; -: < 30%. Suitability: S1: suitable; S2: moderately suitable; S3: marginally suitable; N: not suitable.

Comparing Tables 8.1 and 8.2 proves that there is little difference between the two variants, indicating that the selection of species does not strongly influence the suitability classification. Although the difference in classification of the mapping units is not high, in area coverage, however, the difference is striking as some large mapping units (Cu1u and Cu2u) go from S3 to S1 and unit Du2u chances from S2 to S1. For variant b (the wide selection of species), there are no unsuitable areas and the ecological zones B, C and D are equally suitable. The area which was suitable under most important NTFP species (64 190 ha) increases to 129 608 ha for broad selection of species and is thus twice as large.

9 SUITABILITY FOR TIMBER PRODUCTION

9.1 Classification procedure

The suitability of land for timber production in natural forest is determined by the land qualities: availability of timber species and terrain condition (slope percentage and presence of swamps). Terrain conditions have an impact on accessibility: land that has steep slopes cannot be exploited with current techniques. The same holds for areas with predominant swampy conditions. In addition, tolerance to soil erosion (slope percentage) and the size of management unit may be of importance. Although Waterloo *et al*. (1997) found that selective logging (which is common practice in the TCP research area) affects soil erosion significantly, the measured sediment yield of 560 kg/ha/yr. following logging is still low and is likely to decrease rapidly some years after logging stopped. It is therefore omitted in the suitability classification. Size of management unit is a feature of the land utilisation type, rather than a land quality *sensu stricto*. It can best be dealt with in the process of land use planning and not in the suitability classification (see Chapter 12).

A summary of requirements and limitations is given in Table 9.1. The classification procedure can be described as follows:

- suitability classification is based on the principle of the most limiting factor;
- all requirements used in the classification procedure are considered equally important.

Table 9.1. Land use requirements for timber production in natural forest.

		Limitation class*			
Land quality	Diagnostic characteristic	1	2	3	4
Availability of timber species	relative abundance**	1	2	3	4
Terrain condition	slope (%)	<10	10-20	20-30	>30
	coverage swamps (%)	<20	20-30	30-60	>60

* 1: not or slightly limiting; 2: moderately limiting; 3: highly limiting; 4: very strongly limiting
** Relative scaling based on the percentage of the maximum score: 1: 80-100%, 2: 60-80%, 3: 40-60% and 4: 0-40%.

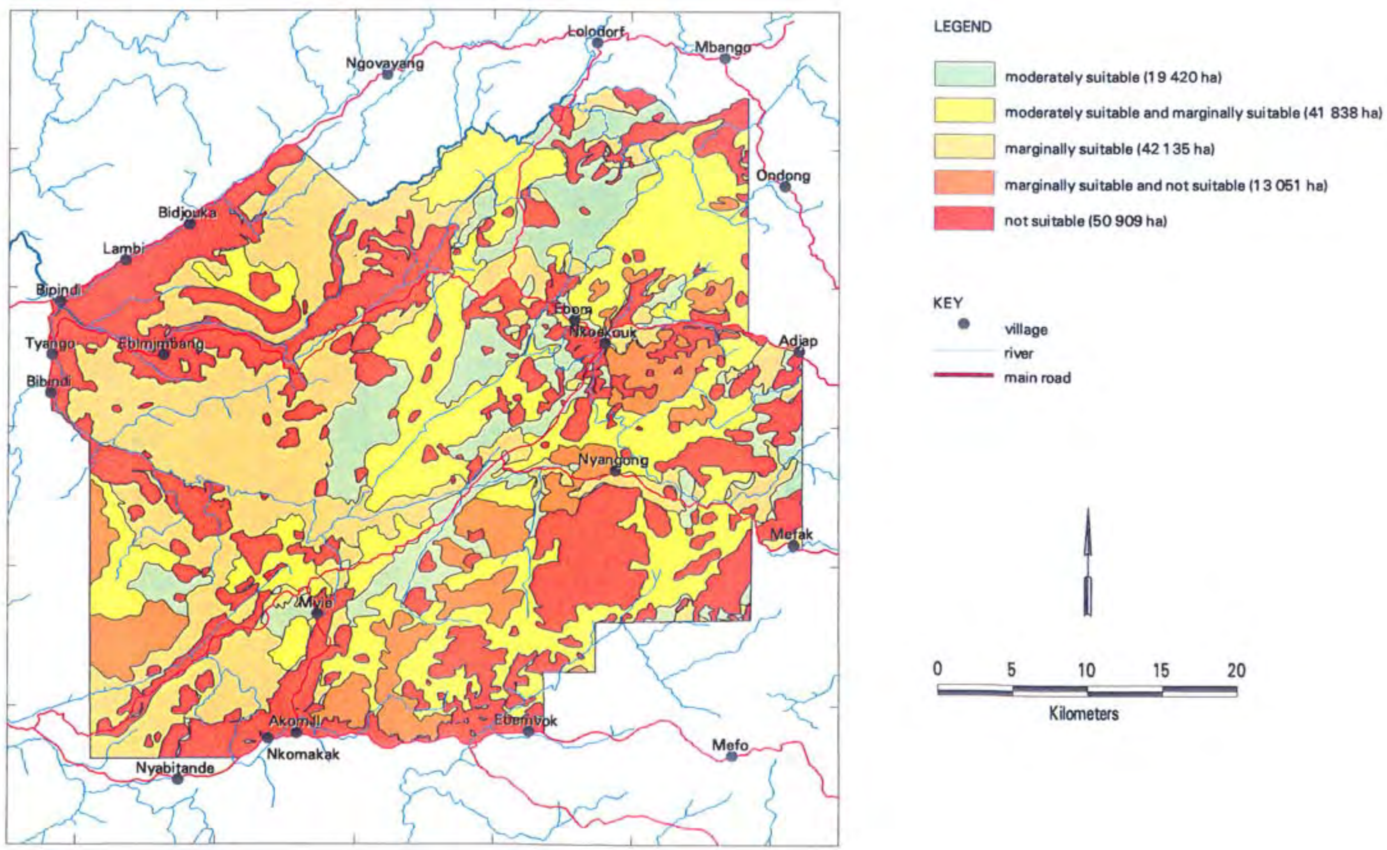
In this land evaluation study two variants of timber production are considered: (a) directed at a small selection of 'traditional' timber species (Section 9.2), and (b) directed at a wide variety of species (Section 9.3). The procedure described, however, enables any alternative approach of land evaluation directed at a specific (category of) timber species (see Chapter 6).

9.2 Traditional selection of timber species

In this 'traditional' variant only the superior grade timber species like Azobé (*Lophira alata*), Tali (*Erythrophleum ivorense*), and Padouk (*Pterocarpus soyauxii*) are included (Annex 3, Category 1) Following the procedure described above (Section 9.1), the final suitability classification of the land mapping units for timber production can be calculated. The results are given in Table 9.2 and presented on Map 9.1.

SUITABILITY FOR THE PRODUCTION OF TIMBER; traditional selection of species

Bipindi– Akom II– Lolodorf region, South Cameroon



Map 9.1

Table 9.2. Suitability classification for the production of timber (traditional selection of species).

LMU	Availability timber	Limitations slope	Limitations swamps	Suitability	notes
Am (u)	4	4	1	N	
Ah1 (u)	4	4	1	N	
Bh1 (u)	1	4	1	N	
Bh1 (l)	2	4	1	N	
Bh2 (u)	1	3-4	1	S3-N	1
Bh2 (l)	2	3-4	1	S3-N	1
Bh2 (h)	4	3-4	1	N	
Bu2 (u)	1	2-3	1	S2-3	2
Bu2 (l)	2	2-3	1	S2-3	2
Bu2 (h)	4	2-3	1	N	
Bu1 (u)	2	2	1	S2	
Bu1 (l)	3	2	1	S3	
Bu1 (h)	3	2	1	S3	
Ch1 (u)	1	4	1	N	
Ch1 (l)	2	4	1	N	
Cu2 (u)	1	2-3	1	S2-3	2
Cu2 (l)	2	2-3	1	S2-3	2
Cu2 (h)	4	2-3	1	N	
Cu1 (u)	2	2	1	S2	
Cu1 (l)	3	2	1	S3	
Cu1 (h)	4	2	1	N	
Dh1 (u)	3	4	1	N	
Dh1 (l)	3	4	1	N	
Du2 (u)	3	2-3	1	S3	
Du2 (l)	3	2-3	1	S3	
Du2 (h)	4	2-3	1	N	
Du1 (u)	3	2	1	S3	
Du1 (l)	4	2	1	N	
Du1 (h)	4	2	1	N	
Dpd (u)	3	1-2	1	S3	
Dpd (l)	4	1-2	1	N	
Dpd (h)	4	1-2	1	N	
Ev (u)	4	1	4	N	
Ev (l)	4	1	4	N	

Notes: (1) N: slopes > 30%; (2) S3: slopes > 20%. Limitations: 1: not or slightly limiting; 2: moderately limiting; 3: highly limiting; 4: very strongly limiting. Suitability: S1: suitable; S2: moderately suitable; S3: marginally suitable; N: not suitable.

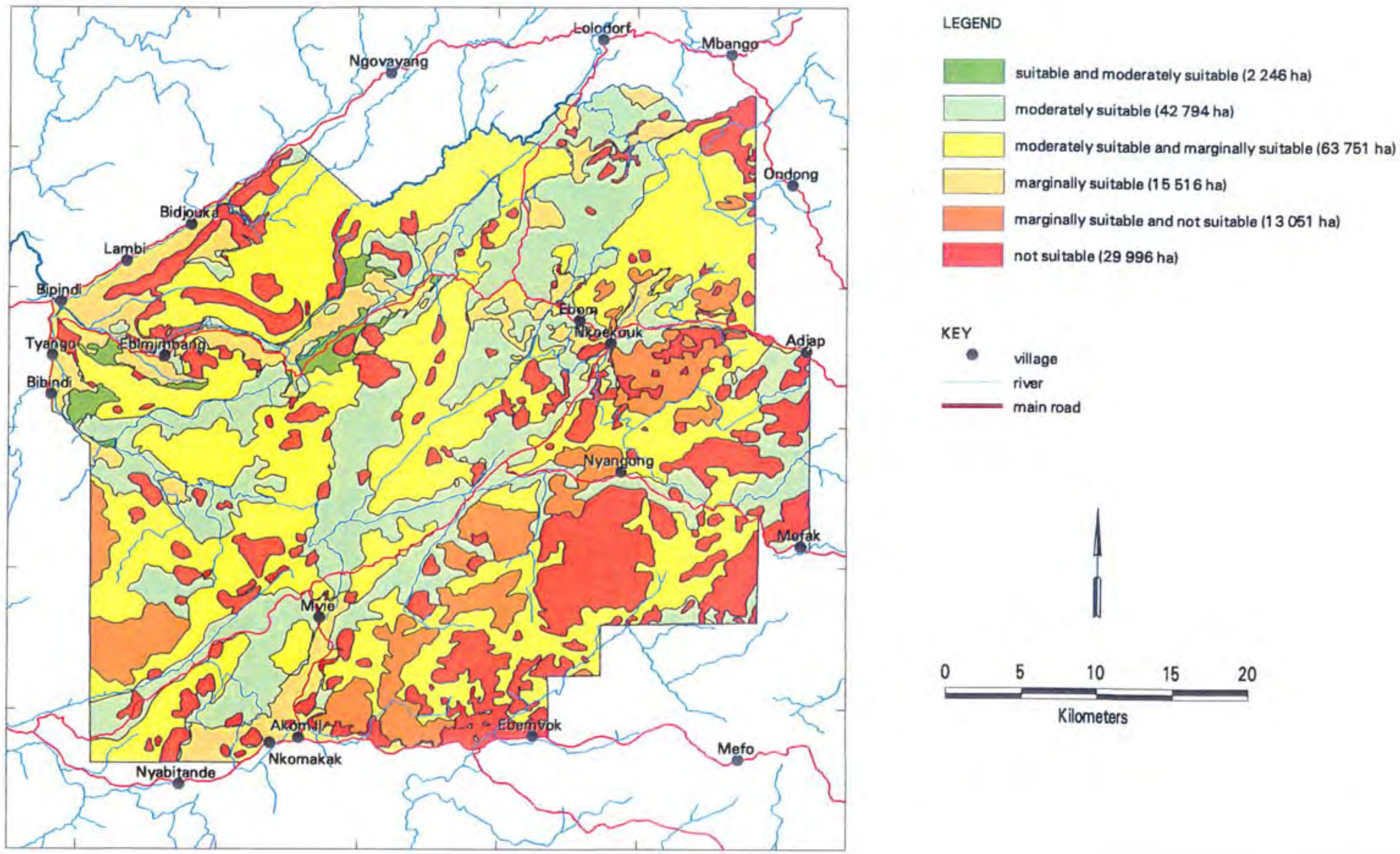
The results given in Table 9.2 show that ecological zone A, the hills (h1) of ecological zones B, C and D and all valley bottoms (Ev) are not suitable due to unfavourable terrain conditions, in spite of abundance of timber species in some of the land mapping units. Moreover, all land mapping units that are heavily disturbed by shifting cultivation are marginally suitable to unsuitable due to lack of timber. For the extraction of the 'traditional' selection of timber species no suitable areas are left. Moderately suitable areas are restricted to the moderately dissected uplands (u1) and parts of the strongly dissected parts (u2) of ecological zone B and C. It is striking that in ecological zone D, in which terrain conditions generally are favourable and which originally is the core of the Azobé distribution, no suitable or moderately suitable areas are left, due to both the extent of agricultural activities and long logging history.

9.3 Broad selection of timber species

In this alternative variant next to the superior and high grade timber species, a large variety of less valuable and lesser known timber species is included (Annex 3, Categories 1 – 4). Following the procedure described above (Section 9.1), the final suitability classification of the land mapping units for timber production can be calculated. The results are given in Table 9.3 and presented on Map 9.2.

SUITABILITY FOR THE PRODUCTION OF TIMBER; broad selection of species

Bipindi– Akom II– Lolodorf region, South Cameroon



Map 9.2

Table 9.3. Suitability classification for the production of timber (broad selection of species).

LMU	Availability timber	Limitations slope	Limitations swamps	Suitability	notes
Am (u)	3	4	1	N	
Ah1 (u)	3	4	1	N	
Bh1 (u)	1	4	1	N	
Bh1 (l)	2	4	1	N	
Bh2 (u)	1	3-4	1	S3-N	1
Bh2 (l)	2	3-4	1	S3-N	1
Bh2 (h)	4	3-4	1	N	
Bu2 (u)	1	2-3	1	S2-3	2
Bu2 (l)	2	2-3	1	S2-3	2
Bu2 (h)	4	2-3	1	N	
Bu1 (u)	1	2	1	S2	
Bu1 (l)	2	2	1	S2	
Bu1 (h)	3	2	1	S3	
Ch1 (u)	1	4	1	N	
Ch1 (l)	2	4	1	N	
Cu2 (u)	1	2-3	1	S2-3	2
Cu2 (l)	2	2-3	1	S2-3	2
Cu2 (h)	4	2-3	1	N	
Cu1 (u)	1	2	1	S2	
Cu1 (l)	2	2	1	S2	
Cu1 (h)	3	2	1	S3	
Dh1 (u)	1	4	1	N	
Dh1 (l)	2	4	1	N	
Du2 (u)	1	2-3	1	S2-3	
Du2 (l)	2	2-3	1	S2-3	
Du2 (h)	4	2-3	1	N	
Du1 (u)	1	2	1	S2	
Du1 (l)	2	2	1	S2	
Du1 (h)	3	2	1	S3	
Dpd (u)	1	1-2	1	S1-2	3
Dpd (l)	2	1-2	1	S2	
Dpd (h)	3	1-2	1	S3	
Ev (u)	1	1	4	N	
Ev (l)	2	1	4	N	

Notes: (1) N: slopes > 30%; (2) S3: slopes > 20%; (3) S2: slopes > 10%. Limitations: 1: not or slightly limiting; 2: moderately limiting; 3: highly limiting; 4: very strongly limiting. Suitability: S1: suitable; S2: moderately suitable; S3: marginally suitable; N: not suitable.

Although the availability of timber in the two variants shows significant differences (see Chapter 6), as far as the suitability of land for timber production is concerned, the two variants do not differ strongly. This due to the overriding effect of the terrain conditions, most notably steep slopes, on timber extraction. These effects are identical for both variants. As was stated above, ecological zone A, the hills (h1) of ecological zones B, C and D and all valley bottoms (Ev) are not suitable due to unfavourable terrain conditions, in spite of abundance of timber species in some land mapping units. Moreover, all land mapping units that are heavily disturbed by shifting cultivation are marginally suitable to unsuitable due to lack of timber.

In general, suitability for variant a (traditional selection) and variant b (wide selection of timber species) suitability in ecological zones A, B and C is quite similar, but in ecological zone D there are more possibilities for the alternative variant (b). Most notably the less disturbed parts of the moderately dissected uplands (Du1) and dissected erosional plain (Dpd) are considered to be (moderately) suitable.

10 SUITABILITY FOR SHIFTING CULTIVATION

10.1 Classification procedure

In this land evaluation study the suitability classification for shifting cultivation refers to the traditional technology of shifting cultivation as is currently practised in the TCP research area. The results are given in Section 10.2. In addition, the suitability for alternative technologies is discussed briefly in a qualitative way (Section 10.3).

Suitability classification for shifting cultivation (traditional technology) is based on the combined suitability for the most important crops: banana, maize, groundnuts, cassava, and macabo. Ngôn and cocoyam are not included because sufficient data on the requirements are not available. Requirements for cocoyam are probably similar to those for cassava. For the five most important crops the requirements and limitations are listed in tables (Tables 10.1 – 10.5). These tables are combined into one summary table of requirements and limitations. In general, this summary table is based on the limitations of the most demanding crop (for each requirement). It is consequently used as an expedient for the suitability classification for shifting cultivation as a whole. No attempt was made to assess the suitability for the separate crops as the cropping system in the area is based on mixed cropping.

The classification procedure for shifting cultivation is rather complex since the various requirements and accompanying land characteristics refer to various spatial scales. Drainage condition, effective soil depth, nutrient availability, and workability (texture topsoil) are characteristics of the soil type (which occupy a given percentage of each land mapping unit). Erosion risk depends on slope percentage, which is a characteristic of the landforms (and thus implicitly also of the land mapping units). Distance to roads and villages (accessibility) is a land characteristic, which has no relation at all to the land mapping units. To overcome this problem, suitability classification is done step by step, starting with an assessment of limitations per soil type.

In general the procedure can be summarised as follows:

- requirements and limitations for banana, maize, groundnuts, cassava, and macabo are combined into one summary table with requirements and limitations for shifting cultivation as a whole;
- the suitability classification for shifting cultivation is primarily based on the principle of the most limiting factor, taking into account the following land characteristics and qualities:
  - drainage condition (soil type);
  - effective soil depth (soil type);
  - nutrient availability (soil type);
  - slope percentage (LMU);
  - accessibility (area).
- the limitation class for effective soil depth corresponds with the limitation class of the actual soil depth, unless the coarse fragment contents of the topsoil provides higher limitations; in that case the overall classification is downgraded with one scale;
- the limitation class for nutrient availability of a given soil type is found by taking the average value of the limitation classes for CEC, base saturation, and organic matter content (if relevant);
- workability (texture topsoil) is considered to be a factor of minor importance as other limitations are always dominating; it is included in the tables with requirements and limitations, but not used in the classification procedure.

Climatic requirements are not differentiating between the various LMUs and therefore not included. Nearly optimal climatic requirements concerning rainfall and temperature ranges for all crops are present in the TCP area. Most crops demand temperatures between 18 and 30^{o} C in the growing season and rainfall over 1500 mm. Only maize prefers slightly less rainfall.

The terrain conditions: slope percentage, coverage of rock outcrops, and flooding frequency are not included either. The limitations concerning slope percentage (terrain condition) happen to be identical with, or less strict than, limitations for slope percentage (erosion risk). Limitations concerning flooding frequency (only relevant in the valley bottoms) correspond with the limitations related to drainage condition. Rock outcrops, finally, do not provide more than slight limitations in any land mapping unit (coverage < 2%; limitation class 1).

Accessibility of the land is mainly determined by the distance to be covered by the land user. In this setting these distances are covered on foot. The distance from roads and villages to the agricultural fields is determined by the availability of land: an increase in population will increase these distances. As a general guideline we consider land within 5 km from roads (along which the villages are located) to have no or only slight limitations, land which is more remote is considered unsuitable (limitation class 4).

10.2 Suitability for shifting cultivation

Suitability for shifting cultivation is assessed by combining the requirements of the various crops (banana, maize, groundnuts, cassava and macabo).

Banana

Bananas (*Musa spp.*) thrive best on free draining, well aerated, deep, fertile loams, but are grown on a wide range of soil types. Banana roots do not tolerate any water logging and bananas are very susceptible to moisture stress. The nutrient demands are medium to high. For high yield levels in commercial plantations, nitrogen, phosphorous and potassium demands are 200-400, 45-60 and 240-480 kg/ha, respectively. The optimal pH is between 5 and 7. Yields are not known for the TCP research area (likely, <15 t/ha - less than 200 plants/ha if grown as monoculture). In the TCP research area both sweet bananas and plantain are grown. Literature data generally refer to sweet bananas. The requirements and class limits for plantain are assumed to be similar and are given in Table 10.1.

Table 10.1. Requirements and limitations for banana (Sys, 1985; Touber et al., 1989).

		Limitation class*			
Land Quality	Diagnostic Characteristic	1	2	3	4
Drainage	Soil drainage	moderate	imperfect	poor	very poor
Effective soil depth	Soil depth (cm)	>75	>50	>25	<25
	Crs fragment content (%, 25-100cm)	<15	<35	<55	>55
Nutrient availability	CEC (meq/100g)	>8	<8		
	Base Saturation (%)	>35	>20	<20	
	Organic Matter (% C, 0-15cm)	>1.5	>0.8	<0.8	
Workability	Texture (topsoil)**	all exc. hc	hc		
Erodability	Slope (%)	<8	8-16	16-30	>30

* 1: not or slightly limiting; 2: moderately limiting; 3: highly limiting; 4: very strongly limiting
** hc: heavy clay.

Maize

Maize (*Zea mays*) requires well drained, moderately deep, well aerated, deep loams and silt loams with adequate organic matter. The optimal pH is between 5.5 and 7. The nutrient demands are high, especially for nitrogen: 100-200 kg N, 50-80 kg P and 60-100 kg K are ranges found in literature (for high yields). Grain yields under smallholder rainfed conditions are between 0.5-1.5 kg/ha. Requirements and limitation classes are given in Table 10.2.

Table 10.2. Requirements and limitation classes for maize (Sys, 1985; Touber *et al.*, 1989).

		Limitation class*			
Land Quality	Diagnostic Characteristic	1	2	3	4
Drainage	Soil/surface drainage	well	moderate	poor	very poor
Effective soil depth	Soil depth (cm)	>75	>50	>25	<25
	Coarse fragment content (%, 25-100cm)	<15	<35	<55	>55
Nutrient availability	CEC (meq/100g)	>8	<8		
	Base Saturation (%)	>35	>20	<20	
	Organic matter (% C, 0-15cm)	>1.2	>0.8	<0.8	
Workability	Texture (topsoil)**	s,ls,sl	scl,sc,c	hc	
Erodability	Slope (%)	<8	8-16	16-30	>30

* 1: not or slightly limiting; 2: moderately limiting; 3: highly limiting; 4: very strongly limiting
** s: sand; ls: loamy sand; sl: sandy loam; scl: sandy clay loam; sc: sandy clay; c: clay; hc: heavy clay.

Groundnuts

Groundnut (*Arachis hypogaea*) requires a well drained, moderately deep, medium textured soil with a well structured, loose topsoil. Water logging is harmful and resistance to drought is medium. Nutrient demands are low to medium: N, P and K recommendations for high yields are 10-20, 15-40 and 25-40 kg/ha, respectively. The optimal pH is 5 - 7. Yields of 0.5 t/ha for smallholder rainfed fields are reported by Landon (1991). Requirements and limitation classes are given in Table 10.3.

Table 10.3. Requirements and limitations for groundnuts (Sys, 1985; Touber *et al.*, 1989).

		Limitation class*			
Land Quality	Diagnostic Characteristic	1	2	3	4
Drainage	Soil/surface drainage	well	moderate	imperfect	very poor
Effective soil depth	Soil depth (cm)	>75	>50	>25	<25
	Coarse fragment content1 (%, 0-25cm)	<3	<15	<35	>35
	(%, 25-100cm)	<15	<35	<55	>55
Nutrient availability	CEC (meq/100g)	any			
	Base Saturation (%)	>35	<35		
Workability	Texture (topsoil)**	s,ls,sl	scl,sc,c	hc	
Erodability	Slope (%)	<8	8-16	16-30	>30

* 1: not or slightly limiting; 2: moderately limiting; 3: highly limiting; 4: very strongly limiting
** s: sand; ls: loamy sand; sl: sandy loam; scl: sandy clay loam; sc: sandy clay; c: clay; hc: heavy clay.

Cassava

Cassava (*Manihot esculenta*) thrives best on deep, well drained, medium textured soils. Light textured and well-structured soils favour root formation. Cassava is drought resistant. The nutrient demands are medium and it can tolerated low amounts. Optimal pH is between 5.5 - 6.5. On moderate to good soils yields of 5-15 t/ha (average rainfed smallholder) are possible. Requirements and limitations for cassava are given in Table 10.4.

Table 10.4. Requirements and limitations for cassava (Sys, 1985; Touber *et al.*, 1989).

		Limitation class*			
Land Quality	Diagnostic Characteristic	1	2	3	4
Drainage	Soil/surface drainage	well	moderate	imperfect	poor
Effective soil depth	Soil depth (cm)	>100	>75	>50	<50
	Coarse fragment content (%, 0-25cm)	<3	<15	<35	>35
	(%, 25-100cm)	<15	<35	<55	>55
Nutrient availability	CEC (meq/100g)	any			
	Base saturation (%)	>20	<20		
	Organic matter (% C, 0-15cm)	>0.8	<0.8		
Workability	Texture (topsoil)**	s,ls,sl	scl,sc,c	hc	
Erodability	Slope (%)	<8	8-16	16-30	>30

* 1: not or slightly limiting; 2: moderately limiting; 3: highly limiting; 4: very strongly limiting
** s: sand; ls: loamy sand; sl: sandy loam; scl: sandy clay loam; sc: sandy clay; c: clay; hc: heavy clay.

Macabo

Macabo (*Xanthosoma sagittifolium*) requires a growing season of 12 months and rainfall above 2000 mm/yr. for good yields. The crop is sensitive to soil compaction. It is more tolerant of shade and water-stress and less demanding in labour than cocoyam (Hackett, 1984). Nutrient requirements are medium. The optimal pH range is 5.5 - 6.5 (extremes are 4.5 - 7.5). Important requirements for this crop are especially drainage, soil depth and workability. Requirements and limitations are given in Table 10.5.

Table 10.5. Requirements and limitations for macabo (Hackett, 1984; Touber et al., 1989).

		Limitation class*			
Land Quality	Diagnostic Characteristic	1	2	3	4
Drainage	Soil/surface drainage	well	imperfect	excessive	poor
Effective soil depth	Soil depth (cm)	>100	>50	>25	<25
	Coarse fragment content (%, 25-100cm)	<15	<35	<55	>55
Nutrient availability	CEC (meq/100g clay)	all			
	Base Saturation (%)	>50	20-50	10-20	<10
Workability	Texture (topsoil)**	s,ls,sl	scl,sc,c	hc	
Erosion prevention	Slope (%):	<8	8-16	16-30	>30

* 1: not or slightly limiting; 2: moderately limiting; 3: highly limiting; 4: strongly limiting
** s: sand; ls: loamy sand; sl: sandy loam; scl: sandy clay loam; sc: sandy clay; c: clay; hc: heavy clay.

Combination of crops

When we compare the class limits it proves that banana has the lowest requirements for drainage; maize and banana have the highest requirements for nutrient availability; cassava and groundnuts have the highest requirements for effective soil depth. As far as vulnerability for erosion is concerned, class limits (slope %) are identical for all crops. As for workability groundnuts have the highest requirements. Combined limitation classes for all five crops are given in Table 10.6. In general, class limits in Table 10.6 are based on the crop that is most selective for the requirement at issue.

Table 10.6. Requirements and limitations for shifting cultivation (traditional technology)

		Limitation class*			
Land Quality	Diagnostic Characteristic	1	2	3	4
Drainage	Soil/surface drainage	well	moderate	imperfect	poor
Effective soil depth	Soil depth (cm)	>75	50-75	25-50	<25
	Coarse fragment content1 (%, 0-25cm)	<3	<15	<35	>35
	(%, 25-100cm)	<15	<35	<55	>55
Nutrient availability	CEC (meq/100g)	>8	4-8	<4	
	Base Saturation (%)	>35	20-35	<20	
	Organic Matter (% C, 0-15cm)	>1.5	0.8-1.5	<0.8	
Workability	Texture (topsoil)**	s,ls,sl	scl,sc,c	hc	
Erodability	Slope (%)	<8	8-16	16-30	>30

* 1: not or slightly limiting; 2: moderately limiting; 3: highly limiting; 4: very strongly limiting
** s: sand; ls: loamy sand; sl: sandy loam; scl: sandy clay loam; sc: sandy clay; c: clay; hc: heavy clay.

Table 10.7 presents the requirements for shifting cultivation (traditional technology) and the accompanying limitations of land characteristics per soil type. It proves that Ebom soils are most favourable for shifting cultivation purposes having no to only moderate limitations (the latter due to local insufficiency of the base saturation of the topsoil). Nyangong soils and Ebimimbang soils both have moderate limitations, respectively due to insufficient base saturation and high coarse fragment contents. Shifting cultivation on Valley bottom soils is strongly limited by unfavourable drainage conditions.

Table 10.7. Limitation classes per soil type for shifting cultivation.

Land quality	Limitation class* Nyangong soils	Ebom soils	Ebimimbang soils	Valley bottom soils
Drainage	**1**	**1**	**2**	**4**
Effective soil depth				
actual soil depth	1	1	1-2	1-2
coarse fragment content (topsoil)	1	1	2	1
total	**1**	**1**	**2**	**1-2**
Nutrient availability				
CEC (topsoil)	1	1	1-2	1-2
base saturation (topsoil)	3	1-3	1	1-3
organic matter content (topsoil)	1	1	1	1
total	**2**	**1-2**	**1**	**1-2**
Final classification*	**2**	**1-2**	**2**	**4**

* 1: not or slightly limiting; 2: moderately limiting; 3: highly limiting; 4: very strongly limiting.

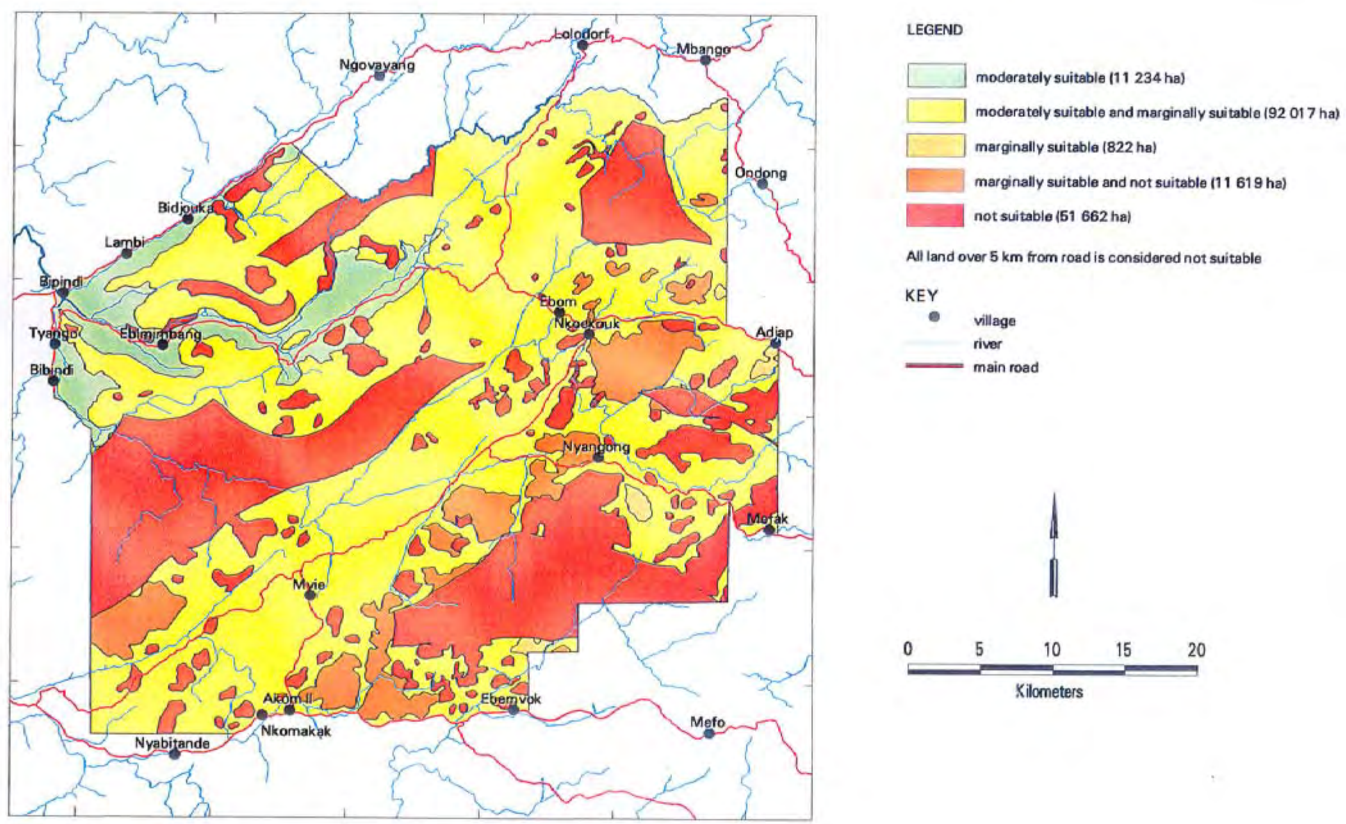
Following the general procedure described above (Section 10.1), the final suitability classification of the land mapping units for shifting cultivation can be calculated. The results are given in Table 10.8 and presented on Map 10.1.

The figures presented in Table 10.8 show that, if we focus on the zone within 5 km from the roads, in almost all land mapping units the suitability for shifting cultivation (traditional technology) is primarily limited by the erosion risks (slope steepness). However, in the dissected erosional plains of ecological zone D limitations of the soil (Ebimimbang: insufficient drainage and relatively high coarse fragment content of the topsoil) are decisive. Here, the land mapping units are classified as moderately suitable. The Valley bottoms are classified as unsuitable due to unfavourable drainage conditions.

All land, which is more remote than 5 km from the nearest road, is classified as unsuitable irrespective of soil characteristics and slope percentage.

SUITABILITY FOR SHIFTING CULTIVATION

Bipindi– Akom II– Lolodorf region, South Cameroon



Map 10.1

Table 10.8. Suitability classification for shifting cultivation.

LMU	Soil type	Limitations soil	Limitations erosion	Suitability* 0-5 km	Suitability* > 5 km	Notes
Am (u)	Ny	2	4	N	N	
Ah1 (u)	Ny	2	4	N	N	
Bh1 (u)	Ny	2	4	N	N	
Bh1 (l)	Ny	2	4	N	N	
Bh2 (u)	Ny	2	3-4	S3-N	N	1
Bh2 (l)	Ny	2	3-4	S3-N	N	1
Bh2 (h)	Ny	2	3-4	S3-N	N	1
Bu2 (u)	Ny, Eb	1-2	2-3	S2-3	N	2
Bu2 (l)	Ny, Eb	1-2	2-3	S2-3	N	2
Bu2 (h)	Ny, Eb	1-2	2-3	S2-3	N	2
Bu1 (u)	Ny, Eb, Vb	1-2(4)	2-3	S2-3(N)	N	2,3
Bu1 (l)	Ny, Eb, Vb	1-2(4)	2-3	S2-3(N)	N	2,3
Bu1 (h)	Ny, Eb, Vb	1-2(4)	2-3	S2-3(N)	N	2,3
Ch1 (u)	Eb	1-2	4	N	N	
Ch1 (l)	Eb	1-2	4	N	N	
Cu2 (u)	Eb	1-2	2-3	S2-3	N	2
Cu2 (l)	Eb	1-2	2-3	S2-3	N	2
Cu2 (h)	Eb	1-2	2-3	S2-3	N	2
Cu1 (u)	Eb, Vb	1-2(4)	2-3	S2-3(N)	N	2,3
Cu1 (l)	Eb, Vb	1-2(4)	2-3	S2-3(N)	N	2,3
Cu1 (h)	Eb, Vb	1-2(4)	2-3	S2-3(N)	N	2,3
Dh1 (u)	Em	2	4	N	N	
Dh1 (l)	Em	2	4	N	N	
Du2 (u)	Em	2	2-3	S2-3	N	2
Du2 (l)	Em	2	2-3	S2-3	N	2
Du2 (h)	Em	2	2-3	S2-3	N	2
Du1 (u)	Em, Vb	2(4)	2-3	S2-3(N)	N	2,3
Du1 (l)	Em, Vb	2(4)	2-3	S2-3(N)	N	2,3
Du1 (h)	Em, Vb	2(4)	2-3	S2-3(N)	N	2,3
Dpd (u)	Em, Vb	2(4)	1-2	S2(N)	N	3
Dpd (l)	Em, Vb	2(4)	1-2	S2(N)	N	3
Dpd (h)	Em, Vb	2(4)	1-2	S2(N)	N	3
Ev (u)	Vb	4	1	N	N	
Ev (l)	Vb	4	1	N	N	

Notes: (1) N: slopes > 30%; (2) S3: slopes > 16%; (3) values in brackets refer to Valley bottom soils covering 10-20% of the LMU. S1: suitable; S2: moderately suitable; S3: marginally suitable; N: not suitable.
* distance from field to road.

10.3 Alternative technologies

Locally in the TCP research area the traditional shifting cultivation system with a long fallow period has changed to a system with a short fallow period (3-5 years). This is the so-called *Chromolaena* fallow. In Ivory Coast, research (Slaats, 1995) has shown that a 3 years fallow period with one year cropping is a viable system even without applying fertilisers. The most limiting nutrient is phosphorous followed by nitrogen and application of these improved crop yields considerably.

The *Chromolaena* fallow system could be further tested in the TCP area. The suitability classification for such an improved fallow system is similar to the one using traditional technology.

Further intensification could be thought of, leading to a permanent cropping system. This however, requires a complete change in land management and can not be done without proper training of farmers in integrated pest and nutrient management. The key issue in this system will be the management of soil organic matter. Also for this system, the suitability classes as given in Section 10.2 can be taken as a general guideline.

11 SUITABILITY FOR PLANTATION AGRICULTURE

11.1 Classification procedure

The land utilisation type 'plantation agriculture' is subdivided into the following crops: cocoa (*Theobroma cacao*), rubber (*Hevea brasiliensis*), oil palm (*Elaeis guineensis*) and pineapple (*Ananas comosus*).

The suitability per crop is presented in distinct sections (Sections 11.2 - 11.5), each including a table with requirements and limitation classes for the land qualities. Data on requirements are mainly extracted from Sys (1985), NSS (1988) and Landon (1991). The procedure of suitability classification is comparable to the procedure described for shifting cultivation (Section 10.1):

- classification is primarily based on the principle of the most limiting factor;
- the limitation class for effective soil depth corresponds with the limitation class of the actual soil depth, unless the coarse fragment contents of the subsoil (cocoa, oil palm, and rubber) or the topsoil (pineapple) provides higher limitations; in that case the overall classification is downgraded with one scale;
- the limitation class for nutrient availability of a given soil type is found by taking the average value of the limitation classes for CEC, base saturation, organic matter content, and pH (if relevant).

Compared to the procedure described for shifting cultivation there are two differences:

- all requirements (expressed as land qualities) listed per crop are considered equally important;
- distance to roads and villages is not taken into account.

Optimal climatic requirements do not differ much for the four selected crops: mean monthly temperatures of 20 - 30^{o} C and well-distributed rainfall of minimal 1500 mm. Both requirements are met in the area. For all four crops flooding frequency is relevant, but limitations correspond to those caused by drainage condition. Therefore, flooding frequency is not presented as a distinct land use requirement. Coverage of rock outcrops is not included either, since for all crops the percentage rock outcrops in all land mapping units can be classified as not or only slightly limiting (class 1; coverage < 2%). Accessibility is not included since limitations for the relevant land characteristic (slope) are similar to those given for erosion risk (in the case of cocoa, oil palm and rubber) or less limiting (in the case of pineapple). Finally, workability of the topsoil is considered to be of importance for pineapple, but not for the tree crops (cocoa, oil palm and rubber).

11.2 Cocoa

Cocoa (*Theobroma cacao*) thrives best on soils consisting of well-aggregated sands, silt and clay. Adequate soil aeration is necessary in case of high rainfall amounts. Cocoa has a low drought resistance. Shade protection is essential for (young) plants under poor soil conditions. Rooting depth is 2 m, but 80% of roots occur in the top 15 cm. A tap root provides anchorage and the root mat looks after nutrient and water uptake. Steep slopes, bare rocks and swamp areas are not suitable for cocoa (Are and Guyne-Jones, 1974). Organic C% and pH of topsoil need to be more than 1.75% and between 5.5 - 7.5, respectively. Medium to high amounts of nutrients are needed. In literature, yields of dry cocoa beans range between 0.6 and 1.5 ton/ha (650-1500 trees/ha). In the TCP area reported yields are between 0.6 and less than 0.2 ton/ha. The removal of N, P and K with a yield of 0.56 t/ha dry beans are 25, 4.5 and 36 kg, respectively (Landon, 1991). A summary of requirements and limitations is given in Table 11.1.

Table 11.1. Requirements and limitations for cocoa (Sys, 1985; Touber *et al.*, 1989).

		Limitation class*			
Land Quality	Diagnostic characteristic	1	2	3	4
Drainage	Soil drainage	well	moderate	imperfect	very poor
Effective soil depth					
	Soil depth (cm)	>150	>100	>50	<50
	Coarse fragment content (%; subsoil)	<15	<35	<55	>55
Nutrient availability	CEC (meq/100g)	>8	<8	-	-
	Base saturation (%)	>35	20-35	<20	-
	Organic matter (% C)	>1.5	>0.8	<0.8	-
Erodability	Slope (%)	<8	8-16	16-30	>30

* 1: not or slightly limiting; 2: moderately limiting; 3: highly limiting; 4: very strongly limiting.

Table 11.2 presents the requirements for the cultivation of cocoa and the accompanying limitations of land characteristics per soil type. It proves that Ebom soils are most suitable for the growth of cocoa, although part of these soils provide moderate limitations due to insufficient soil depth and/or base saturation. The same limitations apply to all Nyangong soils which are therefore all classified as moderately limiting. Ebimimbang soils are classified as moderately to strongly limiting depending on soil depth and/or coarse fragment content in the subsoil. All Valley bottom soils, finally, are classified as strongly limiting, due to unfavourable drainage conditions.

Table 11.2 Requirements and limitation classes per soil type for cocoa.

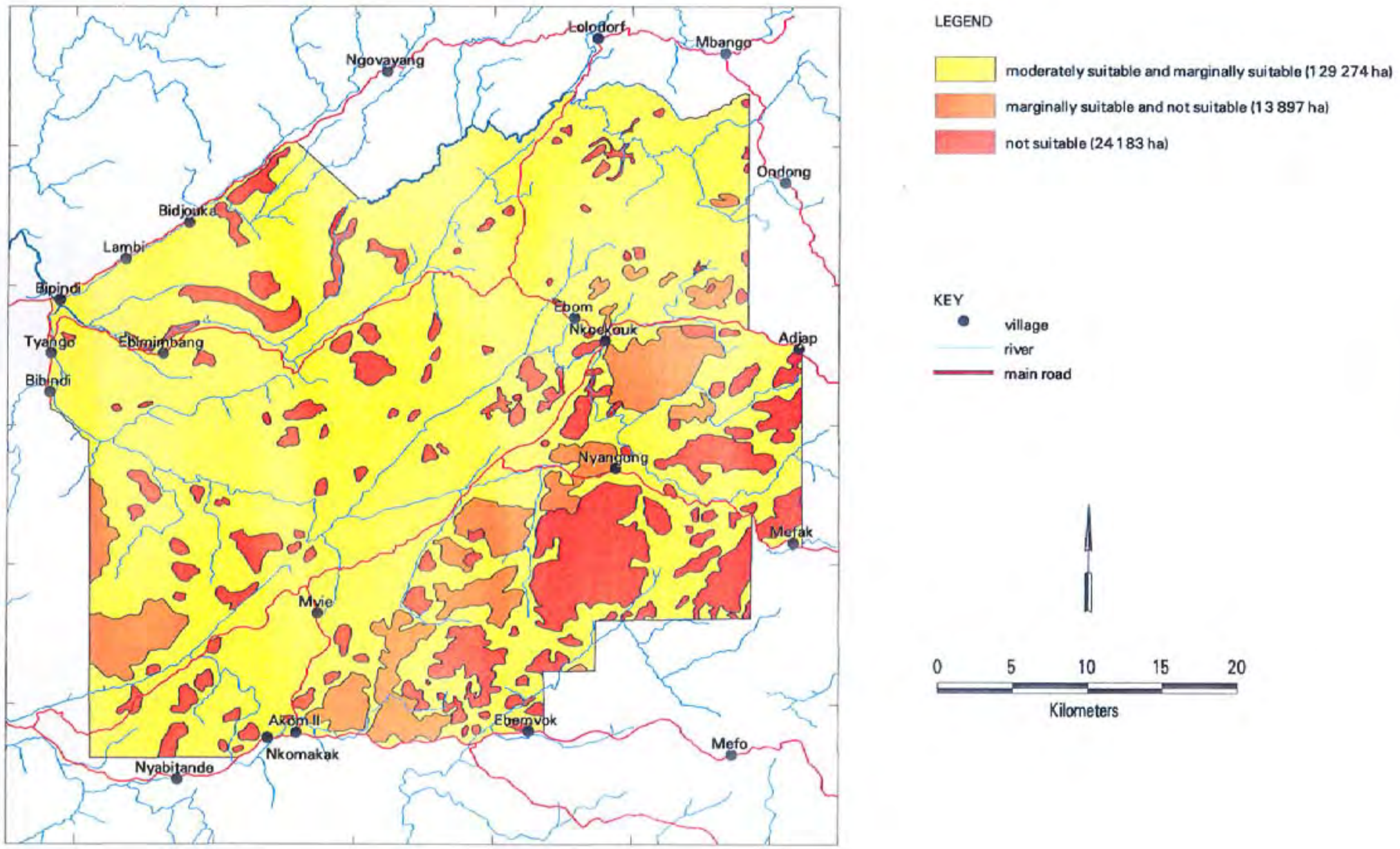
	Limitation class*			
Land Quality	Nyangong soils	Ebom soils	Ebimimbang soils	Valley bottom soils
Drainage:	**1**	**1**	**1-2**	**4**
Effective soil depth				
actual soil depth	1-2	1-2	1-3	1-3
coarse fragment content (subsoil)	1	1	2-3	1-4
total	**1-2**	**1-2**	**2-3**	**1-4**
Nutrient availability				
CEC (topsoil)	1	1	1-2	1-2
base saturation (topsoil)	3	1-3	1	1-3
organic matter content (topsoil)	1	1	1	1
total	**2**	**1-2**	**1**	**1-2**
Final classification*	**2**	**1-2**	**2-3**	**4**

* 1: not or slightly limiting; 2: moderately limiting; 3: highly limiting; 4: very strongly limiting.

Following the general procedure described above (Section 11.1), the final suitability classification of the land mapping units for cultivation of cocoa can be calculated. The results are given in Table 11.3 and presented on Map 11.1.

SUITABILITY FOR THE CULTIVATION OF COCOA

Bipindi– Akom II– Lolodorf region, South Cameroon



Map 11.1

Table 11.3 Suitability classification for the cultivation of cocoa.

LMU	Soil type	Limitations soil	Limitations erosion	Suitability	notes
Am (u)	Ny	2	4	N	
Ah1 (u)	Ny	2	4	N	
Bh1 (u)	Ny	2	4	N	
Bh1 (l)	Ny	2	4	N	
Bh2 (u)	Ny	2	3-4	S3-4	1
Bh2 (l)	Ny	2	3-4	S3-4	1
Bh2 (h)	Ny	2	3-4	S3-4	1
Bu2 (u)	Ny, Eb	1-2	2-3	S2-3	2
Bu2 (l)	Ny, Eb	1-2	2-3	S2-3	2
Bu2 (h)	Ny, Eb	1-2	2-3	S2-3	2
Bu1 (u)	Ny, Eb, Vb	1-2(4)	2-3	S2-3(N)	2,3
Bu1 (l)	Ny, Eb, Vb	1-2(4)	2-3	S2-3(N)	2,3
Bu1 (h)	Ny, Eb, Vb	1-2(4)	2-3	S2-3(N)	2,3
Ch1 (u)	Eb	1-2	4	N	
Ch1 (l)	Eb	1-2	4	N	
Cu2 (u)	Eb	1-2	2-3	S2-3	2
Cu2 (l)	Eb	1-2	2-3	S2-3	2
Cu2 (h)	Eb	1-2	2-3	S2-3	2
Cu1 (u)	Eb, Vb	1-2(4)	2-3	S2-3(N)	2,3
Cu1 (l)	Eb, Vb	1-2(4)	2-3	S2-3(N)	2,3
Cu1 (h)	Eb, Vb	1-2(4)	2-3	S2-3(N)	2,3
Dh1 (u)	Em	2-3	4	N	
Dh1 (l)	Em	2-3	4	N	
Du2 (u)	Em	2-3	2-3	S2-3	4
Du2 (l)	Em	2-3	2-3	S2-3	4
Du2 (h)	Em	2-3	2-3	S2-3	4
Du1 (u)	Em, Vb	2-3(4)	2-3	S2-3(N)	3,4
Du1 (l)	Em, Vb	2-3(4)	2-3	S2-3(N)	3,4
Du1 (h)	Em, Vb	2-3(4)	2-3	S2-3(N)	3,4
Dpd (u)	Em, Vb	2-3(4)	1-2	S2-3(N)	3,5
Dpd (l)	Em, Vb	2-3(4)	1-2	S2-3(N)	3,5
Dpd (h)	Em, Vb	2-3(4)	1-2	S2-3(N)	3,5
Ev (u)	Vb	4	1	N	
Ev (l)	Vb	4	1	N	

Notes: (1) N: slopes > 30%; (2) S3: slopes > 16%; (3) values in brackets refer to Valley bottom soils covering 10-20% of the LMU; (4) S3: soil depth < 100 cm and/or CFC (subsoil) > 35% and/or slopes > 16%; (5) S3: soil depth < 100 cm and/or CFC (subsoil) > 35%. S1: suitable; S2: moderately suitable; S3: marginally suitable; N: not suitable.

When we compare the actual conditions of the land with the requirements of cacao we notice that the high erosion risk due to slope steepness is the most limiting condition in most of the mapping units. The mountains (m) and isolated hills (h1) are unsuitable for cacao. The complexes of hills (h2; only in ecological zone B) are either marginally suitable or unsuitable for cacao, depending on the slope. The uplands are all moderately to marginally suitable, again depending on slope. Only in the uplands of ecological zone D (Ebimimbang soils) classification is more complex: the suitability (moderate to marginal) depends on both slope and effective soil depth. The latter factor is solely decisive in the dissected erosional plain (Dpd; moderately to marginally suitable). In the valley bottom drainage conditions are the decisive factor: not suitable.

11.3 Oil palm

Oil palm (*Elaeis guineensis*) requires a deep (over 100 cm) permeable soil with a good structure and a sandy loam to light clay texture. Oil palm is tolerant to waterlogging for short periods, whereas the drought resistance is low. Nutrient demands are high, especially for potassium. Nutrient removal with 15 ton/ha of fruit bunches is 90 kg of nitrogen, 20 kg P_2O_5 and 135 kg K_2O. Yield amounts for the TCP area are not available. A summary of requirements and limitations is given in Table 11.4.

Table 11.4. Requirements and limitations for oil palm (data derived from: Sys, 1985; Touber *et al.*, 1989).

		Limitation class*			
Land Quality	Diagnostic characteristic	1	2	3	4
Drainage	Soil drainage	imperfect	imperfect	poor	very poor
Effective soil depth	Soil depth (cm)	>100	>50	>25	<25
	Coarse fragment content (subsoil; %)	<15	<35	<55	>55
Nutrient availability2	CEC (meq/100g)	any	-	-	-
	Base saturation (%)	>20	<20	-	-
	Organic matter (% C, 0-15cm)	>0.8	<0.8	-	-
Erosion risk	Slope (%)	<8	8-16	16-30	>30

* 1: not or slightly limiting; 2: moderately limiting; 3: highly limiting; 4: very strongly limiting.

Table 11.5 presents the requirements for the cultivation of oil palm and the accompanying limitations of land characteristics per soil type. It proves that both Nyangong soils and Ebom soils have no or only slight limitations for the cultivation of oil palm. In Ebimimbang soils the effective soil depth (most notably the coarse fragment contents of the subsoil) is moderately to highly limiting. In Valley bottom soils drainage condition is the most limiting factor (highly to strongly limiting).

Table 11.5. Requirements and limitation classes per soil type for oil palm.

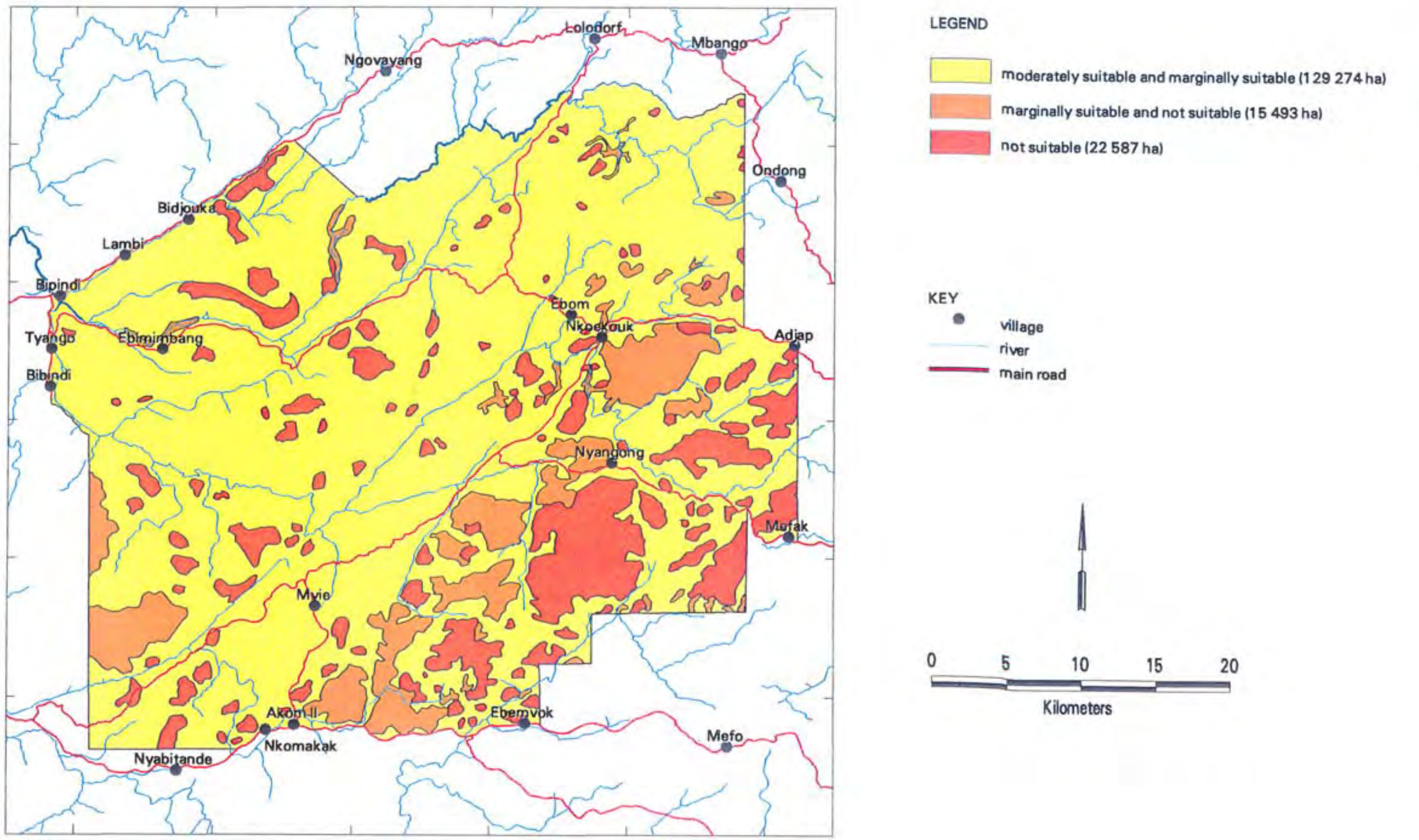
	Limitation class*			
Land quality	Nyangong soils	Ebom soils	Ebimimbang soils	Valley bottom soils
Drainage	**1**	**1**	**1**	**3-4**
Effective soil depth				
actual soil depth	1	1	1-2	1-2
coarse fragment content (subsoil)	1	1	2-3	1-4
total	**1**	**1**	**2-3**	**1-3**
Nutrient availability				
CEC (topsoil)	1	1	1	1
base saturation (topsoil)	2	1-2	1	1-2
organic matter content (topsoil)	1	1	1	1
total	**1**	**1**	**1**	**1**
Final classification*	**1**	**1**	**2-3**	**3-4**

* 1: not or slightly limiting; 2: moderately limiting; 3: highly limiting; 4: very strongly limiting.

Using the data presented in Tables 11.4 and 11.5 the suitability for the cultivation of oil palm per land mapping unit can be can calculated. The results are given in Table 11.6 and presented on Map 11.2.

SUITABILITY FOR THE CULTIVATION OF OIL PALM

Bipindi– Akom II– Lolodorf region, South Cameroon



Map 11.2

Table 11.6. Suitability classification for the cultivation of oil palm.

LMU	Soil type	Limitations soil	Limitations erosion	Suitability	notes
Am (u)	Ny	1	4	N	
Ah1 (u)	Ny	1	4	N	
Bh1 (u)	Ny	1	4	N	
Bh1 (l)	Ny	1	4	N	
Bh2 (u)	Ny	1	3-4	S3-N	1
Bh2 (l)	Ny	1	3-4	S3-N	1
Bh2 (h)	Ny	1	3-4	S3-N	1
Bu2 (u)	Ny, Eb	1	2-3	S2-3	2
Bu2 (l)	Ny, Eb	1	2-3	S2-3	2
Bu2 (h)	Ny, Eb	1	2-3	S2-3	2
Bu1 (u)	Ny, Eb, Vb	1(3-4)	2-3	S2-3(N)	2,3
Bu1 (l)	Ny, Eb, Vb	1(3-4)	2-3	S2-3(N)	2,3
Bu1 (h)	Ny, Eb, Vb	1(3-4)	2-3	S2-3(N)	2,3
Ch1 (u)	Eb	1	4	N	
Ch1 (l)	Eb	1	4	N	
Cu2 (u)	Eb	1	2-3	S2-3	2
Cu2 (l)	Eb	1	2-3	S2-3	2
Cu2 (h)	Eb	1	2-3	S2-3	2
Cu1 (u)	Eb, Vb	1(3-4)	2-3	S2-3(N)	2,3
Cu1 (l)	Eb, Vb	1(3-4)	2-3	S2-3(N)	2,3
Cu1 (h)	Eb, Vb	1(3-4)	2-3	S2-3(N)	2,3
Dh1 (u)	Em	2-3	4	N	
Dh1 (l)	Em	2-3	4	N	
Du2 (u)	Em	2-3	2-3	S2-3	4
Du2 (l)	Em	2-3	2-3	S2-3	4
Du2 (h)	Em	2-3	2-3	S2-3	4
Du1 (u)	Em, Vb	2-3(4)	2-3	S2-3(N)	3,4
Du1 (l)	Em, Vb	2-3(4)	2-3	S2-3(N)	3,4
Du1 (h)	Em, Vb	2-3(4)	2-3	S2-3(N)	3,4
Dpd (u)	Em, Vb	2-3(4)	1-2	S2-3(N)	3,5
Dpd (l)	Em, Vb	2-3(4)	1-2	S2-3(N)	3,5
Dpd (h)	Em, Vb	2-3(4)	1-2	S2-3(N)	3,5
Ev (u)	Vb	3-4	1	S3-N	
Ev (l)	Vb	3-4	1	S3-N	

Notes: (1) N: slopes > 30%; (2) S3: slopes > 16%; (3) values in brackets refer to very poorly drained Valley bottom soils covering 10-20% of the LMU; (4) S3: coarse fragment content (subsoil) > 35% and/or slopes > 16%; (5) S3: CFC (subsoil) > 35%.

S1: very suitable; S2: suitable; S3: marginally suitable; N: not suitable

It proves that due to erosion risks (slope steepness) cultivation of oil palm is unsuitable to only marginally suitable in the mountains and hilly areas. The valley bottoms are unsuitable to marginally suitable due to unfavourable drainage conditions. All other land mapping units are moderately to marginally suitable, depending on slope steepness (ecological zone B and C), effective soil depth (ecological zone D: dissected erosional plains) or a combination of both factors (ecological zone D: uplands).

11.4 Rubber

Rubber (*Hevea brasiliensis*) requires very deep (>150cm), well-aerated soils for its extensive root system. Soils with good structures, sandy clay loam and clay loam textures and high water holding capacities are favourable. Rubber cultivation is optimal on soils with pH between 4.4 and 5.2. Organic carbon contents and CEC hardly influence the suitability of a soil for rubber. The nutrient demands are medium for rubber. Literature mentions yields of 1-2 ton latex per hectare. The annual yield of 1.5 t/ha latex contains 40 kg nitrogen, 10 kg P_2O_5 and 25 K_2O kg (Landon, 1991; Euroconsult, 1989). A summary of requirements and limitations is given in Table 11.7.

Table 11.7. Requirements and limitations for rubber (data derived from: Sys, 1985; Touber *et al.*, 1989).

		Limitation class*			
Land Quality	Diagnostic characteristic	1	2	3	4
Drainage	Soil/surface drainage	well	moderate	imperfect	poor
Effective soil depth	Soil depth (cm)	>150	>100	>50	<50
	Coarse fragment content (subsoil; %)	<15	<35	<55	>55
Nutrient availability	CEC (meq/100g)	any	-	-	-
	Base saturation (%)	20-35	<20 or 35-50	50-80	>80
	Organic matter (% C, 0-15cm)	>1.2	any	-	-
Erosion	Slope (%)	<8	8-16	16-30	>30

* 1: not or slightly limiting; 2: moderately limiting; 3: highly limiting; 4: very strongly limiting.

Table 11.8 presents the requirements for the cultivation of rubber and the accompanying limitations of land characteristics per soil type. It proves that both Nyangong soils and Ebom soils have no to moderate limitations. In the case of moderate limitations, the actual soil depth is less than 100 cm. Ebimimbang soils have moderate to high limitations, depending on actual soil depth and/or coarse fragment contents in the subsoil. Valley bottoms are strongly limiting, due to unfavourable drainage conditions.

Table 11.8 Requirements and limitation classes per soil type for rubber.

	Limitation class*			
Land quality	Nyangong soils	Ebom soils	Ebimimbang soils	Valley bottom soils
Drainage	**1**	**1**	**1-2**	**4**
Effective soil depth				
actual soil depth	1-2	1-2	1-3	1-3
coarse fragment content (subsoil)	1	1	2-3	1-4
total	**1-2**	**1-2**	**2-3**	**1-4**
Nutrient availability				
CEC (topsoil)	1	1	1	1
base saturation (topsoil)	2	1-2	3-4	1-2
organic matter content (topsoil)	1	1	1	1
total	**1**	**1**	**2**	**1**
Final classification*	**1-2**	**1-2**	**2-3**	**4**

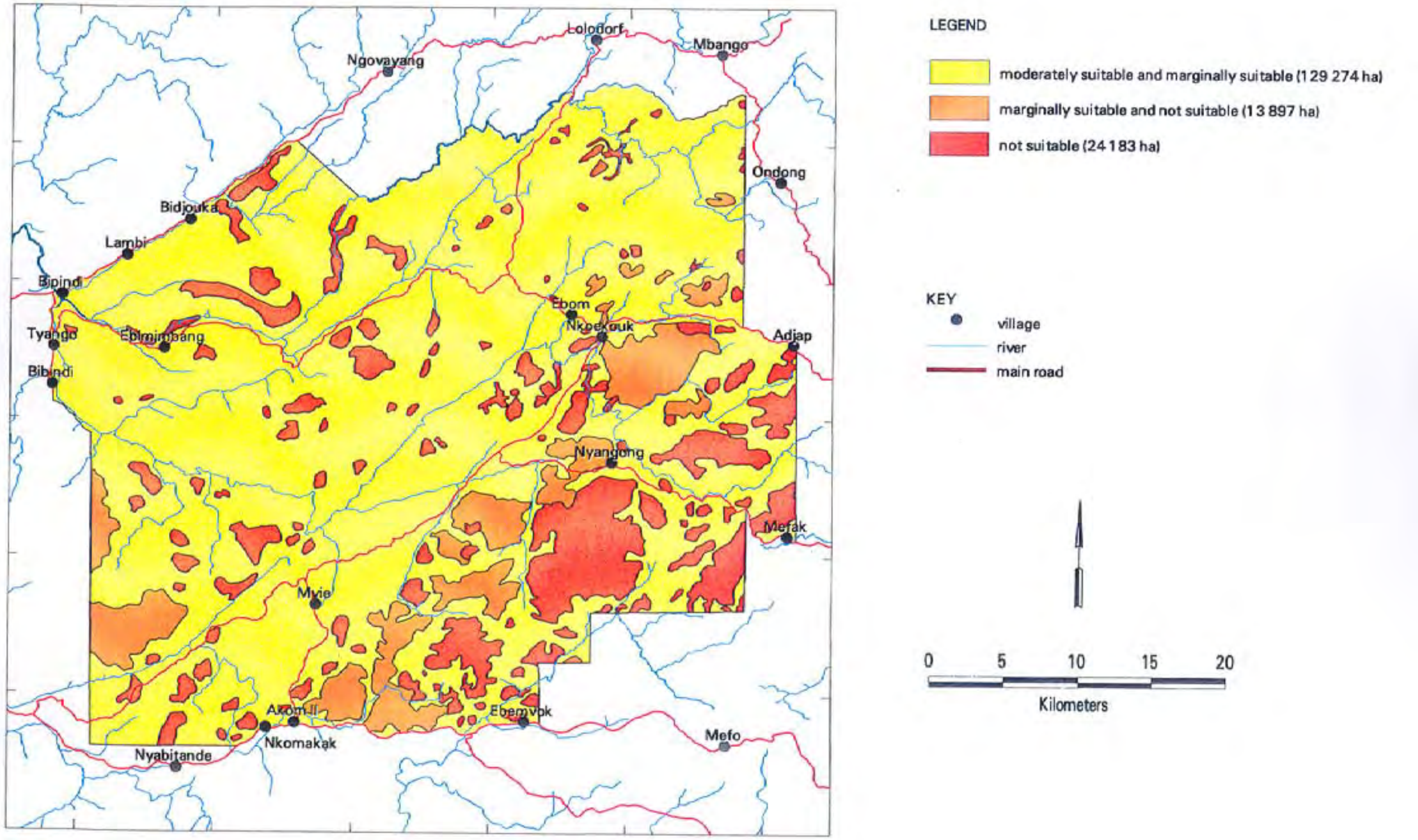
* 1: not or slightly limiting; 2: moderately limiting; 3: highly limiting; 4: very strongly limiting.

Using the data presented in Tables 11.7 and 11.8 the suitability for the cultivation of rubber per land mapping unit can be can calculated. The results are given in Table 11.9 and are presented on Map 11.3.

The figures presented in Table 11.9 show that the suitability for the cultivation of rubber in the TCP area strongly corresponds with the suitability for oil palm: due to erosion risks (slope steepness) cultivation of rubber is unsuitable to marginally suitable in the mountains and hilly areas. The valley bottoms are unsuitable, due to unfavourable drainage conditions (for oil palm: unsuitable to marginally suitable). All other land mapping units are moderately to marginally suitable, depending on slope steepness (ecological zone B and C), effective soil depth (ecological zone D: dissected erosional plains) or a combination of both factors (ecological zone D: uplands).

SUITABILITY FOR THE CULTIVATION OF RUBBER

Bipindi– Akom II– Lolodorf region, South Cameroon



Map 11.3

Table 11.9. Suitability classification for the cultivation of rubber.

LMU	Soil type	Limitations soil	Limitations erosion	Suitability	notes
Am (u)	Ny	1-2	4	N	
Ah1 (u)	Ny	1-2	4	N	
Bh1 (u)	Ny	1-2	4	N	
Bh1 (l)	Ny	1-2	4	N	
Bh2 (u)	Ny	1-2	3-4	S3-N	1
Bh2 (l)	Ny	1-2	3-4	S3-N	1
Bh2 (h)	Ny	1-2	3-4	S3-N	1
Bu2 (u)	Ny, Eb	1-2	2-3	S2-3	2
Bu2 (l)	Ny, Eb	1-2	2-3	S2-3	2
Bu2 (h)	Ny, Eb	1-2	2-3	S2-3	2
Bu1 (u)	Ny, Eb, Vb	1-2(4)	2-3	S2-3(N)	2,3
Bu1 (l)	Ny, Eb, Vb	1-2(4)	2-3	S2-3(N)	2,3
Bu1 (h)	Ny, Eb, Vb	1-2(4)	2-3	S2-3(N)	2,3
Ch1 (u)	Eb	1-2	4	N	
Ch1 (l)	Eb	1-2	4	N	
Cu2 (u)	Eb	1-2	2-3	S2-3	2
Cu2 (l)	Eb	1-2	2-3	S2-3	2
Cu2 (h)	Eb	1-2	2-3	S2-3	2
Cu1 (u)	Eb, Vb	1-2(4)	2-3	S2-3(N)	2,3
Cu1 (l)	Eb, Vb	1-2(4)	2-3	S2-3(N)	2,3
Cu1 (h)	Eb, Vb	1-2(4)	2-3	S2-3(N)	2,3
Dh1 (u)	Em	2-3	4	N	
Dh1 (l)	Em	2-3	4	N	
Du2 (u)	Em	2-3	2-3	S2-3	4
Du2 (l)	Em	2-3	2-3	S2-3	4
Du2 (h)	Em	2-3	2-3	S2-3	4
Du1 (u)	Em, Vb	2-3(4)	2-3	S2-3(N)	3,4
Du1 (l)	Em, Vb	2-3(4)	2-3	S2-3(N)	3,4
Du1 (h)	Em, Vb	2-3(4)	2-3	S2-3(N)	3,4
Dpd (u)	Em, Vb	2-3(4)	1-2	S2-3(N)	3,5
Dpd (l)	Em, Vb	2-3(4)	1-2	S2-3(N)	3,5
Dpd (h)	Em, Vb	2-3(4)	1-2	S2-3(N)	3,5
Ev (u)	Vb	4	1	N	
Ev (l)	Vb	4	1	N	

Notes: (1) N: slopes > 30%; (2) S3: slopes > 16%; (3) values in brackets refer to Valley bottom soils covering 10-20% of the LMU; (4) S3: soil depth < 100 cm and/or coarse fragment content (subsoil) > 35% and/or slopes > 16%; (5) S3: soil depth < 100 cm and/or CFC (subsoil) > 35%. S1: suitable; S2: moderately suitable; S3: marginally suitable; N: not suitable

11.5 Pineapple

Cultivation of pineapple (*Ananas comosus*) is optimal on freely drained friable loamy and fine sandy soils, where no excess of water occurs. It is a medium drought resistant crop. Slopes less than 5%, soil pH 5 - 6.5 and relative high N and K requirements also favour optimal growing conditions. Soil depths of 30 - 60 cm are sufficient (NSS, 1988; Landon, 1991). The root systems of pineapple are superficial and can not penetrate compact soil layers. A summary of requirements and limitations is given in Table 11.10.

Table 11.10. Requirements and limitations for pineapple.

		Limitation class*			
Land Quality	Diagnostic Characteristic	1	2	3	4
Drainage	Soil surface drainage	well	moderate	imperfect	poor
Effective soil depth	Soil depth (cm)	>60	30-60	30-60	<30
	Coarse fragment content (topsoil; %)	<15	<35	<55	>55
Nutrient availability	CEC (meq/100g)	>8	4-8	<4	-
	Base saturation (%)	>50	20-50	<20	-
	pH	5-6.5	4.5-5	4.0-4.5	<4
Workability	Texture (topsoil)**	s,ls,sl	scl,sc	c, hc	-
Erosion risk	Slope (%)	<5	-	5-16	>16

* 1: not or slightly limiting; 2: moderately limiting; 3: highly limiting; 4: very strongly limiting
** s: sand; ls: loamy sand; sl: sandy loam; scl: sandy clay loam; sc: sandy clay; c: clay; hc: heavy clay.

Table 11.11 presents the requirements for the cultivation of pineapple and the accompanying limitations of land characteristics per soil type. It proves that only Ebimimbang soils have little or no limitations for the growth of pineapple. In Nyangong soils and Ebom soils the nutrient availability is moderately to highly limiting, due to unfavourable base saturation and pH. On the Valley bottom soils growth of pineapple is strongly limited, due to unfavourable drainage conditions.

Table 11.11 Requirements and limitation classes per soil type for pineapple.

	Limitation class*			
Land quality	Nyangong soils	Ebom soils	Ebimimbang soils	Valley bottom soils
Drainage	**1**	**1**	**1-2**	**4**
Effective soil depth				
actual soil depth	1	1	1(-2)	1(-2)
coarse fragment content (topsoil)	1	1	1	1
total	**1**	**1**	**1-(2)**	**1(-2)**
Nutrient availability				
CEC (topsoil)	1	1	1-2	1(-2)
base saturation (topsoil)	3	2-3	1	2-3
pH (topsoil)	3-4	2-4	1	1
total	**2-3**	**2-3**	**1**	**1-2**
Workability; texture (topsoil)	**3**	**1-2**	**1**	**1-2**
Final classification*	**3**	**2-3**	**1-2**	**4**

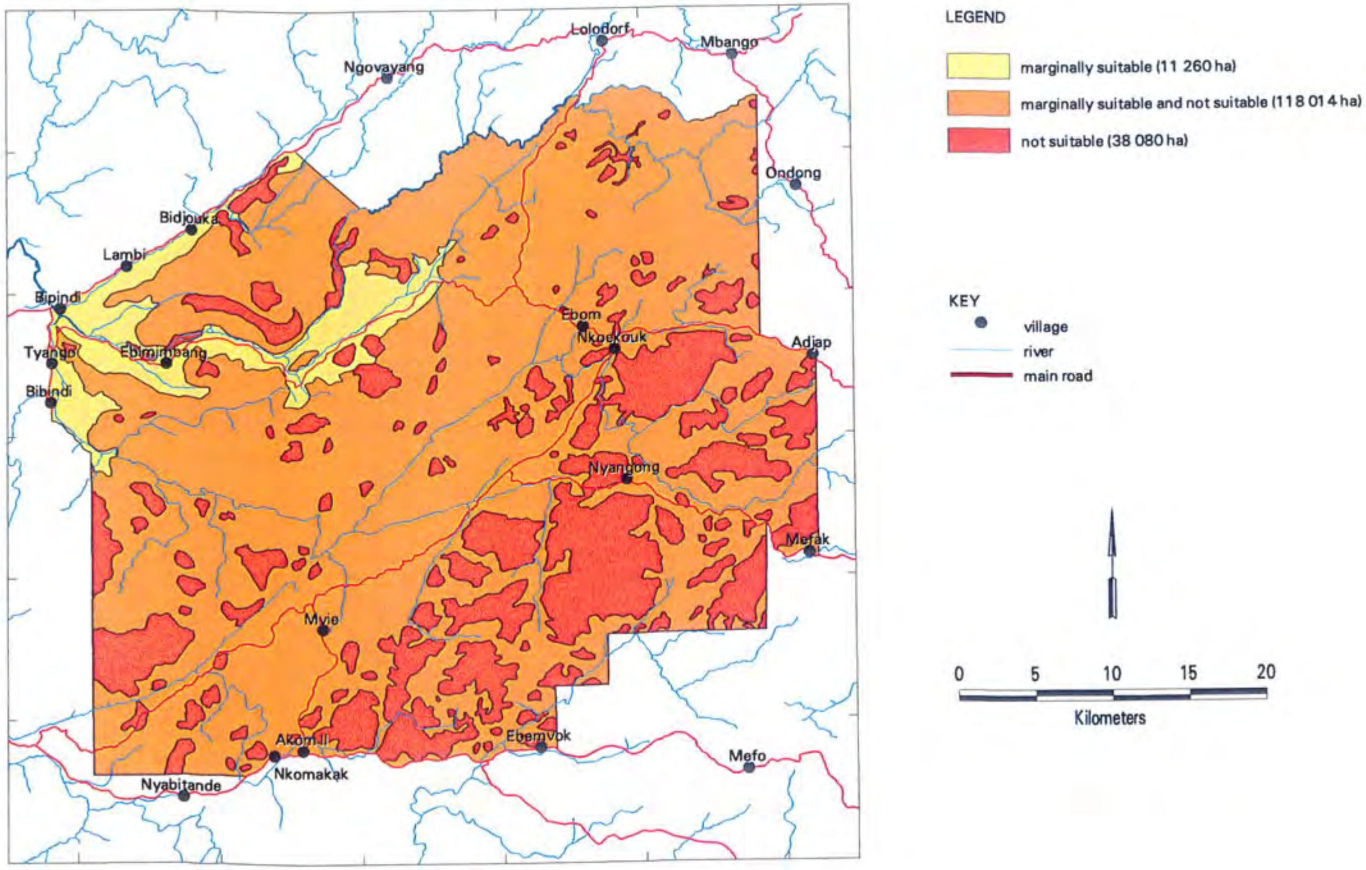
* 1: not or slightly limiting; 2: moderately limiting; 3: highly limiting; 4: very strongly limiting.

Using the data presented in Tables 11.10 and 11.11 the suitability for the cultivation of pineapple per land mapping unit can be can calculated. The results are given in Table 11.12 and presented on Map 11.4.

The results presented in Table 11.12 show that the TCP research area does not offer good chances for the successful, commercial cultivation of pineapple. In the Valley bottoms growth of pineapple is strongly limited due to unfavourable drainage conditions. In all other land mapping units slope the relief (slope steepness) is highly to strongly limiting. Least unfavourable are the dissected erosional plains in ecological zone D (slopes 5-15%), but even there growth of pineapple is highly limited and will require extensive erosion preventing measures.

SUITABILITY FOR THE CULTIVATION OF PINEAPPLE

Bipindi– Akom II– Lolodorf region, South Cameroon



Map 11.4

Table 11.12. Suitability classification for the cultivation of pineapple.

LMU	Soil type	Limitations soil	Limitations erosion	Suitability	notes
Am (u)	Ny	3	4	N	
Ah1 (u)	Ny	3	4	N	
Bh1 (u)	Ny	3	4	N	
Bh1 (l)	Ny	3	4	N	
Bh2 (u)	Ny	3	4	N	
Bh2 (l)	Ny	3	4	N	
Bh2 (h)	Ny	3	4	N	
Bu2 (u)	Ny, Eb	2-3	3-4	S3-N	1
Bu2 (l)	Ny, Eb	2-3	3-4	S3-N	1
Bu2 (h)	Ny, Eb	2-3	3-4	S3-N	1
Bu1 (u)	Ny, Eb, Vb	2-3(4)	3-4	S3-N	1
Bu1 (l)	Ny, Eb, Vb	2-3(4)	3-4	S3-N	1
Bu1 (h)	Ny, Eb, Vb	2-3(4)	3-4	S3-N	1
Ch1 (u)	Eb	2-3	4	N	
Ch1 (l)	Eb	2-3	4	N	
Cu2 (u)	Eb	2-3	3-4	S3-N	1
Cu2 (l)	Eb	2-3	3-4	S3-N	1
Cu2 (h)	Eb	2-3	3-4	S3-N	1
Cu1 (u)	Eb, Vb	2-3(4)	3-4	S3-N	1
Cu1 (l)	Eb, Vb	2-3(4)	3-4	S3-N	1
Cu1 (h)	Eb, Vb	2-3(4)	3-4	S3-N	1
Dh1 (u)	Em	1-2	4	N	
Dh1 (l)	Em	1-2	4	N	
Du2 (u)	Em	1-2	3-4	S3-N	1
Du2 (l)	Em	1-2	3-4	S3-N	1
Du2 (h)	Em	1-2	3-4	S3-N	1
Du1 (u)	Em, Vb	1-2(4)	3-4	S3-N	1
Du1 (l)	Em, Vb	1-2(4)	3-4	S3-N	1
Du1 (h)	Em, Vb	1-2(4)	3-4	S3-N	1
Dpd (u)	Em, Vb	1-2(4)	3	S3(N)	2
Dpd (l)	Em, Vb	1-2(4)	3	S3(N)	2
Dpd (h)	Em, Vb	1-2(4)	3	S3(N)	2
Ev (u)	Vb	4	1	N	
Ev (l)	Vb	4	1	N	

Notes: (1) N: slopes > 16%; (2) values in brackets refer to Valley bottom soils covering 10-20% of the LMU. S1: suitable; S2: moderately suitable; S3: marginally suitable; N: not suitable

12 DISCUSSION

12.1 Main trends in suitability of the land

In Table 12.1 a summary is given of the suitability of the land, in percentage of the total area and in hectares, for the various land utilisation types.

Table 12.1. Suitability of the land for the various land utilisation types

LUT	Extent of suitability classes in % of total area and in ha						
	S1	S1+S2*	S2	S2+S3*	S3	S3+N*	N
Conservation of flora	**70%** 114 900		**20%** 31 100		**10%** 21 300		
Conservation of fauna	**5%** 8900		**35%** 57 600		**30%** 47 700		**30%** 53 300
NTFP, most important species	**40%** 64 200	**8%** 13 900	**20%** 32 900		**25%** 41 500		**9%** 14 900
NTFP, broad selection	**75%** 129 600	**8%** 13 900	7% 12 900		7% 10 900		
Timber, traditional selection			**10%** 19 400	**25%** 41800	**25%** 42100	**10%** 13 100	**30%** 50 900
Timber, broad selection		**1%** 2200	**25%** 42 800	**40%** 63 800	**10%** 15 500	**10%** 13 100	**20%** 30 000
Shifting cultivation			7% 11 200	**55%** 9200	**0.5%** 800	7% 11 600	**30%** 51 700
Cacao				**75%** 129 300		**10%** 13 900	**15%** 24 200
Oil palm				**75%** 129 300		**10%** 15 500	**15%** 22 600
Rubber				**75%** 129 300		**10%** 13 900	**15%** 24 200
Pineapple					7% 11 300	**70%** 118 000	**25%** 38 100

S1: suitable; S2: moderately suitable; S3: marginally suitable; N: not suitable; *some mapping unit show such a range in characteristics that they cannot fit in one suitability class and thus belong to two classes.

The general trend observed in Table 12.1 is that the suitability of the land in the TCP area decreases from the most ‘natural’, least disturbing types of land use to the plantation crops. There are two exceptions: the suitability for fauna conservation and timber production. The explanations are rather logical: fauna conservation is heavily influenced by the presence of human activities (main roads and larger villages). The lower suitability for timber production can be explained by the fact that relatively few tree species are marketable and all suitable land in the area has been logged over already once or twice.

The observed trend has a certain logic as well. The tropical forest in south Cameroon is a species-rich forest. People in the area are adapted to the forest and know how to use its products, hence the relatively high suitability for the use of (non-animal) NTFPs.

The main reason for the low suitability for agricultural activities is the sloping character of the landscape. Opening up the forest for agricultural activities will increase the risk of erosion. This is especially the case for pineapple plantations where the soil surface is kept bare. Secondly, mechanised agriculture is not possible on strongly sloping lands. A third reason for the less than optimal conditions for agricultural activities is the low inherent soil fertility. This limits especially the productivity of the shifting cultivation agriculture. It is likely that with the use of nitrogen and phosphorous fertiliser, crop yields can be increased. In how far this is economically feasible is a question that needs further research.

12.2 Spatial aspects of suitability classification

While carrying out the land suitability classification a 'vertical' approach was used; requirements related to minimum or optimal size and fragmentation of management units have not been taken into account as this is more part of the land use planning process. Hereafter, we will briefly tackle the size requirements and compare these with the results of the suitability classification.

Suitability for conservation of biodiversity
The minimum area requirement for biodiversity conservation is difficult to estimate as it differs from species to species, both for flora and fauna. Bekhuis (1997) mentions home ranges for some of the larger mammals of 8 (for Mandrill) to 10 – 40 km^2 (for Gorilla). We assume that home ranges for animals living in social groups are about the same size as minimum area needed for survival. We thus assume that a minimum size for a biodiversity conservation reserve is 25 km^2 and a more preferred area is 40 km^2. The area suitable for flora conservation is far larger (see Map 7.1), for fauna conservation the highly suitable areas (see Map 7.2) are scattered but the moderately suitable areas are sufficiently big. In addition, the suitable areas are surrounded by moderately suitable areas, which in turn are surrounded by marginally suitable areas. So fragmentation is not the case.

Conservation for flora is ideally combined with conservation for fauna. As all mapping units with high intensity shifting cultivation are marginally to not suitable for both fauna conservation and flora conservation, all areas suitable and moderately suitable for fauna conservation are also suitable or moderately suitable for flora conservation (almost 40% of the area). So in 40% of the area this combination is possible. The story, however, is a bit more complicated: conservation for biodiversity, especially flora, is location specific. The biodiversity within all ecological zones is high and it differs considerably between the ecological zones. In the ideal case, areas within each ecological zone are preserved. This is, however, not realistic and therefore those areas where and rare species and the species of the primary forest are abundant should get highest priority. These are the mapping units in which vegetation types I or IIa or IIb or IIc are dominant (see Tables 6.8 and 7.1). These vegetation units occur in the ecological zones A, B, C and D.

When a decision is being made on which areas are most in need of conservation, not only the TCP area should be looked at but also the surrounding forest areas. Generally, the higher altitude areas are least disturbed because these are located in the steep mountain areas. Here the risk for disappearance of species is less than in the flatter lowlands, which are more accessible for loggers and farmers. From this point of view, the mapping units Cu1u, Cu2u, Dh1u, Du1u, Du2u, Dpdu (one or more within each ecological zone) are having priority for biodiversity conservation. These areas, however, are also attractive for shifting cultivation, thus giving rise to a potential conflict.

Suitability for NTFP collection
The suitability for NTFP is mainly determined by the presence of the right species within acceptable distance of the homestead. How many of these species at which distance depends on the type of product and the price paid for it as well as on the person collecting it. Therefore a quantification of a minimum area is at this stage not possible. Fragmentation is not problematic as long as the acceptable distance to the NTFP source is not restrictive.

Suitability for the production of timber
According to Eba'a (2000) a forest management unit of about 30 000 ha is needed in the TCP area for a small forestry enterprise. In order to support a medium-sized sawmill some 60 000 ha is needed. Ideally, this land is not too fragmented and within reasonable distance from main roads. The results of the suitability classification (Map 9.1) show that there is no highly suitable land in the area and about 19 000 ha is moderately suitable for the production of traditional species. Within the TCP area there is presently insufficient (moderately suitable) land for timber production if one concentrates on the traditional species. If a broad selection of species is taken

into account (Map 9.2), the area that is suitable and moderately suitable is about 45 000 ha, so that should be sufficient for a small forestry enterprise if that enterprise was to rely solely on the TCP area.

Suitability for shifting cultivation
According to Nounamo and Yemefack (1997), a farmer (household) opens yearly an average 1.5 ha land, which is used for 2 years in succession. With an average rotation cycle of about 7 years a household uses about 10 ha land for shifting cultivation. If there are 2900 households (Lescuyer *et al*., 1999), some 29 000 ha land is needed for shifting cultivation. This fits with the inventory of the extent of land used for shifting cultivation (see Map 3.2). The extent of moderately suitable land is some 11 000 ha. If all land that is moderately suitable and marginally suitable for shifting cultivation (92 000 ha) is added to that, there is plenty of land available within 5 km from the main roads. It is concluded that total available land for shifting cultivation is not problematic and size of fields does not influence the land use planning. We need to mention, however, that other claims on the land may exist which limit the availability of land for shifting cultivation.

Suitability for plantation agriculture
Size of the fields may range from 1 to over 100 ha. For cacao, oil palm and rubber, there should not be any problem in finding sufficiently large, not fragmented, plots within the category of moderately suitable land (roughly estimated at 50 000 ha).

12.3 Dynamics in land use

Dynamics in the agricultural use of the land has been low. Van Gemerden and Hazeu (1999) concluded that there has been no noticeable increase in the area used for shifting cultivation since the early eighties till present. This is likely to be related to the more or less stable population size in the same period. The only noticeable change in land use is the increase in (small) plantation agriculture, notably oil palm. The total area covered by oil palm plantations is not exactly known but can not be more than a few hundreds of hectares.

The most noticeable changes have been the logging activities. As a selective logging system was used, regeneration of the forests is possible. Although changes in forest structure and species composition have taken place, no drastic change in land cover and related hydrological effects occurred.

12.4 Potentially coinciding and conflicting land use types

The land evaluation study has studied the suitability of the land for selected, well-defined land utilisation types in isolation of each other. Reality, of course, is different. Several land use types occur within the area, some of which are overlapping in space and time; others may have conflicting purposes. In Table 12.2 the possibilities or impossibilities of combining LUTs are shown. It should be noted that with NTFP, non-animal products are meant.

The overall picture we get out of Table 12.2 is that at the right hand side LUT combinations are impossible. This is especially the case for intensive agricultural use: the way in which the land is used does not allow any other, simultaneous use. Shifting cultivation has an intermediate position as there the location changes during time and possibilities to combine this land utilisation type with the collection of NTFP exist.

At the left-hand side of the table, combinations of LUTs seem to be possible. How flora and fauna conservation can be combined with selective logging is not sure. Using the land for timber, especially with a selective logging method, is not necessarily interfering with flora and fauna conservation. The extent, to which interference occurs, however, is presently not sufficiently known. The most fragile species will certainly have problems in surviving the disturbances caused by logging, as they need undisturbed areas as a refuge. Highly mobile species may adapt quickly. Therefore, further research is needed into what the effects are on botanical species diversity and which accompanying forest management activities are recommended in order not to disturb the fauna to such an extent that recovery of the population / spontaneous re-migration to the logged area will not be possible anymore.

Table 12.2 Possibilities for coinciding or conflicting land utilisation types

LUT [1)]	Flora	Fauna	NTFP selected	NTFP broad	Timber, traditional	Timber, broad	Shifting cultivation	Cacao	Oil palm	Rubber	Pineapple
Flora conservation		++[2)]	+	+	+/-	+/-	-	--	--	--	--
Fauna conservation			+	+	+/-	+/-	-	--	--	--	--
NTFP, selected species				++	++	++	++	--	--	--	--
NTFP, broad selection of species					++	++	++	--	--	--	--
Timber, traditional species						++	--	--	--	--	--
Timber, broad selection of species							--	--	--	--	--
Shifting cultivation								--	--	--	--
Cacao									--	--	--
Oil palm										--	--
Rubber											--
Pineapple											

[1)] For full description of the LUTs, see chapter 3. [2)] ++ LUTs go very well together; + LUTs maybe combined; only slight interference; +/- combining LUTs causes interference, more research needed; - LUTs can not be combined; -- combination of these LUTs is impossible.

In this study, the use of the area for NTFP has been limited to non-animal products as insufficient data on wildlife and fish populations are available. Hunting and fishing, however, are essential activities for the survival of the Bakola and to a certain extent also for the Bantu population. According to Bekhuis (1997), large animals still occur in the TCP area but most of these keep distances of several kilometres from human activities. In general it is concluded that in large parts of the TCP area both large and small animals are present to such an extent that at least the demands of the Bakola people can be met and likely those of the Bantu people as well.

12.5 Locating and solving conflicts: an example

The results of the suitability classification for flora conservation indicate that all land mapping units which are heavily used for shifting cultivation (some 21 000 ha or about 10%) are marginally suitable for flora conservation. All land mapping units with low intensity shifting cultivation are moderately suitable for flora conservation (about 31 000 ha or almost 20% of the total area). All the other land mapping units (with no shifting cultivation) are highly valued for flora conservation (about 115 000 ha or almost 70% of the total area) with the exception of the valley bottoms where the dominating vegetation community (*Carapa-Mitragyna*) has a moderate value only.

As an example of locating and solving potential conflicts between conservation of biodiversity and shifting cultivation, the area suitable and moderately suitable for the conservation of biodiversity was superimposed on the suitability map for shifting cultivation. Hereafter, the suitability of the land for the conservation of flora and fauna is superimposed on the suitability of the land for shifting cultivation. Potential areas of conflicts are indicated and a solution is proposed on how to go about it.

The results of the overlay are given in Table 12.3 and on Map 12.1.

Table 12.3. Spatial comparison of the suitability for shifting cultivation with the suitability for conservation of biodiversity

Suitability for shifting cultivation	Suitability for biodiversity conservation	Potential conflict?	Extent	
			ha	%
Moderate suitable	Marginally and not suitable	No	10900	6.5
Moderately suitable	Suitable and moderately suitable	Yes	300	0.2
Moderately and marginally suit.	Marginally and not suitable	No	66600	40
Moderately and marginally suit.	Suitable and moderately suitable	Yes	25400	15
Marginally suitable	Marginally and not suitable	No	800	0.5
Marginally and not suitable	Marginally and not suitable	No	2700	1.5
Marginally and not suitable	Suitable and moderately suitable	No	8900	5
Not suitable	Marginally and not suitable	No	19800	12
Not suitable	Suitable and moderately suitable	No	31800	20

The areas with possible conflicts are those that are suitable or moderately suitable for biodiversity conservation **and** suitable to marginally suitable for shifting cultivation. They comprise some 25 700 ha or about 15 % of the area. These areas are located in the uplands and dissected plains and in the zone between 3 and 5 km from the main roads.

Areas where no conflicts can be expected are located within 3 km from the roads as these areas are already marginally or not suitable for biodiversity conservation. Other areas where no conflicts can be expected are those which are marginally or not suitable for shifting cultivation and are suitable to moderately suitable for conservation of biodiversity. These areas are located at least five kilometres from the main roads. It should be noted that the size of this area is heavily dependent on the location of roads: If the road between Mvié and Bipindi is upgraded to a main road, larger areas will be suitable for shifting cultivation and less land for biodiversity conservation. The same holds for the area between Lolodorf and Ebom where there are plenty of logging roads.

If at all, an area was to be set aside for biodiversity conservation, the area between Akom II and Nyangong seems to be logical. In this part there are hardly any (presently accessible) logging roads and no villages. Moreover, there are two mountain blocks in that area, which are not suitable for any kind of commercial use but suitable for, for instance, gorillas. Together, this area is far larger than the 25 km^2 regarded by Bekhuis (1997) to be the minimum size for fauna conservation.

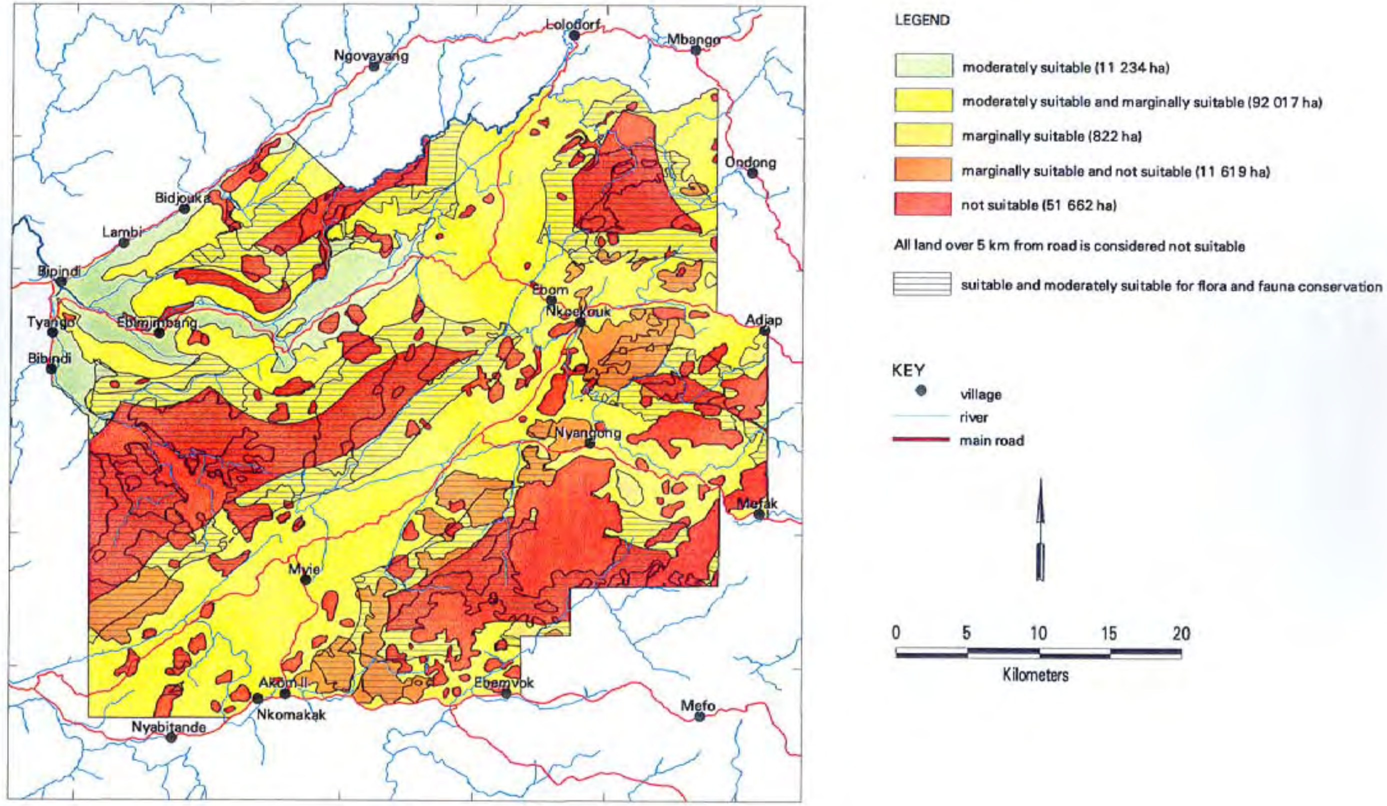
It has to be kept in mind, however, that this proposed solution is merely a desk exercise. Without consultation of the stakeholders, such a solution is unlikely to be accepted and cannot be implemented. Nevertheless, this example shows one of the methods on how to analyse potentially conflicting types of land use.

12.6 Sustainability of land use

The sustainable use of resources is embedded in the definition of land evaluation and land use planning (FAO, 1993). In the present study the potential of land to sustain certain types of utilisation is mainly assessed on the basis of the biophysical potential of these areas to meet the requirements of the land uses. It is assumed that in a later stage clear directives will be established for management to meet sustainability criteria. Moreover, in the present study the LUTs are treated separately. Prioritisation will only be dealt with in a later stage, that is, in a land use planning procedure, which includes consultation with the various stakeholders and which is facilitated by

SUITABILITY FOR SHIFTING CULTIVATION; combined with suitability for flora and fauna conservation

Bipindi– Akom II– Lolodorf region, South Cameroon



Map 12.1

scenario studies and an ecological impact assessment (Lescuyer, unpublished project proposal; Lescuyer and Fines, in press). In the process of land use planning, specific management questions will need to be answered for the final management plan to be ecologically sound, economically viable and socially acceptable.

Despite the limitations of the scope of present qualitative biophysical land evaluation, already some remarks can be made about aspects of sustainability of the described LUTs. The following overview is not exhaustive but is meant to indicate potential hazards for sustainable use.

Biodiversity conservation
Ecological sustainability of conservation of biodiversity (flora and fauna) is met if the size of the management unit is truly large enough to harbour viable populations of species pertaining to its ecosystems. The protected areas are not isolated and if corridors to nearby suitable habitats exist the species concerned need not solely depend on the protected areas for their survival. Small-scale collection of NTFP is allowed for subsistence needs but measures need to be established to assess what products and what levels of harvesting can be permitted. Monitoring of ecosystem quality is clearly of vital importance for this utilisation type. An integrated approach with both botanical and faunal indicators should be adopted. Guild diversity is a promising and cost-effective way to indicate the extent of human disturbance (van der Hoeven *et al*., 2000). Through vulnerability analyses the most important threats to the protected area can be identified.

Conversion of forest land into agricultural fields or logging is strictly opposed to the management objectives and public awareness and support is needed for a successful conservation strategy. The social sustainability also depends on the legal consequences of the designation of a tract of land as conservation area. Land rights and user rights need to be established and clearly defined in close collaboration with the communities involved. Job opportunities and revenues derived from for instance visitors and scientific research need to be channelled to the same communities so that they have an interest in maintaining the area.

Collection of Non-Timber Forest Products (NTFPs)
Ecological sustainability criteria are the NTFP species population dynamics in relation to exploitation levels, and the continued presence of keystone and endangered species. Interactions with other forms of land use should be taken into account. Monitoring of resource status is vital. At present the evaluation does not include the faunal component of NTFP collection. Hunting intensity is at present very high and should be examined in light of ecological sustainability.

Economic sustainability depends on the NTFP yields that can be harvested in a cost-effective way without trespassing the limits set by ecological sustainability. Cost-effectiveness depends on collection and processing technology, infrastructure and access to markets. Also consumption trends and seasonality will influence the economic sustainability of NTFP collection. The formation of cooperations of NTFP collectors can improve their trade position. The possibilities to increase exploitation levels are according to van Dijk (1999) limited due to low stocks. Commercialisation of a few promising NTFPs can be an interesting option to increase economic sustainability (Ros-Tonen *et al.*, 1995).

Social and political sustainability implies the clear definition of land and user rights. The activities itself are already part of the Bantu and Bagyeli cultures and are therefore not considered disruptive for the social and cultural setting. Combinations of NTFP collection and other land uses like timber exploitation and biodiversity conservation could improve the acceptance of the latter.

Timber production
Ecological sustainability of timber production should be evaluated over the complete management cycle (i.e. about 30 years according to Eba'a, 2000). The population dynamics of timber species in relation to logging and silvicultural treatments need to be studied. Also the

impact of timber production on other land uses (especially collection of NTFPs and biodiversity conservation) needs to be evaluated. A code for sound forest practice must be established (ITTO, 1992; 1998; Prabhu *et al.*, 1998). Especially disruptive activities like logging and road construction need to be executed cautiously and should have minimal impact on the forest resources and long-term natural values. Monitoring of key-stone and endangered species gives insight in ecosystem quality. Parts of the forest management units, preferably areas of high conservation value, should remain undisturbed to serve as forest sanctuaries.

Economic sustainability of timber production in the TCP area is studied in-depth by Eba'a (2000). He calculated that the optimal cutting cycle is about 30 years with a harvest of 13.4 m^3 / ha for species currently commercialised. It would require about 120 years to convert forest in the TCP area into a steady state forest. Other factors influencing the economic sustainability are government policy and international trade. The present study does not include recent logging histories in the evaluation. On a more local scale this will certainly influence the (short-term) economic viability of this LUT.

Social and political sustainability is related to government policy of meso-scale land use planning (e.g. Côté, 1993) and aspects related to land and user rights. Job opportunities and other spin-offs for the economies of the local communities are short-term benefits and may not outweigh the long-term decrease of the quality of the forests in general (especially for hunting). Especially the effects of logging on the livelihood of the Bagyeli minority needs attention (Biesbrouck, 1999b; Booijink, 2000).

Shifting cultivation

Ecological sustainability of shifting cultivation depends on the capacity of the fallow vegetation to restore soil fertility and overall soil characteristics. If the shifting cultivation area is confined to a specific zone and no primary forest is cleared, the loss of biodiversity is minimal (fallow vegetation has only low conservation values). Soil fertility restoration can also be influenced by management activities. Erosion risks are low and general avoidance of steep slopes and the creation of large fields are probably sufficient for the maintenance of normal eco-hydrological processes (Waterloo *et al.*, 2000; van Gemerden *et al.*, in prep.).

The majority of the agricultural produce from the TCP area is for subsistence. Economic sustainability depends on the yields that can be achieved by cost-effective means. Production can be influenced by the introduction of new tilling techniques. The use of fertilisers and pest control is at present minimal and this is not likely to change in the near future. The possibilities to enhance the value of the crops by (partial) processing at village level may increase the profitability. The infrastructure is very important in light of transportation of agricultural produce to markets and presently leaves to be desired.

Social and political sustainability is probably easily reached as this type of land utilisation is already embedded in the culture of the local communities. The effects of expansion of the area under shifting cultivation on the livelihood of the Bagyeli needs examination (Biesbrouck, 1999b; Booijink, 2000).

Plantation agriculture

With respect to the natural ecosystem, plantation agriculture is the most destructive LUT described. Ecological sustainability focuses on the avoidance of conversion of areas of high conservation values (generally primary and old secondary forests), the control of erosion and the maintenance of normal eco-hydrological processes. Soil nutrient cycles are likely to be disrupted.

Economic sustainability is the main objective and depends on the cost-effective production of marketable goods. Especially the relatively long period before harvesting (e.g. rubber, oil palm, cocoa) may hinder economic sustainability. The international trade for rubber and cocoa may fluctuate. Existing infrastructure and access to markets is of moderate importance as these can (in general) be created by the relatively capital intensive enterprises. Technology of tilling, harvesting and processing can also influence the profitability of plantation agriculture.

Till present it are mainly 'élites' (comparatively wealthy villagers who work and live in towns but still have access to land in their native villages) that are involved in plantation agriculture. Social and political sustainability seems to be within reach as these elites are often appreciated for their activities to stimulate development at village level. Land and user rights should, however, be clearly established.

12.7 From land evaluation to land use planning, and back …

The whole set of land suitability maps, together with tables and explanatory notes, is the final product of land evaluation. The evaluation indicates the biophysical potential of the land and water resources for land use.

The land suitability maps, together with more detailed insight in the socio-economic environment, are the starting point of land use planning. Land use planning is, unlike landscape survey and land evaluation, primarily a task and responsibility of politicians, ideally with full involvement of all stakeholders.

The land utilization types considered in this land evaluation exercise reflect the most important demands on land resources in the area (van Berkum, 1996; van Gemerden and Hazeu, 1999). However, the list of land uses is not exhaustive and moreover the demands on land are not static. For sound land use it is of paramount importance that all stakeholders are involved in the planning process. Lescuyer and Fines (2000) stipulate the steps necessary achieve stakeholder participation in the elaboration of management plans for the TCP area.

Each stakeholder has his own priorities for land use, which may in turn affect the potential of the area for other uses. The spatial character of the results of the land evaluation makes it a suitable tool to pinpoint areas of potential friction. Scenario studies, in which priority for reasons of study is given to subsequent land use objectives, can help to give stakeholders insight in the consequences of land use choices. In collaboration with the stakeholders it can then be examined how frictions can be reduced. This may lead to adjustment of or even new land utilization types with specific objectives and requirements, resulting in different land suitabilities and land use combinations. The iterative process of land evaluation and land use planning can thus contribute to ecologically, socially and economically sound land management.

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Annex 1 Landscape ecological map of the Bipindi-Akom II-Lolodorf region, Southwest Cameroon. Scale 1:100 000.
(map in folder)

Annex 2 Annotated list of plant species (after van Gemerden and Hazeu, 1999)

Family	Species	growth form[1]	type I[2]	Type IIa	type IIb	type IIc	type III	Type IV	Type V
	Number of relevés:		31	22	25	36	22	20	20
Anacardiaceae	*Antrocaryon klaineanum Pierre*	LT	. [3]	r	.	R	.	2	+
Anacardiaceae	*Pseudospondias microcarpa (A.Rich.) Engl.*	MT	+	r	.	r	r	2	r
Anacardiaceae	*Sorindeia gr1*	MT	1	1	2	1	.	+	.
Anacardiaceae	*Sorindeia grandifolia Engl.*	ST	3	3	2	1	r	1	.
Anacardiaceae	*Trichoscypha acuminata Engl.*	MT	r	1	+	r	.	.	.
Anacardiaceae	*Trichoscypha ferruginea Engl.*	MT	r	1	r	.	.	.	r
Annonaceae	*Anonidium mannii (Oliv.) Engl. & Diels*	MT	r	1	+	.	+	.	.
Annonaceae	*Cleistopholis glauca Pierre ex Engl. & Diels*	MT	.	.	.	.	1	r	.
Annonaceae	*Cleistopholis patens (Benth.) Engl. & Diels*	MT	r	r	1	+	+	3	1
Annonaceae	*Enantia chlorantha Oliv. (= Annickia chlorantha (Oliv.) Setten & P.J. Maas)*	MT	1	3	2	1	2	1	+
Annonaceae	*Hexalobus crispiflorus A. Rich.*	MT	+	+	1	1	.	+	.
Annonaceae	*Meiocarpidium lepidotum (Oliv.) Engl. & Diels*	S	r	2	2	1	1	r	.
Annonaceae	*Pachypondanthium staudtii Engl. & Diels*	LT	1	1	1	.	r	.	.
Annonaceae	*Polyalthia suaveolens Engl. & Diels (= Greenwayodendron suaveolens (Engl. & Diels) Verdc.)*	MT	2	4	4	4	2	1	.
Annonaceae	*Uvariodendron sp1*		r	1	r	+	1	.	r
Annonaceae	*Xylopia aethiopica (Dunal) A. Rich.*	MT	2	1	2	1	2	4	2
Apocynaceae	*Alstonia congensis Engl.*	LT	+	2	+	2	1	2	2
Apocynaceae	*Apocynaceae gr1*		.	.	r	1	r	+	.
Apocynaceae	*Funtumia elastica (Preuss) Stapf*	MT	.	+	r	+	+	2	3
Apocynaceae	*Picralima nitida (Stapf) Th. & H. Dur.*	MT	2	1	1	2	.	r	.
Apocynaceae	*Rauvolfia macrophylla Stapf (= Rauvolfia caffra Sond.)*	MT	.	.	.	+	r	3	3
Apocynaceae	*Rauvolfia vomitoria Afzel.*	ST	.	.	.	.	.	1	3
Apocynaceae	*Tabernaemontana crassa Benth.*	ST	2	2	3	4	2	4	1
Apocynaceae	*Tabernaemontana sp1*		r	1	r	.	.	r	.
Apocynaceae	*Voacanga africana Stapf*	ST	2	2	2	+	+	+	.
Araceae	*Anchomanes sp1*	H	.	.	.	.	.	r	2
Araceae	*Anubias hastifolia Engl.*	H	.	.	.	.	1	.	.
Araceae	*Araceae gr1*	H	r	.	r	r	1	+	.
Araceae	*Cercestis ivorensis A. Chev.*	H	+	2	2	2	2	2	2
Araceae	*Cercestis kamerunianus (Engl.) N.E.Br.*	H	2	.	1	1	1	.	.
Araceae	*Colocasia esculenta (Linn.) Schott & Endlicher*	H	.	.	.	.	.	.	2
Araceae	*Culcasia dinklagei Engl.*	H	r	1	.	.	.	.	.
Araceae	*Nephthytis sp1*	H	1	2	2	1	1	2	1
Araceae	*Rhektophyllum mirabile N.E.Br. (= Cercestis mirabilis (N.E.Br.) Bogner)*	H	2	2	5	3	4	3	2
Araceae	*Stylochaeton zenkeri Engl.*	H	+	3	2	2	2	3	+
Bignoniaceae	*Newbouldia laevis (P.Beauv.) Seemann ex Bureau*	ST	+	r	1	2	1	1	1
Bombacaceae	*Ceiba pentandra (Linn.) Gaertn.*	LT	r	r	.	1	r	r	3
Burseraceae	*Canarium schweinfurthii Engl.*	LT	+	.	r	+	1	2	2
Burseraceae	*Dacryodes edulis (G. Don) H.J. Lam.*	MT	4	3	2	1	2	.	+
Burseraceae	*Dacryodes gr1*	MT	1	2	2	+	1	1	.
Burseraceae	*Santiria trimera (Oliv.) Aubrev.*	MT	3	4	3	2	1	.	.
Caesalpiniaceae	*Anthonotha fragrans (Bak. f.) Exell & Hillcoat*	LT	+	.	2	1	r	1	.
Caesalpiniaceae	*Anthonotha macrophylla P. Beauv.*	ST	2	3	2	3	4	3	2
Caesalpiniaceae	*Baikiaea insignis Benth.*	MT	+	1	1	2	+	r	.
Caesalpiniaceae	*Berlinia bracteosa Benth.*	MT	.	.	+	+	1	+	.
Caesalpiniaceae	*Caesalpiniaceae sp1*		.	r	1	+	+	+	.
Caesalpiniaceae	*Dialium dinklagei Harms*	MT	3	4	4	3	2	2	r
Caesalpiniaceae	*Distemonanthus benthamianus Baill.*	LT	r	r	2	2	1	1	1
Caesalpiniaceae	*Erythrophleum ivorense A. Chev.*	LT	r	2	3	1	+	.	.
Caesalpiniaceae	*Hylodendron gabunense Taub.*	MT	1	3	2	3	+	3	1
Caesalpiniaceae	*Hymenostegia afzelii (Oliv.) Harms*	MT	+	3	1	r	r	.	.
Caesalpiniaceae	*Monopethalanthus gr1*	LT	3	3	1	1	2	.	.
Caesalpiniaceae	*Plagiosiphon gr1*	MT	1	+	+	.	+	.	.
Caesalpiniaceae	*Scorodophloeus zenkeri Harms*	MT	4	1	+	+	.	.	r
Caesalpiniaceae	*Tetraberlinia bifoliata (Harms) Hauman*	LT	2	1	3	2	2	1	.
Capperidaceae	*Buchholzia coriacea Engl.*	MT	r	r	+	2	+	.	.

Family	Species	growth form[1]	type I[2]	Type IIa	type IIb	type IIc	type III	Type IV	Type V
	Number of relevés:		31	22	25	36	22	20	20
Celastraceae	*Salacia sp1*	L	.	1	2	+	.	+	r
Celastraceae	*Salacia staudtiana Loes.*	L	r	2	r	.	r	+	.
Chrysobalanaceae	*Maranthes glabra (Oliv.) Prance*	LT	3	.	.	.	.	.	.
Combretaceae	*Terminalia superba Engl. & Diels*	LT	.	1	.	2	1	2	1
Commelinaceae	*Palisota ambigua (P. Beauv.) C.B.Cl.*	H	+	+	2	2	2	3	2
Commelinaceae	*Palisota hirsuta (Thunb.) K. Schum.*	H	r	r	.	.	1	1	1
Commelinaceae	*Palisota mannii C.B.Cl.*	H	2	4	3	2	3	1	r
Compositae	*Aspillia africana (Pers.) C.D. Adams*	H	.	.	1	.	r	.	+
Compositae	*Chromolaena odorata*	H	.	.	.	.	.	+	4
Compositae	*Vernonia conferta Benth.*	ST	.	.	.	.	.	2	+
Conneraceae	*Agelaea sp1*	L	2	1	2	3	+	+	.
Costaceae	*Costus afer Ker Gawler*	H	.	.	.	.	1	.	3
Costaceae	*Costus englerianus K. Schum.*	H	r	2	1	+	+	r	.
Cyperaceae	*Cyperaceae gr1*	GH	.	+	1	+	.	.	.
Cyperaceae	*Mapania amplivaginata K. Schum.*	GH	1	1	.	r	r	.	.
Cyperaceae	*Scleria barteri Boeck.*	GH	.	.	.	.	.	.	1
Dichapetalaceae	*Tapura africana Oliv.*	ST	+	1	+	r	.	.	.
Dioscoraceae	*Dioscorea bulbifera Linn.*	L	.	.	.	r	.	.	1
Dioscoraceae	*Dioscorea burkilliana J. Miege*	L	.	.	.	.	.	.	1
Dracaenaceae	*Dracaena camerooniana Bak.*	S	+	r	.	1	+	.	.
Dracaenaceae	*Dracaena phrynioides Hook.*	H	+	1	1	1	2	+	.
Ebenaceae	*Diospyros conocarpa Gurke & K. Schum.*	ST	r	1	r	.	.	r	.
Ebenaceae	*Diospyros crassiflora Hiern.*	MT	1	.	+	+	.	.	.
Ebenaceae	*Diospyros gr3*	ST	r	+	2	1	r	2	.
Ebenaceae	*Diospyros hoyleana F. White*	ST	2	+	1	+	.	.	.
Ebenaceae	*Diospyros kamerunensis Gurke*	ST	1	2	1	1	r	1	.
Ebenaceae	*Diospyros obliguifolia (Hiern. ex Gurke) F. White*	S	r	3	2	1	r	r	.
Ebenaceae	*Diospyros physocalycina Gurke*	ST	2	2	2	1	+	+	.
Ebenaceae	*Diospyros preussii Gurke*	ST	r	.	r	.	2	.	.
Ebenaceae	*Diospyros suaveolens Gurke*	ST	+	1	1	4	3	r	r
Erythroxylaceae	*Erythroxylum mannii Oliv.*	MT	+	+	.	.	.	+	1
Euphorbiaceae	*Alchornea floribunda Mull. Arg.*	ST	1	2	+	1	r	2	+
Euphorbiaceae	*Antidesma laciniatum Mull. Arg.*	ST	+	+	1	+	1	.	.
Euphorbiaceae	*Crotonogyne preussii Pax*	S	r	2	.	r	.	.	.
Euphorbiaceae	*Dichostemma glaucescens Pierre*	ST	2	3	2	1	.	+	.
Euphorbiaceae	*Discoglypremna caloneura (Pax) Prain*	MT	r	+	r	+	r	1	+
Euphorbiaceae	*Drypetes leonensis Pax*	MT	1	r	.	.	.	.	.
Euphorbiaceae	*Drypetes preussii (Pax) Hutch.*	MT	3	1	1	+	r	.	.
Euphorbiaceae	*Grossera gr1*	S	2	3	3	3	1	2	1
Euphorbiaceae	*Grossera macrantha Pax*	S	.	+	1	r	r	.	.
Euphorbiaceae	*Hamilcoa zenkeri (Pax) Prain*	S	.	.	r	r	+	2	2
Euphorbiaceae	*Macaranga barteri Mull. Arg.*	ST	.	r	.	.	r	2	4
Euphorbiaceae	*Macaranga heudelotii Baill.*	ST	.	.	.	.	+	1	2
Euphorbiaceae	*Macaranga hurifolia Beille*	ST	.	.	.	.	r	1	r
Euphorbiaceae	*Maesobotrya dusenii (Pax) Hutch.*	ST	.	1	r	r	.	.	.
Euphorbiaceae	*Maesobotrya staudtii (Pax) Hutch.*	ST	.	1	+	r	+	+	.
Euphorbiaceae	*Manihot esculenta Crantz*	S	.	.	.	.	.	r	3
Euphorbiaceae	*Mareyopsis longifolia (Pax) Pax & K. Hoffm.*	ST	2	1	2	1	+	r	+
Euphorbiaceae	*Phyllanthus discoideus (Baill.) Mull.*	MT	.	1	1	1	.	2	1
Euphorbiaceae	*Plagiostyles africana (Mull. Arg.) Prain*	ST	2	4	4	5	3	1	r
Euphorbiaceae	*Pycnocoma macrophylla Benth.*	S	.	1	+	+	.	r	.
Euphorbiaceae	*Ricinodendron heudelotii (Baill.) Heckel*	LT	r	1	.	1	r	2	1
Euphorbiaceae	*Tetrorchidium didymostemon (Baill.) Pax & K. Hoffm.*	MT	.	.	+	.	r	2	2
Euphorbiaceae	*Uapaca guineensis Mull. Arg.*	MT	3	4	3	2	4	2	1
Euphorbiaceae	*Uapaca staudtii Pax*	MT	r	1	.	.	r	1	.
Euphorbiaceae	*Uapaca vanhouttei De Wild.*	ST	2	+	2	+	2	+	.
Flacourtiaceae	*Caloncoba glauca (P. Beauv.) Gilg. (= Oncoba glauca (P. Beauv.) Gilg)*	ST	.	r	.	1	.	+	+
Flacourtiaceae	*Caloncoba welwitschii (Oliv.) Gilg. (= Oncoba welwitschii Oliv.)*	ST	.	r	r	r	2	1	2
Flacourtiaceae	*Homalium dolichophyllum Gilg.*	MT	1	1	1	+	+	1	2
Gramineae	*Gauduella gr1*	GH	2	3	2	2	1	1	1
Guttiferae	*Allanblackia kisonghi Vermoesen*	MT	2	2	3	2	1	1	+

Family	Species	growth form[1)]	type I[2)]	Type IIa	type IIb	type IIc	type III	Type IV	Type V
	Number of relevés:		31	22	25	36	22	20	20
Guttiferae	*Garcinia lucida Vesq.*	ST	2	1	r	r	+	.	.
Guttiferae	*Garcinia mannii Oliv.*	MT	2	3	2	1	2	+	r
Guttiferae	*Harungana madagascariensis Lam. ex Poir.*	ST	.	.	.	.	.	r	1
Guttiferae	*Mammea africana Sabine*	MT	1	r	2	+	2	.	.
Guttiferae	*Symphonia globulifera Linn. f.*	MT	3	2	1	1	r	r	.
Humiriaceae	*Sacoglottis gabonensis (Baill.) Urb.*	LT	+	.	1	+	1	r	.
Icacinaceae	*Lasianthera africana P. Beauv.*	S	+	+	2	3	2	1	+
Icacinaceae	*Lasianthera sp2*	S	1	.	r	1	.	.	.
Icacinaceae	*Lavigeria macrocarpa (Oliv.) Pierre*	L	2	+	2	3	r	2	2
Irvingiaceae	*Desbordesia glaucescens (Engl.) Tiegh.*	LT	r	2	1	3	2	+	r
Irvingiaceae	*Irvingia gabonensis (Aubry-Leconte ex O'Rorke) Baill.*	LT	.	1	2	1	2	r	r
Irvingiaceae	*Irvingia robur Mildbr.*	LT	2	r	r	2	.	.	.
Irvingiaceae	*Klainedoxa gabonensis Pierre ex Engl.*	LT	1	2	1	1	1	r	+
Irvingiaceae	*Klainedoxa gabonensis var. microphylla Pierre*	LT	+	1	r	r	r	.	.
Lauraceae	*Beilschmiedia anacardioides (Engl. & Krause) Robyns & Wilczek*	MT	2	1	1	1	2	+	.
Lauraceae	*Beilschmiedia obscura (Stapf) Engl. ex A. Chev.*	LT	3	2	2	2	2	+	.
Lauraceae	*Hypodaphnis zenkeri (Engl.) Stapf*	MT	r	r	1	.	2	1	.
Lauraceae	*Persea americana Miller*	ST	.	.	.	1	.	+	r
Lecythidaceae	*Petersianthus africanus (Welw. ex Benth. & Hook. f.) Merrill*	LT	.	1	r	r	.	r	.
Leeaceae	*Leea guineensis G. Don*	S	r	.	.	.	2	1	2
Loganiaceae	*Anthocleista schweinfurthii Gilg*	MT	.	.	.	.	.	1	1
Loganiaceae	*Anthocleista vogelii Planch.*	MT	.	.	.	.	.	1	2
Loganiaceae	*Strychnos staudtii Gilg*	ST	1	+	+	r	.	+	.
Marantaceae	*Halopegia azurea (K. Schum.) K. Schum.*	H	3	3	4	2	3	r	.
Marantaceae	*Haumania danckelmaniana (J. Braun & K. Schum.) Milne-Redh.*	PL	1	4	4	5	2	5	3
Marantaceae	*Megaphrynium macrostachyum (Benth.) Milne-Redh.*	H	.	.	r	1	+	2	1
Marantaceae	*Thaumantococcus daniellii (Bennet) Benth.*	H	.	.	+	+	+	3	2
Marantaceae	*Trachyphrynium braunianum (K. Schum.) Bak.*	PL	.	+	.	+	+	1	.
Marantaceae	*Trachyphrynium sp1*	PL	2	2	1	3	2	3	2
Melastomataceae	*Dinophora spenneroides Benth.*	H	.	.	r	r	.	+	1
Meliaceae	*Carapa gr1*	LT	2	2	3	2	2	3	1
Meliaceae	*Carapa sp1*	MT	.	.	.	.	3	.	.
Meliaceae	*Entandrophragma utile (Dawe & Sprague) Sprague*	LT	.	1	.	.	r	r	.
Meliaceae	*Guarea cedrata (A. Chev.) Pellegr.*	LT	1	.	+	+	1	r	r
Meliaceae	*Guarea thompsonii Sprague & Hutch.*	LT	+	2	1	+	+	.	.
Meliaceae	*Lovoa trichilioides Harms*	LT	+	1	r	+	+	r	.
Meliaceae	*Trichilia emetica Vahl*	MT	.	.	.	.	.	r	.
Meliaceae	*Trichilia heudelotii Planch. ex Oliv.*	ST	+	+	1	+	2	1	1
Meliaceae	*Trichilia welwitschii C.DC.*	MT	.	.	r	.	+	1	r
Meliaceae	*Turraeanthus africanus (Welw. ex C.DC.) Pellegr.*	MT	1	r	2	.	r	+	.
Menispermaceae	*Jateorhiza macrantha (Hook. f.) Excell & Medonca*	L	.	.	.	.	.	.	2
Menispermaceae	*Penianthus longifolius Miers*	ST	r	1	r	.	r	r	.
Mimosaceae	*Acacia pennata (Linn.) Willd. (= Acacia pentagona (Schum.) Hook. f.)*	S	.	.	1	+	r	+	+
Mimosaceae	*Albizia adianthifolia (Schum.) W.F. Wight*	LT	.	r	.	.	.	1	r
Mimosaceae	*Albizia zygia (DC.) J.F. Macbr.*	MT	+	+	+	1	+	1	3
Mimosaceae	*Calpocalyx dinklagei Harms*	ST	+	1	2	4	2	1	r
Mimosaceae	*Entada gigas (Linn.) Fawcett & Rendle*	L	2	+	1	+	r	.	.
Mimosaceae	*Parkia bicolor A. Chev.*	LT	2	2	2	+	1	+	r
Mimosaceae	*Pentaclethra macrophylla Benth.*	LT	2	3	3	2	2	2	1
Mimosaceae	*Piptadeniastrum africanum (Hook. f.) Brenan*	LT	2	2	2	3	2	3	r
Monimiaceae	*Glossocalyx brevipes Benth.*	S	1	1	2	1	1	.	.
Moraceae	*Dorstenia picta Bureau*	H	.	2	r	r	+	.	r
Moraceae	*Milicia excelsa (Welw.) C.C. Berg*	LT	.	.	.	+	.	.	3
Moraceae	*Moraceae sp2*		+	+	+	3	2	+	1
Moraceae	*Musanga cecropioides R.. Brown ex Tedlie*	MT	r	2	.	1	2	5	4
Moraceae	*Myrianthus arboreus P. Beauv.*	MT	r	.	.	1	.	2	+
Moraceae	*Treculia obovoidea N.E.Br.*	ST	4	4	5	+	+	1	r
Musaceae	*Musa sp1*		.	.	.	.	.	.	1
Myristicaceae	*Coelocaryon preussii Warb.*	LT	3	4	4	4	5	4	1
Myristicaceae	*Pycnanthus angolensis (Welw.) Warb.*	LT	2	5	2	4	4	4	3

Family	Species	growth form[1)]	type I[2)]	Type IIa	type IIb	type IIc	type III	Type IV	Type V
	Number of relevés:		31	22	25	36	22	20	20
Myristicaceae	*Scyphocephalium mannii (Benth.) Warb.*	MT	+	2	1	+	2	1	.
Myristicaceae	*Staudtia kamerunensis Warb.*	MT	1	4	4	5	3	4	r
Ochnaceae	*Lophira alata Banks ex Gaertn. f.*	LT	.	1	1	1	1	2	3
Ochnaceae	*Ouratea flava (Schum. & Thonn.) Hutch. & Dalz. (= Campylospermum flavum (Schum. & Thonn.) Farron)*	S	r	.	r	2	r	2	r
Olacaceae	*Coula edulis Baill.*	LT	2	3	3	3	+	2	.
Olacaceae	*Heisteria parvifolia Sm.*	S	.	r	+	1	r	.	r
Olacaceae	*Olacaceae sp1*		1	.	.	.	.	.	.
Olacaceae	*Olax staudtii Engl.*	S	2	.	1	2	r	r	.
Olacaceae	*Ongokea gore (Hua) Pierre*	LT	r	1	r	+	.	.	.
Olacaceae	*Ptychopetalum petiolatum Oliv.*	S	2	2	3	4	r	1	1
Olacaceae	*Strombosia grandifolia Hook. f. ex Benth.*	S	4	4	2	2	2	2	.
Olacaceae	*Strombosia pustulata Oliv.*	MT	1	2	4	3	1	.	.
Palmae	*Ancistrophyllum secundiflorum (P. Beauv.) Wendl. (= Laccosperma secundiflora Kuntze)*	PL	+	1	1	r	2	2	.
Palmae	*Calamus deeratus Mann & Wendl.*	PL	3	3	4	2	2	3	.
Palmae	*Elaeis guineensis Jacq.*	P	.	.	.	+	2	1	3
Palmae	*Podococcus barteri Mann & Wendl.*	P	.	2	1	+	1	+	.
Palmae	*Raphia sp1*	P	3	3	1	-	-	-	-
Palmae	*Raphia sp2*	P	-	-	-	+	2	1	1
Papilionaceae	*Baphia leptobotrys Harms*	S	3	r	1	2	2	1	.
Papilionaceae	*Millettia macrophylla Benth.*	ST	r	.	r	2	1	r	2
Papilionaceae	*Pterocarpus soyauxii Taub.*	LT	1	2	1	1	2	1	+
Papilionaceae	*Trifolium sp1*	H	.	.	.	.	.	.	3
Passifloraceae	*Barteria fistulosa Mast.*	ST	.	r	r	1	.	+	+
Polygalaceae	*Carpolobia lutea G. Don.*	S	+	1	2	+	.	+	1
Pteridophyta	*Cyathea cf manniana Hook.*	TF	.	.	.	.	1	.	r
Pteridophyta	*Fern gr1*	H	1	+	1	2	+	2	4
Rhamnaceae	*Maesopsis eminii Engl.*	MT	r	+	.	r	.	1	+
Rhizophoraceae	*Anisophyllea polyneura Floret*	MT	5	2	1	r	.	+	r
Rhizophoraceae	*Anopyxis klaineana (Pierre) Engl.*	LT	1	r	r	.	.	.	.
Rubiaceae	*Coffea sp1*	S	1	2	1	2	.	+	r
Rubiaceae	*Geophila sp1*	H	+	2	.	r	r	.	.
Rubiaceae	*Massularia acuminata (G. Don) Bullock ex Hoyle*	ST	+	+	.	.	.	1	.
Rubiaceae	*Mitragyna stipulosa (DC.) O. Ktze. (= Hallea stipulosa (D.C.) Leroy)*	MT	.	.	r	.	5	.	+
Rubiaceae	*Nauclea diderrichii (De Wild. & Th. Dur.) Merrill*	LT	.	.	+	.	.	1	r
Rubiaceae	*Pentas gr1*	S	+	1	1	1	+	1	2
Rubiaceae	*Porterandia cladantha (K. Schum.) Keay*	MT	1	r	.	.	.	r	.
Rubiaceae	*Psychotria gr1*	S	+	1	1	+	1	r	r
Rubiaceae	*Psychotria gr2*	S	1	2	2	1	2	2	1
Rubiaceae	*Psychotria sp1*	S	1	.	+	2	.	.	.
Rubiaceae	*Rubiaceae gr1*		2	1	2	r	1	1	r
Rubiaceae	*Rubiaceae gr2*		1	2	2	2	+	2	r
Rubiaceae	*Rubiaceae gr4*		1	r	1	+	.	+	1
Rubiaceae	*Rubiaceae gr5*		1	r	1	+	.	+	.
Rubiaceae	*Rubiaceae gr8*		+	+	2	1	1	+	+
Rubiaceae	*Rubiaceae sp1*		2	2	2	2	2	r	.
Rubiaceae	*Rubiaceae sp2*		.	.	.	.	2	.	.
Rubiaceae	*Rubiaceae sp3*		2	.	.	.	r	r	r
Rubiaceae	*Stipularia africana P. de Beauv.*	S	r	.	2	r	1	3	.
Rutaceae	*Fagara heitzii Aubr. & Pell. (= Zanthoxylum heitzii (Aubrev. & Pellegr.) P.G. Waterman)*	LT	+	1	1	r	+	2	+
Rutaceae	*Fagara macrophylla (Oliv.) Engl. (= Zanthoxylum gilletii (De Wild.) P.G. Waterman)*	LT	r	1	1	1	1	3	3
Rutaceae	*Fagara tessmannii Engl. (= Zanthoxylum gilletii (De Wild.) P.G. Waterman)*	LT	r	r	r	.	.	2	.
Sapindaceae	*Blighia welwitschii (Hiern) Radlk.*	LT	+	2	1	+	r	2	.
Sapindaceae	*Chytranthus talbotii (Bak. f.) Keay*	ST	2	1	2	3	2	.	r
Sapindaceae	*Sapindaceae sp1*		+	1	1	+	2	.	r
Sapotaceae	*Gambeya gr1*	MT	3	2	1	2	.	+	.
Scytopetalaceae	*Oubangia africana Baillon*	S	1	+	r	+	+	r	.
Simaroubaceae	*Simaroubaceae sp1*		.	.	.	r	.	r	2
Sterculiaceae	*Cola attiensis Aubrev. & Pellegr.*	ST	1	r	.	.	r	r	.

Family	Species	growth form[1)]	type I[2)]	Type IIa	type IIb	type IIc	type III	Type IV	Type V
	Number of relevés:		31	22	25	36	22	20	20
Sterculiaceae	*Cola cordifolia (Cav.) R. Br.*	ST	.	r	2	+	+	.	.
Sterculiaceae	*Cola ficifolia Mast.*	ST	+	1	2	1	+	.	.
Sterculiaceae	*Cola lepidota K. Schum.*	MT	r	1	.	+	1	.	.
Sterculiaceae	*Cola marsupium K. Schum.*	ST	.	.	1	r	.	r	.
Sterculiaceae	*Cola rostrata K. Schum.*	ST	1	+	1	+	r	r	.
Sterculiaceae	*Cola verticilata (Thonn.) Stapf ex A. Chev.*	MT	+	1	2	+	1	.	.
Sterculiaceae	*Eribroma oblonga (Mast.) Pierre ex A. Chev. (= Sterculia oblonga Mast.)*	LT	+	r	.	2	r	1	3
Sterculiaceae	*Scaphopetalum blackii Mast.*	ST	2	4	4	2	2	+	1
Sterculiaceae	*Scaphopetalum thonneri Willd.*	S	3	4	3	2	1	1	.
Sterculiaceae	*Sterculia subviolacea K. Schum.*	MT	.	.	r	.	1	r	.
Sterculiaceae	*Sterculia tragacantha Lindl.*	ST	+	1	.	.	2	1	2
Sterculiaceae	*Theobroma cacao Linn.*	ST	.	.	.	.	.	r	1
Thymelaceae	*Dicranolepis sp1*		+	r	r	.	1	.	.
Tiliaceae	*Duboscia macrocarpa Bocq.*	ST	+	1	+	1	1	.	r
Tiliaceae	*Glyphaea brevis (Spreng.) Monachino*	MT	.	r	+	.	+	1	.
Tiliaceae	*Grewia coriacea Mast. (= Microcos coriacea (Mast.) Burret)*	S	+	.	1	1	+	1	.
Ulmaceae	*Celtis mildbraedii Engl.*	LT	1	2	1	2	r	r	.
Ulmaceae	*Trema orientalis (Linn.) Blume*	ST	.	r	.	.	.	.	1
Verbenaceae	*Vitex grandifolia Gurke*	ST	1	+	r	+	1	2	+
Verbenaceae	*Vitex rivularis Gurke*	MT	1	.	.	r	r	+	.
Violaceae	*Rinorea dentata (P. Beauv.) O. Ktze*	ST	2	1	2	1	+	+	.
Violaceae	*Rinorea kamerunensis Engl.*	S	2	1	3	4	2	1	.
Vitaceae	*Cissus sp1*	L	+	.	.	1	1	1	r
Zingiberaceae	*Aframomum gr1*	H	r	r	.	+	1	3	2
Zingiberaceae	*Curcuma longa Linn.*	H	.	.	.	.	1	.	.

[1)] LT = large tree (diameter at breast height (dbh)> 60 cm; total height (H)>40 m); MT = medium-sized tree (dbh 20-60 cm; H 15-40m); ST = small tree (dbh 5-20; H, 15m); S = shrub (dbh<5 cm; H<10 m; often multiple stems); L = liana (woody); NWC = non-woody climber or vine; PL = palmoid liana; H = terrestrial herb (broad-leaved); GH = graminoid herb; P = (acaulescent) palm; TF = tree fern. [2)] Plant communities; I = Maranthes – Anisophyllea community; IIa = Podococcus – Polyalthia community; IIb = Strombosia – Polyalthia community; IIc = Diospyros – Polyalthia community; III = Carapa – Mitragyna community; IV = Xylopia – Musanga community; and V = Macaranga – Chromolaena community. [3)] Frequency classes: r=1x; +=1-9%; 1=10-19%; 2=20-39%; 3=40-59%; 4=60-79% and 5=80-100%. The frequency values presented here differ slightly from those presented in van Gemerden and Hazeu (1999) as more relevés have been included in the analysis (176 instead of 114).

Annex 3 Timber species categories

Category 1: Superior grade
(species presently exploited in the TCP area; pers. comm. G.J.R. van Leersum)

Distemonanthus benthamianus (Caesalpiniaceae)
Entandrophragma utile (Meliaceae)
Erythrophleum ivorense (Caesalpiniaceae)
Lophira alata (Ochnaceae)
Milicia excelsa (Moraceae)
Pterocarpus soyauxii (Papilionaceae)
Staudtia kamerunensis (Myristicaceae)

Category 2: High grade
(species coded 11 on list of the National Forest Development Agency (ONADEF, 1992)

Canarium schweinfurthii (Burseraceae)
Diospyros crassiflora (Ebenaceae)
Eribroma oblonga (Sterculiaceae)
Fagara heitzii (Rutaceae)
Guarea cedrata (Meliaceae)
Guarea thompsonii (Meliaceae)
Lovoa trichilioides (Meliaceae)
Monopethalanthus gr1 (Caesalpiniaceae)
Nauclea diderrichii (Rubiaceae)
Pycnanthus angolensis (Myristicaceae)
Terminalia superba (Combretaceae)
Tetraberlinia bifoliata (Caesalpiniaceae)

Category 3: Medium grade
(species coded 12 on list ONADEF)

Anopyxis klaineana (Rhizophoraceae)
Anthonotha fragrans (Caesalpiniaceae)
Desbordesia glaucescens (Irvingiaceae)
Dialium dinklagei (Caesalpiniaceae)
Gambeya gr1 (Sapotaceae)
Hylodendron gabunense (Caesalpiniaceae)
Mammea africana (Guttiferae)
Ongokea gore (Olacaceae)
Piptadeniastrum africanum (Mimosaceae)
Turraeanthus africanus (Meliaceae)

Category 4: Low grade
(species coded 13 on list State Forestry Service ONADEF and/or identified as species with good technical timber qualities but not yet widely marketed by Zijp *et al*. (1999))

Albizia zygia (Mimosaceae)
Alstonia congensis (Apocynaceae)
Beilschmiedia obscura (Lauraceae)
Berlinia bracteosa (Caesalpiniaceae)
Carapa gr1 (Meliaceae)
Ceiba pentandra (Bombacaceae)
Celtis mildbraedii (Ulmaceae)
Coelocaryon preussii (Myristicaceae)
Erythroxylum mannii (Erythroxylaceae)
Irvingia gabonensis (Irvingiaceae)
Klainedoxa gabonensis (Irvingiaceae)
Klainedoxa gabonensis (Irvingiaceae)
Parkia bicolor (Mimosaceae)
Pentaclethra macrophylla (Mimosaceae)
Scorodophloeus zenkeri (Caesalpiniaceae)

Annex 4 NTFP species

Relative importance of NTFP species as indicated by local informants (J.F.W. van Dijk, pers. comm.; van Dijk, 1999). The number of times that a species, for any of its products, was mentioned in the interviews (n = 29) is used as indicator for its importance.

Category 1: Species of high importance (>40 times mentioned)

Alstonia congensis (Apocynaceae)
Coula edulis (Olacaceae)
Elaeis guineensis (Palmae)
Enantia chlorantha (Annonaceae)
Garcinia lucida (Guttiferae)
Irvingia gabonensis (Irvingiaceae)
Musanga cecropioides (Moraceae)
Pachypondanthium staudtii (Annonaceae)
Rauvolfia vomitoria (Apocynaceae)
Ricinodendron heudelotii (Euphorbiaceae)

Category 2: Species of moderately high importance (mentioned 20 – 40 times)

Antrocaryon klaineanum (Anacardiaceae)
Carpolobia lutea (Polygalaceae)
Cola lepidota (Sterculiaceae)
Erythrophleum ivorense (Caesalpiniaceae)
Halopegia azurea (Marantaceae)
Harungana madagascariensis (Guttiferae)
Haumania danckelmaniana (Marantaceae)
Lophira alata (Ochnaceae)
Manihot esculenta (Euphorbiaceae)
Massularia acuminata (Rubiaceae)
Megaphrynium macrostachyum (Marantaceae)
Mitragyna stipulosa (Rubiaceae)
Myrianthus arboreus (Moraceae)
Ongokea gore (Olacaceae)
Pentaclethra macrophylla (Mimosaceae)
Picralima nitida (Apocynaceae)
Pterocarpus soyauxii (Papilionaceae)
Sacoglottis gabonensis (Humiriaceae)
Scorodophloeus zenkeri (Caesalpiniaceae)
Tabernaemontana crassa (Apocynaceae)
Terminalia superba (Combretaceae)
Trichoscypha acuminata (Anacardiaceae)
Vernonia conferta (Compositae)
Xylopia aethiopica (Annonaceae)

Category 3: Species of low importance (mentioned 5 – 20 times)

Aframomum gr1 (Zingiberaceae)
Allanblackia kisonghi (Guttiferae)
Anonidium mannii (Annonaceae)
Anthocleista schweinfurthii (Loganiaceae)
Anthocleista vogelii (Loganiaceae)
Barteria fistulosa (Passifloraceae)
Canarium schweinfurthii (Burseraceae)
Carapa gr1 (Meliaceae)
Chromolaena odorata (Compositae)
Cola verticilata (Sterculiaceae)
Dialium dinklagei (Caesalpiniaceae)
Discoglypremna caloneura (Euphorbiaceae)
Distemonanthus benthamianus (Caesalpiniaceae)
Eribroma oblonga (Sterculiaceae)
Fagara heitzii (Rutaceae)
Funtumia elastica (Apocynaceae)
Hexalobus crispiflorus (Annonaceae)
Lasianthera africana (Icacinaceae)
Lovoa trichilioides (Meliaceae)
Macaranga barteri (Euphorbiaceae)
Macaranga hurifolia (Euphorbiaceae)
Milicia excelsa (Moraceae)
Musa sp1 (Musaceae)
Nauclea diderrichii (Rubiaceae)
Nephthytis sp1 (Araceae)
Persea americana (Lauraceae)
Piptadeniastrum africanum (Mimosaceae)
Podococcus barteri (Palmae)
Pseudospondias microcarpa (Anacardiaceae)
Pycnanthus angolensis (Myristicaceae)
Raphia sp1 (Palmae)
Staudtia kamerunensis (Myristicaceae)
Tetrorchidium didymostemon (Euphorbiaceae)
Theobroma cacao (Sterculiaceae)
Uapaca guineensis (Euphorbiaceae)
Uapaca staudtii (Euphorbiaceae)
Uapaca vanhouttei (Euphorbiaceae)
Vitex grandifolia (Verbenaceae)

Category 4: Species of very low importance (mentioned < 5 times)

Acacia pennata (Mimosaceae)
Alchornea floribunda (Euphorbiaceae)
Anchomanes sp1 (Araceae)
Ancistrophyllum secundiflorum (Palmae)
Anthonotha macrophylla (Caesalpiniaceae)
Blighia welwitschii (Sapindaceae)
Caloncoba welwitschii (Flacourtiaceae)
Ceiba pentandra (Bombacaceae)
Cola rostrata (Sterculiaceae)
Dacryodes edulis (Burseraceae)
Desbordesia glaucescens (Irvingiaceae)
Diospyros conocarpa (Ebenaceae)
Diospyros crassiflora (Ebenaceae)
Diospyros kamerunensis (Ebenaceae)
Diospyros physocalycina (Ebenaceae)
Diospyros suaveolens (Ebenaceae)
Drypetes preussii (Euphorbiaceae)
Duboscia macrocarpa (Tiliaceae)
Fagara macrophylla (Rutaceae)
Garcinia mannii (Guttiferae)
Hylodendron gabunense (Caesalpiniaceae)
Hypodaphnis zenkeri (Lauraceae)
Jateorhiza macrantha (Menispermaceae)
Klainedoxa gabonensis (Irvingiaceae)
Klainedoxa gabonensis (Irvingiaceae)
Leea guineensis (Leeaceae)
Maesopsis eminii (Rhamnaceae)
Meiocarpidium lepidotum (Annonaceae)
Newbouldia laevis (Bignoniaceae)
Petersianthus africanus (Lecythidaceae)
Plagiostyles africana (Euphorbiaceae)
Polyalthia suaveolens (Annonaceae)
Santiria trimera (Burseraceae)
Scleria barteri (Cyperaceae)
Stipularia africana (Rubiaceae)
Strombosia grandifolia (Olacaceae)
Strombosia pustulata (Olacaceae)
Trachyphrynium braunianum (Marantaceae)
Trachyphrynium sp1 (Marantaceae)

Category 5: Potential NTFP species (mentioned only in literature)

Albizia adianthifolia (Mimosaceae)
Anisophyllea polyneura (Rhizophoraceae)
Anthonotha fragrans (Caesalpiniaceae)
Antidesma laciniatum (Euphorbiaceae)
Baphia leptobotrys (Papilionaceae)
Beilschmiedia anacardioides (Lauraceae)
Beilschmiedia obscura (Lauraceae)
Berlinia bracteosa (Caesalpiniaceae)
Calamus deeratus (Palmae)
Calpocalyx dinklagei (Mimosaceae)
Celtis mildbraedii (Ulmaceae)
Cleistopholis glauca (Annonaceae)
Cleistopholis patens (Annonaceae)
Coelocaryon preussii (Myristicaceae)
Dichostemma glaucescens (Euphorbiaceae)
Dinophora spenneroides (Melastomataceae)
Entada gigas (Mimosaceae)
Entandrophragma utile (Meliaceae)
Erythroxylum mannii (Erythroxylaceae)
Glossocalyx brevipes (Monimiaceae)
Grewia coriacea (Tiliaceae)
Guarea cedrata (Meliaceae)
Guarea thompsonii (Meliaceae)
Heisteria parvifolia (Olacaceae)
Irvingia robur (Irvingiaceae)
Lavigeria macrocarpa (Icacinaceae)
Mammea africana (Guttiferae)
Mareyopsis longifolia (Euphorbiaceae)
Millettia macrophylla (Papilionaceae)
Olax staudtii (Olacaceae)
Oubangia africana (Scytopetalaceae)
Parkia bicolor (Mimosaceae)
Penianthus longifolius (Menispermaceae)
Ptychopetalum petiolatum (Olacaceae)
Rinorea dentata (Violaceae)
Rinorea kamerunensis (Violaceae)
Scaphopetalum blackii (Sterculiaceae)
Scyphocephalium mannii (Myristicaceae)
Sterculia subviolacea (Sterculiaceae)
Sterculia tragacantha (Sterculiaceae)
Symphonia globulifera (Guttiferae)
Tetraberlinia bifoliata (Caesalpiniaceae)
Treculia obovoidea (Moraceae)
Trichilia heudelotii (Meliaceae)
Trichilia welwitschii (Meliaceae)

Turraeanthus africanus (Meliaceae)

Annex 5: Geographical distribution of plant species

Species information is based on regional floras and checklists such as the Flora of West Tropical Africa (Keay and Hepper, 1954 – 1972); Flore du Cameroun (Aubréville and Leroy, 1963 – 1998; Flore du Gabon (Aubréville and Leroy, 1961 – 1992) and Hawthorne (1996).

Category 1: Species restricted to Cameroon

Cola ficifolia (Sterculiaceae)
Hamilcoa zenkeri (Euphorbiaceae)
Rinorea kamerunensis (Violaceae)

Category 2: Species restricted to south Nigeria, Gabon, Equatorial Guinea, Congo (Zaire) and Cameroon

Antrocaryon klaineanum (Anacardiaceae)
Baphia leptobotrys (Papilionaceae)
Beilschmiedia anacardioides (Lauraceae)
Calpocalyx dinklagei (Mimosaceae)
Cercestis kamerunianus (Araceae)
Chytranthus talbottii (Sapindaceae)
Cola lepidota (Sterculiaceae)
Cola marsupium (Sterculiaceae)
Cola rostrata (Sterculiaceae)
Crotonogyne preussii (Euphorbiaceae)
Diospyros conocarpa (Ebenaceae)
Diospyros obliguifolia (Ebenaceae)
Diospyros physocalycina (Ebenaceae)
Diospyros preussii (Ebenaceae)
Diospyros suaveolens (Ebenaceae)
Dorstenia picta (Moraceae)
Drypetes preussii (Euphorbiaceae)
Duboscia macrocarpa (Tiliaceae)
Enantia chlorantha (Annonaceae)
Fagara heitzii (Rutaceae)
Garcinia mannii (Guttiferae)
Glossocalyx brevipes (Monimiaceae)
Haumania danckelmaniana (Marantaceae)
Hylodendron gabunense (Caesalpiniaceae)
Hypodaphnis zenkeri (Lauraceae)
Irvingia robur (Irvingiaceae)
Klainedoxa gabonensis (Irvingiaceae)
Maesobotrya dusenii (Euphorbiaceae)
Maesobotrya staudtii (Euphorbiaceae)
Mapania amplivaginata (Cyperaceae)
Mareyopsis longifolia (Euphorbiaceae)
Meiocarpidium lepidotum (Annonaceae)

Millettia macrophylla (Papilionaceae)
Olax staudtii (Olacaceae)
Palisota ambigua (Commelinaceae)
Podococcus barteri (Palmae)
Porterandia cladantha (Rubiaceae)
Pseudospondias microcarpa (Anacardiaceae)
Ptychopetalum petiolatum (Olacaceae)
Rauvolfia macrophylla (Apocynaceae)
Salacia staudtiana (Celastraceae)
Scorodophloeus zenkeri (Caesalpiniaceae)
Scyphocephalium mannii (Myristicaceae)
Sorindeia grandifolia (Anacardiaceae)
Staudtia kamerunensis (Myristicaceae)
Strychnos staudtii (Loganiaceae)
Tapura africana (Dichapetalaceae)
Tetraberlinia bifoliata (Caesalpiniaceae)
Uapaca staudtii (Euphorbiaceae)

Category 3: Species restricted to Central Africa

Anisophyllea polyneura (Rhizophoraceae)
Anonidium mannii (Annonaceae)
Anthocleista schweinfurthii (Loganiaceae)
Baikiaea insignis (Caesalpiniaceae)
Barteria fistulosa (Passifloraceae)
Berlinia bracteosa (Caesalpiniaceae)
Cleistopholis glauca (Annonaceae)
Dacryodes edulis (Burseraceae)
Desbordesia glaucescens (Irvingiaceae)
Dichostemma glaucescens (Euphorbiaceae)
Diospyros crassiflora (Ebenaceae)
Diospyros hoyleana (Ebenaceae)
Grewia coriacea (Tiliaceae)
Grossera macrantha (Euphorbiaceae)
Lasianthera africana (Icacinaceae)
Lavigeria macrocarpa (Icacinaceae)
Oubangia africana (Scytopetalaceae)
Palisota mannii (Commelinaceae)
Penianthus longifolius (Menispermaceae)
Plagiostyles africana (Euphorbiaceae)
Polyalthia suaveolens (Annonaceae)
Pterocarpus soyauxii (Papilionaceae)
Sterculia subviolacea (Sterculiaceae)
Strombosia grandifolia (Olacaceae)
Treculia obovoidea (Moraceae)

Trichilia welwitschii (Meliaceae)
Trichoscypha acuminata (Anacardiaceae)
Uapaca vanhouttei (Euphorbiaceae)

Category 4: Species restricted to West and Central Africa

Alchornea floribunda (Euphorbiaceae)
Alstonia congensis (Apocynaceae)
Ancistrophyllum secundiflorum (Palmae)
Anopyxis klaineana (Rhizophoraceae)
Anthonotha fragrans (Caesalpiniaceae)
Anthonotha macrophylla (Caesalpiniaceae)
Antidesma laciniatum (Euphorbiaceae)
Anubias hastifolia (Araceae)
Blighia welwitschii (Sapindaceae)
Buchholzia coriacea (Capperidaceae)
Calamus deeratus (Palmae)
Caloncoba glauca (Flacourtiaceae)
Caloncoba welwitschii (Flacourtiaceae)
Carpolobia lutea (Polygalaceae)
Cercestis ivorensis (Araceae)
Cleistopholis patens (Annonaceae)
Coelocaryon preussii (Myristicaceae)
Cola verticilata (Sterculiaceae)
Costus englerianus (Costaceae)
Coula edulis (Olacaceae)
Culcasia dinklagei (Araceae)
Dialium dinklagei (Caesalpiniaceae)
Dinophora spenneroides (Melastomataceae)
Diospyros kamerunensis (Ebenaceae)
Discoglypremna caloneura (Euphorbiaceae)
Distemonanthus benthamianus (Caesalpiniaceae)
Dracaena camerooniana (Dracaenaceae)
Dracaena phrynioides (Dracaenaceae)
Drypetes leonensis (Euphorbiaceae)
Entandrophragma utile (Meliaceae)
Eribroma oblonga (Sterculiaceae)
Erythrophleum ivorense (Caesalpiniaceae)
Erythroxylum mannii (Erythroxylaceae)
Fagara macrophylla (Rutaceae)
Fagara tessmannii (Rutaceae)
Funtumia elastica (Apocynaceae)
Guarea cedrata (Meliaceae)
Guarea thompsonii (Meliaceae)
Heisteria parvifolia (Olacaceae)

Homalium dolichophyllum (Flacourtiaceae)
Hymenostegia afzelii (Caesalpiniaceae)
Jateorhiza macrantha (Menispermaceae)
Lophira alata (Ochnaceae)
Lovoa trichilioides (Meliaceae)
Macaranga barteri (Euphorbiaceae)
Macaranga heudelotii (Euphorbiaceae)
Macaranga hurifolia (Euphorbiaceae)
Mammea africana (Guttiferae)
Maranthes glabra (Chrysobalanaceae)
Massularia acuminata (Rubiaceae)
Musanga cecropioides (Moraceae)
Newbouldia laevis (Bignoniaceae)
Ongokea gore (Olacaceae)
Ouratea flava (Ochnaceae)
Pachypondanthium staudtii (Annonaceae)
Palisota hirsuta (Commelinaceae)
Parkia bicolor (Mimosaceae)
Pentaclethra macrophylla (Mimosaceae)
Petersianthus africanus (Lecythidaceae)
Picralima nitida (Apocynaceae)
Pycnanthus angolensis (Myristicaceae)
Pycnocoma macrophylla (Euphorbiaceae)
Rauvolfia vomitoria (Apocynaceae)
Rhektophyllum mirabile (Araceae)
Rinorea dentata (Violaceae)
Sacoglottis gabonensis (Humiriaceae)
Santiria trimera (Burseraceae)
Sterculia tragacantha (Sterculiaceae)
Stipularia africana (Rubiaceae)
Strombosia pustulata (Olacaceae)
Stylochaeton zenkeri (Araceae)
Tabernaemontana crassa (Apocynaceae)
Terminalia superba (Combretaceae)
Tetrorchidium didymostemon (Euphorbiaceae)
Thaumantococcus daniellii (Marantaceae)
Trichilia heudelotii (Meliaceae)
Turraeanthus africanus (Meliaceae)
Uapaca guineensis (Euphorbiaceae)
Vitex grandifolia (Verbenaceae)
Vitex rivularis (Verbenaceae)
Xylopia aethiopica (Annonaceae)

Category 5: Species restricted to Tropical Africa

Acacia pennata (Mimosaceae)
Albizia adianthifolia (Mimosaceae)
Albizia zygia (Mimosaceae)
Anthocleista vogelii (Loganiaceae)
Aspillia africana (Compositae)
Canarium schweinfurthii (Burseraceae)
Celtis mildbraedii (Ulmaceae)
Costus afer (Costaceae)
Glyphaea brevis (Tiliaceae)
Harungana madagascariensis (Hypericeae)
Hexalobus crispiflorus (Annonaceae)
Irvingia gabonensis (Irvingiaceae)
Klainedoxa gabonensis (Irvingiaceae)
Leea guineensis (Leeaceae)
Maesopsis eminii (Rhamnaceae)
Megaphrynium macrostachyum (Marantaceae)
Milicia excelsa (Moraceae)
Mitragyna stipulosa (Rubiaceae)
Myrianthus arboreus (Moraceae)
Nauclea diderrichii (Rubiaceae)
Phyllanthus discoideus (Euphorbiaceae)
Piptadeniastrum africanum (Mimosaceae)
Ricinodendron heudelotii (Euphorbiaceae)
Trachyphrynium braunianum (Marantaceae)
Trema orientalis (Ulmaceae)
Trichilia emetica (Meliaceae)
Voacanga africana (Apocynaceae)

Category 6: Pantropical species

Ceiba pentandra (Bombacaceae)
Chromolaena odorata (Compositae)
Colocasia esculenta (Araceae)
Curcuma longa (Zingiberaceae)
Dioscorea bulbifera (Dioscoraceae)
Elaeis guineensis (Palmae)
Entada gigas (Mimosaceae)
Manihot esculenta (Euphorbiaceae)
Persea americana (Lauraceae)
Symphonia globulifera (Guttiferae)
Theobroma cacao (Sterculiaceae)

Annex 6 Food plants for wildlife (modified after Bekhuis, 1997)

	Gorilla	Mandrill	Chimpanzee	Collared mangabey
Pseudospondias microcarpa (Anacardiaceae)			x	
Trichoscypha acuminata (Anacardiaceae)		x	x	
Enantia chlorantha (Annonaceae)	x	x		
Hexalobus crispiflorus (Annonaceae)	x	x	x	
Pachypondanthium staudtii (Annonaceae)		x		x
Polyalthia suaveolens (Annonaceae)		x	x	x
Xylopia aethiopica (Annonaceae)		x		
Canarium schweinfurthii (Burseraceae)			x	
Santiria trimera (Burseraceae)	x	x	x	x
Anthonotha macrophylla (Caesalpiniaceae)		x		
Erythrophleum ivorense (Caesalpiniaceae)	x			
Monopethalanthus gr1 (Caesalpiniaceae)				x
Scorodophloeus zenkeri (Caesalpiniaceae)		x		x
Diospyros preussii (Ebenaceae)		x		
Uapaca guineensis (Euphorbiaceae)	x		x	
Uapaca staudtii (Euphorbiaceae)		x		x
Caloncoba glauca (Flacourtiaceae)		x		x
Sacoglottis gabonensis (Humiriaceae)		x		x
Lavigeria macrocarpa (Icacinaceae)			x	
Irvingia gabonensis (Irvingiaceae)	x		x	x
Klainedoxa gabonensis (Irvingiaceae)			x	
Halopegia azurea (Marantaceae)		x		x
Haumania danckelmaniana (Marantaceae)		x	x	x
Trachyphrynium braunianum (Marantaceae)			x	
Parkia bicolor (Mimosaceae)			x	
Pentaclethra macrophylla (Mimosaceae)		x		
Piptadeniastrum africanum (Mimosaceae)	x		x	
Milicia excelsa (Moraceae)	x			
Musanga cecropioides (Moraceae)	x		x	
Myrianthus arboreus (Moraceae)			x	
Coelocaryon preussii (Myristicaceae)				x
Pycnanthus angolensis (Myristicaceae)			x	
Staudtia kamerunensis (Myristicaceae)	x	x		x
Lophira alata (Ochnaceae)		x		
Coula edulis (Olacaceae)		x		
Heisteria parvifolia (Olacaceae)			x	
Elaeis guineensis (Palmae)			x	
Podococcus barteri (Palmae)		x		
Raphia sp1 (Palmae)	x			
Gambeya gr1 (Sapotaceae)	x		x	
Eribroma oblonga (Sterculiaceae)	x		x	
Scaphopetalum blackii (Sterculiaceae)		x		
Duboscia macrocarpa (Tiliaceae)		x		
Grewia coriacea (Tiliaceae)		x	x	x
Aframomum gr1 (Zingiberaceae)	x		x	

Annex 7 Habitat preference of plant species

Species information is based on regional floras and checklists such as the Flora of West Tropical Africa (Keay and Hepper, 1954 – 1972); Flore du Cameroun (Aubréville and Leroy, 1963 – 1998; Flore du Gabon (Aubréville and Leroy, 1961 – 1992) and Hawthorne (1996).

Category 1: Species of primary forest

Anisophyllea polyneura (Rhizophoraceae)
Antidesma laciniatum (Euphorbiaceae)
Buchholzia coriacea (Capperidaceae)
Celtis mildbraedii (Ulmaceae)
Chytranthus talbottii (Sapindaceae)
Cola verticilata (Sterculiaceae)
Crotonogyne preussii (Euphorbiaceae)
Cyathea manniana (Pteridophyta)
Diospyros conocarpa (Ebenaceae)
Diospyros crassiflora (Ebenaceae)
Diospyros hoyleana (Ebenaceae)
Diospyros kamerunensis (Ebenaceae)
Diospyros obliguifolia (Ebenaceae)
Diospyros physocalycina (Ebenaceae)
Dracaena camerooniana (Dracaenaceae)
Dracaena phrynioides (Dracaenaceae)
Drypetes leonensis (Euphorbiaceae)
Grossera macrantha (Euphorbiaceae)
Guarea cedrata (Meliaceae)
Guarea thompsonii (Meliaceae)
Heisteria parvifolia (Olacaceae)
Hexalobus crispiflorus (Annonaceae)
Hymenostegia afzelii (Caesalpiniaceae)
Mammea africana (Guttiferae)
Mapania amplivaginata (Cyperaceae)
Maranthes glabra (Chrysobalanaceae)
Palisota ambigua (Commelinaceae)
Palisota mannii (Commelinaceae)
Petersianthus africanus (Lecythidaceae)
Picralima nitida (Apocynaceae)
Podococcus barteri (Palmae)
Polyalthia suaveolens (Annonaceae)
Pycnocoma macrophylla (Euphorbiaceae)
Rinorea dentata (Violaceae)
Santiria trimera (Burseraceae)
Scorodophloeus zenkeri (Caesalpiniaceae)
Strombosia pustulata (Olacaceae)
Treculia obovoidea (Moraceae)
Turraeanthus africanus (Meliaceae)

Category 2: (Primary and/or secondary) forest species

Acacia pennata (Mimosaceae)
Alchornea floribunda (Euphorbiaceae)

Allanblackia kisonghi (Guttiferae)
Anonidium mannii (Annonaceae)
Anopyxis klaineana (Rhizophoraceae)
Anthonotha fragrans (Caesalpiniaceae)
Anthonotha macrophylla (Caesalpiniaceae)
Antrocaryon klaineanum (Anacardiaceae)
Anubias hastifolia (Araceae)
Baikiaea insignis (Caesalpiniaceae)
Barteria fistulosa (Passifloraceae)
Beilschmiedia anacardioides (Lauraceae)
Beilschmiedia obscura (Lauraceae)
Berlinia bracteosa (Caesalpiniaceae)
Blighia welwitschii (Sapindaceae)
Calamus deeratus (Palmae)
Caloncoba glauca (Flacourtiaceae)
Calpocalyx dinklagei (Mimosaceae)
Carpolobia lutea (Polygalaceae)
Cercestis ivorensis (Araceae)
Cercestis kamerunianus (Araceae)
Coelocaryon preussii (Myristicaceae)
Cola attiensis (Sterculiaceae)
Cola ficifolia (Sterculiaceae)
Cola lepidota (Sterculiaceae)
Cola marsupium (Sterculiaceae)
Cola rostrata (Sterculiaceae)
Costus afer (Costaceae)
Costus englerianus (Costaceae)
Coula edulis (Olacaceae)
Culcasia dinklagei (Araceae)
Dacryodes edulis (Burseraceae)
Desbordesia glaucescens (Irvingiaceae)
Dialium dinklagei (Caesalpiniaceae)
Dichostemma glaucescens (Euphorbiaceae)
Dioscorea burkilliana (Dioscoraceae)
Diospyros preussii (Ebenaceae)
Diospyros suaveolens (Ebenaceae)
Distemonanthus benthamianus (Caesalpiniaceae)
Dorstenia picta (Moraceae)
Drypetes preussii (Euphorbiaceae)
Duboscia macrocarpa (Tiliaceae)
Enantia chlorantha (Annonaceae)
Entandrophragma utile (Meliaceae)
Erythrophleum ivorense (Caesalpiniaceae)
Garcinia lucida (Guttiferae)
Garcinia mannii (Guttiferae)
Grewia coriacea (Tiliaceae)
Hypodaphnis zenkeri (Lauraceae)
Irvingia gabonensis (Irvingiaceae)
Irvingia robur (Irvingiaceae)
Klainedoxa gabonensis (Irvingiaceae)
Klainedoxa gabonensis var. microphylla (Irvingiaceae)
Lasianthera africana (Icacinaceae)
Lavigeria macrocarpa (Icacinaceae)

Lovoa trichilioides (Meliaceae)
Macaranga heudelotii (Euphorbiaceae)
Maesobotrya dusenii (Euphorbiaceae)
Maesobotrya staudtii (Euphorbiaceae)
Mareyopsis longifolia (Euphorbiaceae)
Massularia acuminata (Rubiaceae)
Meiocarpidium lepidotum (Annonaceae)
Mitragyna stipulosa (Rubiaceae)
Ongokea gore (Olacaceae)
Oubangia africana (Scytopetalaceae)
Ouratea flava (Ochnaceae)
Pachypondanthium staudtii (Annonaceae)
Parkia bicolor (Mimosaceae)
Penianthus longifolius (Menispermaceae)
Pentaclethra macrophylla (Mimosaceae)
Piptadeniastrum africanum (Mimosaceae)
Plagiostyles africana (Euphorbiaceae)
Pseudospondias microcarpa (Anacardiaceae)
Pterocarpus soyauxii (Papilionaceae)
Ptychopetalum petiolatum (Olacaceae)
Rhektophyllum mirabile (Araceae)
Rinorea kamerunensis (Violaceae)
Sacoglottis gabonensis (Humiriaceae)
Salacia staudtiana var. staudtiana (Celastraceae)
Scaphopetalum thonneri (Sterculiaceae)
Scyphocephalium mannii (Myristicaceae)
Strombosia grandifolia (Olacaceae)
Strychnos staudtii (Loganiaceae)
Stylochaeton zenkeri (Araceae)
Symphonia globulifera (Guttiferae)
Tabernaemontana crassa (Apocynaceae)
Tapura africana (Dichapetalaceae)
Tetraberlinia bifoliata (Caesalpiniaceae)
Trichilia welwitschii (Meliaceae)
Trichoscypha acuminata (Anacardiaceae)
Uapaca guineensis (Euphorbiaceae)
Uapaca staudtii (Euphorbiaceae)
Uapaca vanhouttei (Euphorbiaceae)
Vitex rivularis (Verbenaceae)
Xylopia aethiopica (Annonaceae)

Category 3: Species of secondary forest

Ancistrophyllum secundiflorum (Palmae)
Caloncoba welwitschii (Flacourtiaceae)
Cleistopholis glauca (Annonaceae)
Cleistopholis patens (Annonaceae)
Eribroma oblonga (Sterculiaceae)
Erythroxylum mannii (Erythroxylaceae)
Glyphaea brevis (Tiliaceae)
Homalium dolichophyllum (Flacourtiaceae)
Lophira alata (Ochnaceae)

Millettia macrophylla (Papilionaceae)
Myrianthus arboreus (Moraceae)
Nauclea diderrichii (Rubiaceae)
Palisota hirsuta (Commelinaceae)
Porterandia cladantha (Rubiaceae)
Pycnanthus angolensis (Myristicaceae)
Staudtia kamerunensis (Myristicaceae)
Sterculia subviolacea (Sterculiaceae)
Stipularia africana (Rubiaceae)
Terminalia superba (Combretaceae)
Thaumantococcus daniellii (Marantaceae)
Trichilia emetica (Meliaceae)
Trichilia heudelotii (Meliaceae)
Vernonia conferta (Compositae)
Vitex grandifolia (Verbenaceae)
Voacanga africana (Apocynaceae)

Category 4: Species of secondary vegetation

Albizia adianthifolia (Mimosaceae)
Albizia zygia (Mimosaceae)
Alstonia congensis (Apocynaceae)
Anthocleista vogelii (Loganiaceae)
Ceiba pentandra (Bombacaceae)
Discoglypremna caloneura (Euphorbiaceae)
Fagara macrophylla (Rutaceae)
Fagara tessmannii (Rutaceae)
Funtumia elastica (Apocynaceae)
Haumania danckelmaniana (Marantaceae)
Macaranga barteri (Euphorbiaceae)
Macaranga hurifolia (Euphorbiaceae)
Maesopsis eminii (Rhamnaceae)
Megaphrynium macrostachyum (Marantaceae)
Milicia excelsa (Moraceae)
Musanga cecropioides (Moraceae)
Newbouldia laevis (Bignoniaceae)
Ricinodendron heudelotii (Euphorbiaceae)
Sterculia tragacantha (Sterculiaceae)
Tetrorchidium didymostemon (Euphorbiaceae)
Trachyphrynium braunianum (Marantaceae)

Category 5: Species of secondary shrubland

Anthocleista schweinfurthii (Loganiaceae)
Aspillia africana (Compositae)
Canarium schweinfurthii (Burseraceae)
Chromolaena odorata (Compositae)
Colocasia esculenta (Araceae)
Curcuma longa (Zingiberaceae)
Dinophora spenneroides (Melastomataceae)
Dioscorea bulbifera (Dioscoraceae)
Elaeis guineensis (Palmae)

Hamilcoa zenkeri (Euphorbiaceae)
Harungana madagascariensis (Guttiferae)
Jateorhiza macrantha (Menispermaceae)
Leea guineensis (Leeaceae)
Manihot esculenta (Euphorbiaceae)
Persea americana (Lauraceae)
Phyllanthus discoideus (Euphorbiaceae)
Rauvolfia vomitoria (Apocynaceae)
Scleria barteri (Cyperaceae)
Theobroma cacao (Sterculiaceae)
Trema orientalis (Ulmaceae)