Sustainable management of African rain forest. Part II: Symposium

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'SUSTAINABLE MANAGEMENT OF AFRICAN RAIN FOREST',
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PART II: SYMPOSIUM

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In Memory of our colleague and friend Dr. Mama Nsangou,
who died in a car accident shortly before the publication of this proceedings

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PREFACE

Managing the tropical rainforest in a sustainable way is a necessity and a challenge. Improving this management is even more a challenge and needs creative researchers and experts, who act as a sounding board. The former should be working in a research programme, carried out in one or more research institutions. I refer here to the Tropenbos-Cameroon Programme which since 1993 carried out research activities related to sustainable forest management of southern Cameroon rain forests. The latter should be recruited out of the users of the research results, that is out of the surrounding ministries, research institutions, forest services, forest companies, local authorities and people living in and around forests. All these persons should meet and exchange ideas, which can stimulate both sides: research results should be presented to the professional experts, who should critically review these results and after eventual adaptation use them. Problems encountered earlier or when using the new results should be reported back by the professional experts to the researchers for improvement and new research. The process is not stopped there for researchers have again to develop and distribute new ideas.

This acoustic feedback with nearly all partners as described above was carried out during the Symposium on 'Sustainable Management of African Rain forest: Results of the Tropenbos-Cameroon Programme and their applicability', organised by the Tropenbos-Cameroon Programme (TCP) in November 1999. The results presented concern among others, the design of a Master Management Plan for the TCP area and a Forest Management Plan for a medium size forest in this area, reduced impact logging, decision facilitating tree growth models, attention for mycorrhizae in forest management, rotation fallow and the involvement of all stakeholders, with emphasis on the people living in, around and from the forests.

On behalf of the main implementing agencies, the *Institut de la Recherche Agricole pour le Développement* (IRAD) and Wageningen University (WU), which are jointly responsible for the scientific quality, I would like to thank all participants for their contribution, be it a presentation, a critical remark in the discussion or an organisational task. I wish these proceedings a good reception both in forest science and in the praxis of forest policy and forest management, as a co-basis for a sustainable future for the rain forests of Cameroon and surrounding areas.

Yaoundé, March 2001

Dr. A. Ayuk Takem
General Director of IRAD

FOREWORD

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.

In the Tropenbos Programme, the Tropenbos Foundation co-operates with a large number of research organisations based in the Netherlands and in tropical countries. At present, research sites are located in Colombia, Guyana, Indonesia and Cameroon. A new site in Ghana is being developed. At the different locations, research programmes follow an interdisciplinary and common overall approach, which allows to exchange data and to make results mutually comparable.

About the Tropenbos-Cameroon Programme

The Cameroonian Ministry of Environment and Forests (MINEF) and the Tropenbos Foundation established the Tropenbos-Cameroon Programme (TCP) in 1992. 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. TCP consists of several interrelated projects in the fields of ecology, forestry, economy, social sciences, agronomy and soil science[1]. The research is executed by as many as nine research organisations. The 'Institut de la Recherche Agricole pour le Développement' (IRAD) and Wageningen University are the main implementing agencies. Other research organisations involved in the Programme as implementing agencies are the universities of Dschang, Leiden, Ngaoundéré and Yaoundé I, Alterra Green World Research, the 'Institut de Recherches Géologiques et Minières' (IRGM) and the 'Office National de Développement des Forêts' (ONADEF).

The Programme is funded by the Tropenbos Foundation, the implementing agencies and external donor organisations. The International Tropical Timber Organisation (ITTO) and the Common Fund for Commodities (CfC) co-financed six projects which together form ITTO project PD 26/92. ONADEF is the agency responsible towards ITTO and CfC for the implementation of the Project PD 26/92. The European Commission (EC) is another major donor. It made funds available for five projects. Other donors are the Netherlands Organisation for Scientific Research (NWO/WOTRO) and USAID's Central African Research Programme for the Environment (CARPE). The Netherlands Ministry for Development Co-operation (DGIS) made two associate experts available and the Royal Netherlands Society for Agricultural Sciences (KLV) contributed two junior expert. The research was done in a logging concession of Wijma-Douala SARL (GWZ), and GWZ made logging personnel and equipment available for the experiments. The implementing agencies contributed mainly through making its personnel available to TCP.

In November 1999, the Tropenbos-Cameroon Programme organised two workshops and a symposium under the joint title 'Sustainable management of African rain forest'. The present publication deals with the symposium, and describes the main findings of the Tropenbos-Cameroon Programme until the end of 1999. The proceedings of the workshops will be published in the same series.

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[1] For further details, see Foahom, B. and Jonkers, W.B.J. (eds.), 1992. A Programme for Tropenbos research in Cameroon. Final report Tropenbos-Cameroon Programme (Phase 1). The Tropenbos Foundation, Wageningen, the Netherlands.

Acknowledgements
Hundreds of people contributed to the Tropenbos-Cameroon Programme. Special thanks are of course due to all TCP personnel and to the many students who participated in the Programme. Furthermore, we would like to thank the people living in the TCP research area, who not only allowed TCP to do the research but also supplied many of the necessary data.
The funding agencies CfC, DGIS, EC, ITTO, KLV, NWO/WOTRO and the Tropenbos Foundation are thanked for making funds available for this research project and GWZ and the implementing agencies are thanked for making personnel and/or equipment available. The Cameroonian government is acknowledged for its support.

Organising the symposium demanded extra input of TCP staff members and other personnel. Their contribution is acknowledged here.

Wageningen and Kribi, March 2001
W.B.J. Jonkers, B. Foahom and P. Schmidt
Editors

INTRODUCTION TO THE TROPENBOS-CAMEROON PROGRAMME AND ITS MASTER MANAGEMENT PLAN

W.B.J. Jonkers[1], J.P. Fines[2] and M. Tchatat[3]

SUMMARY

The Tropenbos-Cameroon Programme is a research programme, aimed at developing methods and strategies for natural forest management, directed at the sustainable production of other products and services in south Cameroon. A broad range of studies contribute to the technical, social, ecological and economic basis for Master Management Plans (MMP), land use plans at reconnaissance level and Forest Management Plans. The MMP planning procedure and the input of the various studies in this procedure are introduced.

Keywords: land use planning, forest management, research programme, Cameroon.

1. INTRODUCTION TO THE TROPENBOS-CAMEROON PROGRAMME

In 1990, the Government of Cameroon invited the Tropenbos Foundation to start a research programme to help Cameroon in introducing sustainable management for its tropical rain forests. During the discussions that followed, it was recognised that sustainable forest management requires not only knowledge of traditional forestry topics, but that it should also have a firm ecological, social and economic basis, and that there should be a balance between forestry and other forms of land use.

A multi-disciplinary team of Cameroonian and Dutch scientists was formed to identify research needs related to forest management and to formulate a research programme referred to as the Tropenbos-Cameroon Programme or TCP (Foahom and Jonkers, 1992). The general objective of this programme is to develop methods and strategies for natural forest management, directed at the sustainable production of other products and services in south Cameroon.

Initially, the programme consisted of interrelated 14 projects, provisionally clustered in five groups:

- Projects dealing with land inventory, land evaluation and agriculture;
- Ecology projects;
- Social science studies;
- Forestry research; and
- Projects dealing with economy and management issues.

Later on, other activities, such as studies on non-timber forest products and the timber market and the preparation of management plans for the research area, were added. It would have been best, if all projects would have started within two years after the launching of the programme, but due to financial constraints, only eight projects could commence in 1994 and 1995, while others started much later. This is why some projects have been completed or were almost completed by the end of 1999, while others were still in the data collection phase.

[1] Wageningen University, Silviculture and Forest Ecology Group, P.O.B. 342, Wageningen, the Netherlands.
[2] Tropenbos-Cameroon Programme. Present address Project GEF-Campo Ma'an, P.O.B. 219, Kribi, Cameroon.
[3] Tropenbos-Cameroon Programme, P.O.B. 219, Kribi, Cameroon.

The purpose of the present symposium is to give a good impression of what TCP has accomplished between 1994 and 1999. As it is not possible to discuss all results of the research in this symposium, it was decided to concentrate the papers around a central theme, and that is the relevance of the studies for forest management planning. Unfortunately, the authors of two completed TCP studies, one on lesser-known timbers (Zijp *et al*., 1999) and one on non-timber forest products (van Dijk, 1999), could not participate in the symposium. Although reference to their work is made in various papers, one should refer to their publications to appreciate the significance of their work.

2. FOREST MANAGEMENT PLANNING

Planning of rainforest management is a complex matter. Planning procedures usually involve a sequence of plans, starting with a rather general, long-term plan at the national level. Each subsequent plan covers a smaller geographical area and/or has a shorter time span, and prescribes management in more detail than the previous plan in the sequence. This implies that each subsequent plan also requires more detailed knowledge and information than the previous plan. For instance, a plan at the national level is based on the assumption that sustainable forestry methods exist or will be developed in the near future, but actual knowledge of these methods is hardly required at this level. However, in a management plan for a particular permanent production forest, such methods have to be prescribed and precise knowledge of such methods is therefore essential at this more detailed level of planning.

In Cameroon, a plan at the national level was published in 1993 (Côté, 1993). This National Zoning Plan, together with the 1994 forest law and related governmental decrees and guidelines (see Foahom *et al.*, 2001), served as starting point for the management planning methodology, which TCP is currently developing at its research site. Two plans are being prepared for this site: a so-called Master Management Plan, which covers the entire area (167,000 ha), and a Forest Management Plan for one potential permanent forest. The Master Management Plan is introduced in the following sections, while the Forest Management Plan is presented in a contribution to this volume by Foahom *et al.* (2001).

3. THE TCP MASTER MANAGEMENT PLAN

The National Zoning Plan provides a framework for land use planning in the southern, forested part of Cameroon. The forests existing in 1984 are provisionally classified as permanent forests (State forests and Council forests) or as non-permanent forests (Communal forests, Community forests and forests belonging to private individuals). This planning at the national level does not go into detail and a Master Management Plan (MMP) is needed to determine the future land use in a given area. A MMP is designed for an area of several hundred thousands of hectares on the basis of existing information, data gathered in the area, scientific knowledge and the results of a mediation process between the various stakeholders.

The planning process starts with the collection of biophysical data (van Gemerden and Hazeu, 1999; van Gemerden *et al*., 2001). Maps are prepared, showing the spatial distributions of landforms, soils, vegetation types and present land use. For each mapping unit, the biophysical land qualities are assessed. Examples of such land qualities are availability of plant nutrients in the soil, steepness of the terrain, availability of timber species and occurrence of rare species. Next, relevant land utilisation types are identified, based among others on present land use, the potential for other kinds of land use and socio-economic information. In the case of the TCP site, these land utilisation types are: 1) conservation of biodiversity (flora and fauna), 2) collection of non-timber forest products by local population, 3) production of timber in (semi) natural forest, 4) shifting cultivation, and 5) plantation agriculture (van Gemerden *et al*., 2001). Then, for each land utilisation type, the land use requirements are identified and compared to the land qualities. Maps are prepared each showing the suitability of the land for a particular kind of land use. Such maps are based mainly on biophysical requirements, and these have been generated partially through research. Many studies of the Tropenbos-Cameroon Programme provide such information (van Dijk, 1999; van Leersum *et al*., 2001; Nounamo and Yemefack, 2001; Onguene *et al*., 2001; Zijp *et al*., 1999). Other requirements considered include the distance from the nearest village or road, required size of a nature or forest reserve etc.

Next, the social, legal and economic aspects are introduced. A survey is held among the various stakeholders to assess their needs, rights and interests (Lescuyer and Essiane Mendoula, 2001). This information is to be matched with the biophysical potential of the land, so these needs should be expressed in numbers of hectares, and rights have to be specified for specific land areas. This is often difficult and research is often needed to comprehend the issues at stake. For instance, the way in which the local population attributes rights to use land for a specific purpose is complex (see Nkwi *et al.*, 2001; Tiayon *et al.*, 2001), and a survey is not sufficient to delineate such rights. Another example: a timber company will know how much timber it requires to feed its industry, but not how much forest is needed to produce this amount on a sustainable basis, as this can only be determined by using a yield prediction model like the one developed by Eba’a (2000; 2001). Moreover, the information provided by stakeholders is not always straightforward and leaves ample room for misinterpretation, and the interests of various stakeholders are often conflicting.

Therefore, a number of land use planning scenarios have to be drawn up and to be discussed with the stakeholders to arrive at the best possible solution. All scenarios are considered realistic options, based on criteria that vary from one scenario to another. Each scenario gives priority to another land utilisation type, without jeopardising the principle of sustainability and respecting the prime interests of the stakeholders. Therefore, the optimal solution may be not one of these scenarios, but a scenario that is intermediate between the ones initially presented. More detailed information on the Master Management plan is given by Lescuyer and Ngono (2001) and Tchatat (2001).

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AN INTEGRATED APPROACH TOWARDS PARTICIPATORY FOREST MANAGEMENT: A PROPOSAL FOR THE TCP SITE

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SUMMARY

Contrary to forest management that focuses on timber resources alone, the purpose of an integrated management of tropical forest deals with the multiplicity of resources and of stakeholders using these resources. This approach is compatible with the current framework of forest management in Cameroon and is applied at the Tropenbos-Cameroon site for the design of a Master Management Plan. The questions of who should be involved in this integrated forest management and how to commit these stakeholders are key points in this discussion.

Keywords: forest management, Master Management Plan, integrated management, mediation, tropical rain forest, Cameroon

1. INTRODUCTION

The Tropenbos-Cameroon Programme (TCP) is developing a methodology for sustainable management of tropical rain forest. This research deals with the multiplicity of the resources existing in the forest as well as the plurality of the users of the natural environment. Hence the requirement of an "integrated" management of this ecosystem, that aims at combining the interactions of all the users in using the forest. This objective is very often quoted in the forest policy recommendations and guidelines but its implementation on the field is still problematical. Especially the concrete management of the tropical forest tends to focus on sustained timber production, considering the other functions and services of the forest as only secondary benefits or costs. An effort should then be made to fill the gap between theoretical principles of sustainable forest management and the application in the forest.

We propose to resort to two French words to make this difference explicit. On one side, we define *aménagement forestier* as a kind of forest management considering timber production as the main objective. This approach is quite frequent in tropical countries where logging companies are involved: in spite of some efforts to include ecological and socio-economic topics in their forest management plan, the sustained exploitation of the timber resources is central. On the other side, the *gestion forestière* attempts to grasp the total set of forest resources and users in order to establish the (economic, ecological and social) sustainable management of this ecosystem. This approach is clearly defined in the Cameroonian official documents and should guide each forest experience in this country.
These two versions of what "forest management" may be are a bit too simple and may be refined. However their usefulness is mainly to clarify the underneath stakes of this discussion. The aim of an integrated management of the forest is to move from a restrictive *aménagement* to a broader *gestion* of the forest resources, the content of these two terms being more important than the terms themselves. If this change is already accepted by the people in charge of forest policy, such simple definitions may help local decision-makers and other users realise what is expected from us.
On this basis, this contribution discusses the approach adopted by the TCP. It is divided in three parts:

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[1] Tropenbos-Cameroon Programme, P.O.B. 219, Kribi, Cameroon.

- How to define an integrated management of the forest resources;
- The framework of forest management in Cameroon;
- An attempt to implement such an integrated management for the TCP site.

2. WHY AN INTEGRATED APPROACH FOR FOREST MANAGEMENT?

2.1. Understanding the term Management: *Aménagement* or *Gestion*?

In the workshop "Planning and Analysis for Forest Management with special emphasis on lesser-known species", the meaning of forest management and the potential translations in French of the term "management" was discussed extensively (see Foahom *et al.*, 2001). Two translations have been proposed and discussed: *aménagement* and *gestion* that seem to be used in different contexts or applied to different perceptions of what a tropical forest is. The emphasis is not on the precise meaning of the two words in French but rather on the context and the underlying objectives of "forest management". Two kinds of approach may then be distinguished:

<u>Forest Management as "*aménagement forestier*"</u>, that relies on certain assumptions:

- Timber as the main resource of the forest: this is the main tradable resource of the forest and is likely to provide the State and private economic actors with substantial financial benefits.
- Public authorities and logging companies are the main stakeholders in forest management (with marginal consultations of local populations): the State is the owner of the forestlands that are conceded for a period of time to logging companies. The companies are required to submit a Forest Management Plan for the exploited area.
- Based on Faustmann's rule and bio-economics, the principal objectives are to reach a sustained yield for timber production and to establish an optimal rotation of the cutting. Other benefits (Non-Timber Forest Products, biodiversity, etc.) may be included in the forest management model in order to improve the accuracy of the optimal rotation taking into account this secondary benefits (ITTO, 1990). For instance, Eba'a Atyi (2000) shows that the integration of other benefits of the forest tends to lengthen the cutting cycle.
- These objectives are fulfilled by respecting a certain number of technical criteria and guidelines (MINEF, 1998a). The implementation of this model is mainly hindered by the lack of scientific data on ecological dynamics.
- This forest management is sustainable if the timber stock can renew itself during the rotational period and would remain more or less the same for each cutting. Sustainability goes together with permanence of the timber resource over the long term.

Regarding this first translation of forest management in "*aménagement forestier*", it may be said that such an approach is restricted to what Cameroon law designs as production forest, i.e. the ones designated for timber exploitation. But other legal statuses for permanent forest exist in Cameroon (protection forest, recreation forest, etc.), which should also be managed sustainably. Thus, from a theoretical and legal point of view, forest management in Cameroon is not restricted to *aménagement* only. In practice, however, the perception of forest as a stock of timber resources to be logged is still prevailing. Let us refer again to the above-mentioned workshop to illustrate that for most participants there is a systematic connection of the term "forest management" to the context of production forest and timber exploitation[2]. Two observations may support this viewpoint.

First, during this workshop, nobody talked of forest management for protection forest, ecological reserve or research forest. These permanent forests should also be managed according to a forest management plan but this constraint is not yet tackled by specialised

[2] A slight emphasis on the timber resources is even expressed in the general objective of the TCP, which is "*to develop methods and strategies for natural forest management directed at sustainable production of timber and other products and services*".

authorities which have so far only published two guidelines reports for production forest (MINEF, 1998b; ONADEF, 1998). Most discussions were held in French and all people used the term *aménagement*.
Second, this workshop was supposed to put emphasis on "*lesser known species*". As K.F. Wiersum noticed, why have those lesser-known species been reduced to "lesser-known timber species"? Actually, this assumption was taken for granted although many other forest non-timber species or services might have been included. Apparently, for most people attending the workshops/symposium, forest management was associated with timber management and assimilated to *aménagement forestier*.

Obviously, this workshop was only one particular occasion to discuss forest management in Cameroon, and one can imagine that other concerns would have come to light if WWF or IUCN had been the organiser of such a meeting. However, the viewpoints expressed there are quite widespread at least among forest engineers, who play an active role in the existing logging companies and national forest authorities. An alternative approach for forest management may be proposed, perhaps more convenient for sustainable use of tropical forest resources: *gestion de la forêt* may then be preferred to *aménagement forestier*.

Forest management as "*gestion forestière*", that starts from a different conceptual basis:
The forest is a diverse ecosystem, full of different resources that directly or indirectly benefit to human population (Panayotou and Ashton, 1992). The multiplicity of the forest resources is an essential variable for its management and is recognised in the Cameroon Forest Law n° 94/01.
Multiple stakeholders, whose interests and expectations are different, use this ecosystem. Their uses of the resources may be combined or compete with each other. The plurality of the users of the forest resources is another crucial element for sustainable management.
Table 1 gives a short illustration of the multiple uses and users that may support a tropical forest ecosystem. It does not define precisely the roles of all forest stakeholders in Cameroon but it constitutes rather an example of their main concerns. Contrary to the *aménagement forestier* that focuses on one specific use with only a couple of stakeholders, the *gestion forestière* displays a much broader view of what should be included and who should be involved in the forest management process.

Table 1: Multiplicity of uses and users in a tropical forest

	Products				**Services**		
Stakeholders	**Timber**	**NTFP**	**Wildlife**	**Genetic resources**	**Water regulation**	**Erosion control**	**Climate regulation**
Local population		X	X		X	X	
MINEF	X		X		X		X
ONADEF	X						
Logging companies	X						
Nature Protection NGO		X	X				
International community		X	X	X			X
Research project	X	X	X		X	X	

As a result it can be stated that:

- The use of the resources depends on ecological, technical and human characteristics (Lescuyer and Essiane Mendoula, 2001; MINEF, 1998b). Forest management appears to be at the intersection of natural and social dynamics.
- Sustainability is not restricted to ecological concerns. Economic profitability and social acceptance should be considered too.
- These assumptions conduct to a new definition of forest management as the organisation of stakeholders' interactions in using and conserving the resources.

It is in this framework, with such assumptions, that an integrated approach of forest management is relevant. The objective becomes to define the most satisfying combination of forest resource uses.

2.2. Three questions for an integrated management of forest resources

To deal with the multiplicity and complexity of forest resources requires a clear approach. Much literature is already available on management systems of natural resources (de Montgolfier and Natali, 1987; Ostrom, 1990; Hannah *et al*., 1996), from which several basic questions may be drawn[3]:

- Which Forest Management Unit? What is to be managed? This preliminary question aims at identifying the geographical boundaries of the forest to be managed and the social boundaries i.e. the concerned stakeholders and their uses of the forest resources.
- Which organisation/institution would be in charge of the forest management? Who will manage the new Forest Management Unit? This task may be granted to an existing organisation that is able to take into consideration other stakeholders' interests. It may also give the opportunity to create institutions of common use of the forest resources. Examples of such small-scale institutions are available in Cameroon with the *comité villageois-forêt* (village forest committee) and the *Groupement d'Intérêt Communautaire* (Community Interest Group), etc.
- Which co-ordination of the forest resources' uses? How will it be managed? In our opinion, only the concerned stakeholders, who should be involved in a discussion/negotiation process where their viewpoints are presented and confronted, can give this answer. The aim of this mediation is the working out a kind of forest management contract where all rights and obligations are clearly expressed.

The answers to these three fundamental questions depend on the level of analysis of forest management (Filius, 1998). In Cameroon, three levels of analysis for forest management are proposed: macro-level with the official Zoning Plan, meso-level with the Master Management Plan (MMP) and micro-level with the Forest Management Plan (FMP). TCP has so far mainly worked on the meso-planning of forest management by designing a MMP proposal. This framework has provided the opportunity to think about a proposal for an integrated management of the forest resources.

3. A PROPOSAL FOR A FOREST MANAGEMENT PROCESS AT THE TCP SITE

3.1. Rationale of forest management in Cameroon

New forest and environment laws were published in 1994 and 1996 respectively and aim at achieving an efficient and sustainable management of the forest resources. The Cameroon Forest Law of 1994 defines several main steps for forest management. These steps represent the three different planning scales mentioned earlier:

1. An official zoning map of forest was first drawn in 1993 for the southern part of the forest area;
2. This macro-planning is supposed to be followed by more detailed Master Management Plans (MMP) at the sub-regional level;
3. And finally, the MMP is the basis of several Forest Management Plans, which define the authorised uses in the permanent forests.

The Zoning Plan has been completed by MINEF (1993) for the southern part of the country. This zoning map results from a macro-planning procedure with four purposes:

[3] This proposal is similar to the ones formulated by Wiersum (2001). For further details, the reader is invited to refer to his article.

1. To identify the forest areas in Cameroon and to roughly assess the quantity/quality of forest resources;
2. To propose priority land use for each forest area;
3. To indicate prospective boundaries to these specialised forest lands;
4. To make sure that at least 30% of the national territory of Cameroon will remain forest areas in the long run.

This official macro zoning is just a first step towards sustainable management of forest. Its outcomes are only indicative and must be refined at a more detailed level.

The second phase in the management process of Cameroonian forest is the MMP (ONADEF, 1998). On the basis of what has been proposed by the official Zoning Plan, the MMP purposes are:

1. To design priority allocation of forest lands;
2. To propose a meso-zoning of forest lands;
3. To proceed a classification of permanent forests.

The concept of FMP has a major place in the 1994 forest law. The stake is a decentralised and conditions-specific management of forest resources by the stakeholders involved. The aim of FMP design is to recognise and integrate the pluralism of viewpoints about managing forest resources in order to conceive an integrated, effective and sustainable FMP. This includes designing concrete modes of using the forest in association with the priority use elicited by the MMP and defining a micro zoning of forestlands.

3.2. Design of a Master Management Plan for the TCP site

Efforts have been made to design a MMP for the TCP area. Which data should be required to achieve this purpose? Four main sources of inspiration/information were used:

- The Cameroonian laws regarding nature management propose three main global objectives: conservation of nature (law 96/12, art 62), sustained timber production (law 94/01, art 23), development of village communities (law 94/01, art 68 and 71).
- The Zoning Plan: the TCP research area is entirely included in the Zoning Plan and the following specialisations were defined within it: on one side, permanent forest estate (to be classified): production forest (12 435 ha, 7.4% of the area), protection forests (37 650 ha, 22.5%), council forests (16 943 ha; 10.1%); on the other side, non permanent forest estate: human occupancy (habitation, shifting cultivation, industrial cultivation, agro-forestry, community forests, non-permanent forests, etc.), which constitutes 60% of the TCP research (100 325 ha).
- Biophysical data (landform, vegetation, land use, etc.) were available from the TCP landscape ecological survey (van Gemerden and Hazeu, 1999).
- Socio-economic data were gathered or updated (Lescuyer *et al*., 1999).

On the basis of these data and prescriptions, four basic scenarios were identified for the TCP Master Plan (Fines *et al*., in press):

1. The agro-forestry scenario puts emphasis on the "agro-forestry" zone in which shifting cultivation, plantations and community forests can expand. The width of the agro-forestry strip may extend to 5 km along all roads. This scenario also includes a production forest in the middle of the zone as well as a protection forest in the eastern part. The protection forest foreseen in the Zoning Plan and in the landscape ecological map remains and critical erosion areas are protected against intensive exploitation.
2. In the timber production scenario, the emphasis is on forests dedicated to timber exploitation. Three areas of production forest are located in the centre of the site along a

southeast – northwest transverse. The minimum cultivable area, the protected areas, the research zones are kept as such.
3. The nature conservation scenario puts an emphasis on conservation of the natural habitat. The minimum cultivable area is respected; one production forest remains whereas most of the TCP zone is protected against intensive exploitation.
4. Business as usual scenario: this scenario considers the evolution of the TCP area without forest management. It is presented as a reference base when the other scenarios will be analysed and compared to the actual situation.

Here ends the first step of designing a MMP for the TCP area. However, the question of the choice of the best scenario among the four or, better, of the emergence of an intermediate new scenario that would represent a kind of compromise between the initial MMP proposals, remains. This choice is to be made by the stakeholders, with the help of two decision-making tools:

1. Geographic Information System (GIS), that allows a quick and easy understanding of what the MMP scenarios really are;
2. Environmental Impact Assessment (EIA), that provides decision-making with a means to compare on a scientific basis the impacts of each MMP alternative (Smith, 1993; Glasson *et al*., 1994).

However, GIS and EIA are not to design the optimal forest management but must be considered as tools in a participatory approach where stakeholders base their judgement on cartographic and environmental impacts simulations.

4. INTEGRATED MANAGEMENT THROUGH NEGOTIATION AMONG STAKEHOLDERS

4.1. Which mediation process?

Local stakeholders' participation is a very fashionable topic in literature on natural resources management and conservation (Nguinguiri, 1999; FAO, 1989). In Cameroon, the management of forest resources requires the participation or, at least, the consultation of concerned stakeholders (law 96/12, art. 9). Beyond the legal obligation, stakeholders' involvement in decision-making is also an empirical necessity (Vellema and Maas, 1999). From a practical point of view, forest management cannot be defined without integrating perceptions and interests of local stakeholders, who are the *de facto* users of the resources.

People’s participation may take on a variety of forms but they commonly share the objective of mobilising populations around the implementation of a project which objectives have already been defined by political or economic decision-makers. Such a process can easily occur while elaborating an MMP: for instance, "participatory management" may suggest that the MMP is worked out by "experts" with the support of authorities and, once achieved, it is finally submitted to villagers for acceptance or marginal change of the classified forest’s boundaries. Another participatory approach may be conceived, which could be implemented or tried out in the TCP area. Its main steps are presented in Figure 1.

Most of the time, it is suggested that the MMP resulting from experts' surveys should be directly applied. In our view, however, the task of planning specialists is to clarify the conceivable options with a view to initiate and support stakeholders’ negotiation concerning the actual definition of a sustainable management of forest resources. The interest of this MMP designing process is not just to adapt it to local conditions but to make stakeholders define and appropriate an effective and actual set of sustainable forest management actions. This is done through an iterative and multi-level negotiation procedure which aim is to build, step by step, a compromise that satisfactorily fulfils the aspirations of each stakeholder.

This participatory approach breaks up with conventional top-down processes since forest management possibilities are now discussed and worked out by local stakeholders. However, this is not a typical bottom-up approach either: the first drafts of the MMP, to be submitted to stakeholders' negotiation, are conceived according to the forest policy prescriptions. Thus, this kind of co-management of forest seems to be a balanced approach which integrates national considerations about forest strategy while taking into account the local (professional and village) interests and opportunities of managing forest resources (Wiersum, 1998).

Conventional top-down approach	**Proposed TCP approach**
Official Zoning Map (Côté, 1993) Ecological & Socio-economic Data	Official Zoning Map (Côté, 1993) Ecological & Socio-economic Data
↓	↓
Simulation and "Experts" Analysis Acceptance by Public Authority	Working out of potential scenarios By "experts"
↓	↓
One Master management plan proposal, defining allocation of Land Use utilisation	Negotiations of the scenarios by concerned stakeholders (with the help of SEA techniques)
↓	↓
Local populations participation for marginal adaptations to the Master management plan	Collective choice of the definitive Master management plan
↓	
Definitive Master management plan	

Figure 1. Two alternative decision-making processes to the realisation of a Master Management Plan

4.2. Application at the TCP site: identification of the stakeholders

The first question to be answered when considering the stakeholders' negotiation is 'who should be involved?' According to Borrini-Feyerabend (1997), stakeholders generally share three characteristics:

1. They are aware of their interests in a sustainable use of the natural resources;
2. They have specific abilities (technical, cultural, scientific, etc.) to manage these resources;
3. They are willing to invest time and effort for this purpose.

According to these three criteria, seven groups of stakeholders were then identified in the TCP area:

- The local Bantu population: because of the large number of villages and inhabitants in the TCP area, the participation of Bantu population can be ensured through the appointment in every village of representatives who shall express the population claims during meetings with other stakeholders. The issue of empowering local actors is complex (von Benda-Beckmann *et al.*, 1997). This difficulty may be partly overcome when the first discussions about potential forest management are with the whole population of the village. Providing this preliminary information may help villagers to assign the most appropriate people to represent their interests in further and higher-level negotiation. It is advisable that these village representatives both embody the "official" and "traditional" authorities in order to acknowledge these two decision-making mechanisms in use at the village level.

- The Bagyeli groups: due to historical predominance of Bantu people over the Bagyeli pygmies, it seems important to separate voices of the semi-nomad groups from the ones of Bantu. However, identifying representatives for the Bagyeli is a major constraint, as social hierarchy is almost non-existent in this ethnic group. To express the viewpoint of those groups, Biesbrouck (1997) suggests, among others, to call for the co-operation of specialised associations which "*could serve as a channel*" to motivate Bagyeli participation. It is likely that these associations would provide Bagyeli with more convenient means to express their concerns on forest management. Associations of this kind are present in the TCP area (CODEBABIK, *Petites sœurs de Jésus* and others).
- Decentralised authorities, which include among others division and sub-division officers, mayors, *chefs de groupement* (one level above the *chef de village,* chief of the village). Their place in the negotiation is crucial as they represent an intermediate level which function is both to organise the application of the national policy at the local level and to integrate villagers' claims in this application.
- Specialised authorities (Forest Directorate of MINEF, MINAGRI, ONADEF) are in charge of the forest policy and express the national interest. Division delegates and local agents who are the actual and direct interface between local-level management and external policies locally represent these public services. As such, these local agents should be included in the negotiation on forest management and should be trained on new forestry topics like multiple-use management, agro-forestry, technical support to communities, etc. (Wiersum and Lekanne dit Deprez, 1995).
- Private economic actors (logging companies and others), who aim at a profitable exploitation of the resources and contribute to the economic development of isolated villages through many secondary benefits such as road maintenance, employment and trade (Brown and Ekoko, 1999). They also provide communities with substantial amounts of money.
- National and international NGOs related to nature conservation or rural development. The participation of NGOs in the MMP discussion is legitimate since they are rather good representatives of international community's concerns about the ecosystems and people of Central Africa. It may also be useful to involve the neighbouring forest management projects that have accumulated an interesting experience in dealing with local population. Moreover their project area is close to TCP one and joint interventions might be considered.
- Tropenbos-Cameroon Programme. As a research programme, it may have a voice in the negotiation, not only as a mediator but also as an actual stakeholder with concerns and interest of its own (e.g. the preservation of research plots).

4.3. Application in the TCP site: negotiation process

The negotiation on the MMP may be schemed in four steps, from local to sub-regional level.

1. Presentation of the MMP draft maps to the divisional and sub-divisional officers of the relevant administrative divisions. This first step is a necessary requirement to get an explicit official authorisation to carry out the MMP surveys in these administrative divisions. A complete presentation of the MMP design process, the predicted schedule, the people involved, the methodology, the outcomes,… should be given so that the divisional and sub-divisional officers are able to follow all steps of the negotiation approach. The representatives of MINEF and MINAGRI should also be invited.
   Mediation tools: MMP draft maps and explanatory report
2. Introduction of the first drafts of the MMP to each separate group of stakeholders (local populations, commercial enterprises, public authorities,…) to familiarise them with the MMP scenarios and to generate comments and improvements. This should be considered as a step of preparation for the following multi-stakeholders negotiation. It seems particularly important to clarify the approach in each village, to precise the objectives of the survey, and to incite villagers to consider the MMP as a real opportunity to assert their claims on the forest resources. These public meetings would provide the opportunity to show large-size

MMP maps, which are supposed to be the main factor for stimulating discussion among villagers. To deepen the debate, a set of maps (A3 size) should be left to each stakeholders' group so that they have time to reach a common position about their acceptance, claims and recommendations.
Mediation tools: MMP draft maps and explanatory report

3. A meeting at the sub-division (*arrondissement*) level, which aims at broadening the negotiation to new stakeholders and to a larger forest surface. Whereas the first village discussion was conducted within relatively homogeneous groups, the district level mediation makes different stakeholders meet and confront their viewpoints on strategic forest management. The result should be the expression of a common agreement, or at least common concerns, on the most satisfying alternative. Neutral mediators are needed to conduct this negotiation. Their role is to supervise the debate, to equally share the speaking time and make sure that all the viewpoints have been presented and discussed before reaching an agreement.
Mediation tools: amended MMP draft maps, impact matrix
4. An overall meeting should gather all the stakeholders to discuss the feasibility of the MMP scenarios that have been improved to integrate the outcomes of sub-division level mediations. The objective is to establish, with the help of EIA and GIS techniques, a final proposal for the MMP that is accepted by all stakeholders. This document is to be made official by regional authorities and send to the MINEF for ratification. One of the mediators would guide the negotiations.
Mediation tools: amended MMP draft maps, impact matrix

A recapitulative diagram is given in Figure 2, displaying the main steps of the mediation process for the TCP Master Plan.

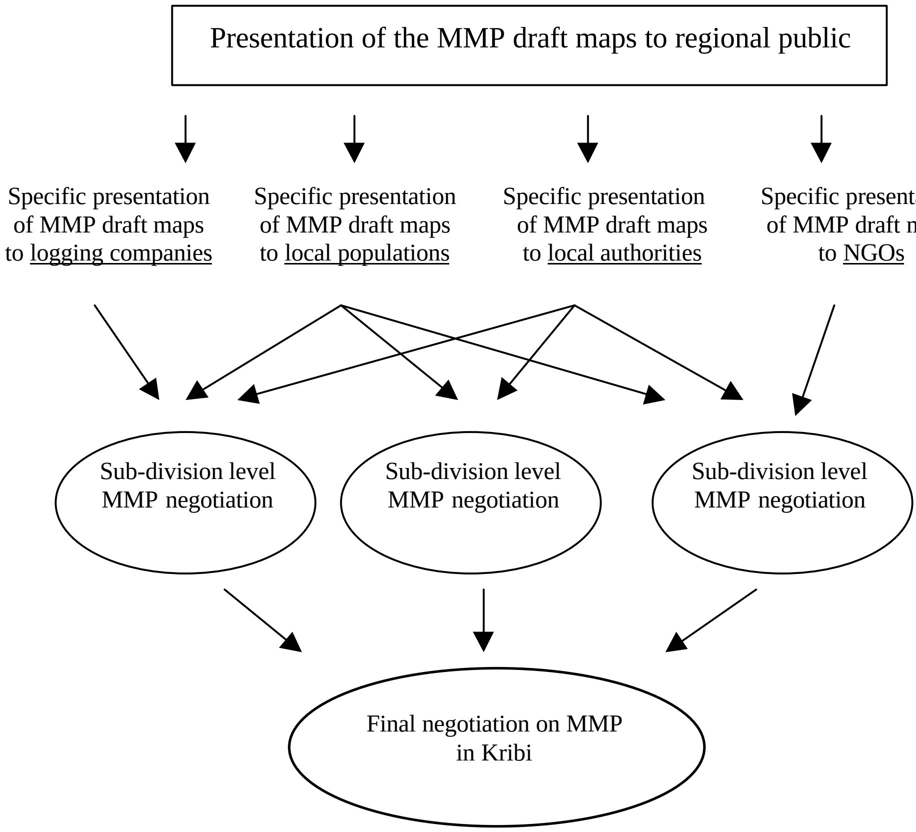

Figure 2. Recapitulative diagram of the mediation process

This negotiation procedure is still in its infancy. Many aspects are still to be changed and refined. But despite the heterogeneous status of the stakeholders (different levels of action, different means of persuasion, etc.), two particular aspects might favour debate and help local actors reach a consensus on the management of the forest resources. First, the MMP has a long-term objective: rather than discussing endlessly on the present and past responsibilities in environmental degradation, stakeholders have to agree on a common vision of the future. The preliminary agreement on the state of the forest in 25 years may allow stakeholders to go beyond their current contentions and to involve themselves in a sustainable way to use the resources (Weber, 1996). Second, this MMP negotiation is supported by two management tools, the GIS and the EIA, that facilitate the participation of the various stakeholders by showing the social and environmental consequences of their choices.

Moreover, this mediation methodology is to be tested first in a small area of the TCP site to appreciate its feasibility and applicability. The final stake is to conceive a participatory approach that may be included in the design of the MMP itself.

5. CONCLUSION

The MMP constituted a stimulating framework to think about a way to conceive and implement an integrated management of the forest. It concerns numerous stakeholders involved in different uses of the forest. Moreover, beyond the proposal of the Zoning Plan, the possibilities of managing the forest are several, as this natural environment is able to support timber production, agro-forestry, biodiversity conservation, etc. Therefore, the choice of a sustainable management of this forest cannot be found out only on the basis of scientific data and should result of a political/social decision-making process. Actually, if the scientific data may help and clarify the choice of how to manage the forest over the long run, the combination and integration of the divergent forest uses is to be done directly by the stakeholders, who have been provided with convenient information.

Such an integrated management of the tropical forest may not be easy. It costs time and money. But, as a viable management of the forest is to be scheduled for several decades, it is essential that this planning is socially supported: how can we imagine that future generations behave according to a forest management plan that was not even accepted by their fathers? Difference is finally not considerable between sustainable management and integrated management of the forest.

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LANDSCAPE SURVEY, LAND EVALUATION AND LAND USE PLANNING IN SOUTH CAMEROON[1]

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SUMMARY

A landscape ecological survey at reconnaissance scale (1 : 100 000) was conducted in the Bipindi – Akom II – Lolodorf region in south Cameroon. Joint descriptions of landforms, soil and vegetation were made along transects laid down in ecologically homogenous aerial photo interpretation units. Seven landforms, four soil types and seven vegetation types were discerned and integrated in one landscape ecological map. Subsequently a land evaluation was carried out on the basis of the survey data. Five major land utilisation types have been studied of which conservation of biodiversity, timber production in natural stands and shifting cultivation are treated in this paper. 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: landscape ecology, land evaluation, land use planning, rain forest, Cameroon.

1. INTRODUCTION

Land use planning is needed when land is becoming scarce and conflicts may arise between different land user groups. In south Cameroon, as in many other tropical forest areas, land is becoming exceedingly scarce and the various types of land use seem hard to reconcile.

Land use planning is the systematic assessment of the potential of land and water and selects the land uses that will best meet the needs of the actors involved while safeguarding the resources for future use (FAO, 1993). The whole land use planning process is long and complex and involves land users and policy makers. It involves the integration of information about the suitability of land and the knowledge of different technologies. Demographic, social and economic aspects are 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, are taken into account.

The aim of land evaluation is to provide a scientific basis for questions related to land use planning.

It predicts land performance, both in terms of expected benefits from and constraints to productive land use, as well as the environmental degradation due to these uses (Rossiter, 1996). Basically the land evaluation should provide an answer to three questions (FAO, 1976):

- Which types of land use are relevant in a given area?

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[1] This contribution will also be published in Foahom *et al.* (2001).

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- What requirements should be met for the successful implementation of these land uses?
- Where can these requirements be fulfilled?

To address these questions land characteristics need to be described, mapped, and interpreted in terms of suitability for the relevant land utilisation types. A landscape survey, resulting in a map, provides the starting point for this procedure.

2. RESEARCH SITE

The Forest Land Inventory and Land Evaluation project (Lu1) of the Tropenbos-Cameroon Programme (TCP) conducted a landscape survey and subsequently a land evaluation of the Bipindi – Akom II – Lolodorf area in south Cameroon (van Gemerden and Hazeu, 1999).

The research area covers 167 000 ha and is situated in south Cameroon at approximately 80 km East of Kribi (2°47’ - 3°14’ N, 10°24’ - 10°51’ E). The climate is humid tropical with two distinct wet seasons (August - November, March - May) and two drier seasons, related to the movement of the intertropical convergence zone over the area. Average annual rainfall shows a decreasing trend in an easterly direction with values ranging from 2836 mm y^{-1} in Kribi to 2096 mm y^{-1} in Lolodorf and 1719 mm y^{-1} in Ebolowa (Olivry, 1986). Figure 1 shows the rainfall distribution in the area. The rainfall seems to be influenced by the topography. Relatively low rainfall totals were observed in the lowland and highland zones, whereas higher values were observed in the central zone where orographic rainfall seems to be significant (e.g. along the Akom II – Lolodorf axis). Evaporation totals obtained from three catchment studies with different land use (e.g. virgin forest, selectively logged forest and shifting cultivation, Waterloo *et al*., 2000), seem to vary within a rather narrow range (1200-1300 mm y^{-1}) in spite of the differences in land use. This suggests that the intensity of the present land use conversions (generally less than 30% of the rainforest area is affected) does not result in a significant change in basin evaporation. Spatial streamflow patterns therefore reflect the variation in rainfall, rather than the type of land use, with the highest runoff generated in the area along the Akom II – Lolodorf axis (800-1000 mm y^{-1} versus less than 600 mm in the western lowland and eastern highland plateau areas).

Air temperature shows little variation over the year (25.0-27.5 °C in Kribi) and relative humidity remains high throughout the year with minimum values of 70% in Kribi and 62% in Ebolowa. Wind speeds are generally low (< 4 m s^{-1}) and the wind direction is predominantly Southwest to West (Olivry, 1986). The natural vegetation is tropical moist evergreen forests of the Guineo-Congolian domain (Letouzey, 1985). In many places shifting cultivation and logging have caused forest degradation.

A total of 14 370 persons were included in the 1999 census of the area (Lescuyer *et al.*, 1999). Average population density in the area is low, i.e. 8.6 persons per km^2. Population growth is estimated to be marginal (+0.4%). Bantus belonging to the Bulu, Fang, Bassa and Ngumba tribes, form the majority (> 95%). They live in villages along the main access roads and practice shifting cultivation. In addition the collection of non-timber forest products (NTFPs) is important. Bakola (or Bagyeli) pygmies form a minority (2-4%). These forest dwelling hunters and gatherers are still rather mobile, despite processes of sedentarisation (Biesbrouck, 1999a). They practise some shifting cultivation, although the scale is limited if 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).

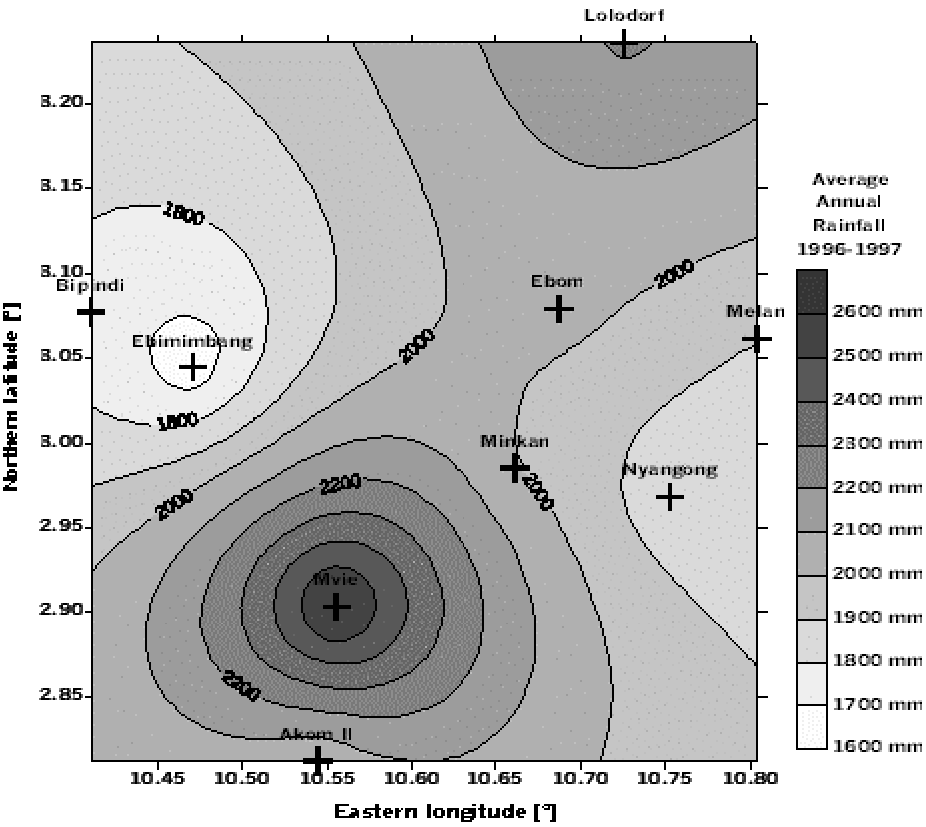

Figure 1. Average annual rainfall (in mm) in the TCP area, compiled from rainfall data collected at 11 stations in the area over the period 27 November 1995 – 26 November 1997 (Waterloo *et al.*, 2000).

The main economic activity in the area is timber exploitation. Most of the area has been logged, and some parts at least twice. The logging involves the use of heavy machinery for road construction and log extraction. Present logging activities focus on Azobé (*Lophira alata*, 60% of the extracted volume), Tali (*Erythrophleum ivorense*) and Padouk (*Pterocarpus soyauxii*). The logging intensity is low, i.e. 10 m^3 ha^{-1} or 0.7 tree ha^{-1}. The felling and extraction of the logs are estimated to physically affect less than 15% of the forest surface, however, locally much higher disturbance rates have been observed.

3. LANDSCAPE SURVEY

Tropenbos has developed a common methodology for land inventory and land evaluation to contribute to systematic and interdisciplinary research and subsequent sound land use planning (Touber *et al.*, 1989). The methodology follows an approach in which the landscape is seen as a fully integrated entity that can and should be studied as a whole (e.g. Breimer *et al.*, 1986; Hommel, 1987; Küchler and Zonneveld, 1988; Zonneveld, 1995).

Based on the size of the area and the need for detail in the land evaluation, a landscape ecological survey at scale 1 : 100 000 (reconnaissance scale) was carried out. Black and white aerial photographs (scale 1 : 20 000) of 1983-‘85 were used to discern tracts of land that are ecologically relatively homogenous. Preliminary maps on landforms and vegetation were drafted and provided the basis for stratified sampling in the field (Touber, 1993). Ecological relevant data on soil, vegetation, geomorphology and land use, as well as geological, hydrological, faunal and other appropriate land attribute information were collected in selected sample sites. In addition, the relevance of the boundaries of the photo interpretation units was determined. Transects of one to two kilometres and perpendicular to the contour lines were laid down in the most important and widespread land units. Along the transects observations were made on topography and landforms. Three to seven observation points were selected for detailed soil and vegetation sampling. The localities were selected as being representative (with respect to the land unit concerned) and homogenous (with respect to vegetation structure) and are located at different topographical positions to detect possible repetitive sequences (‘catenas’).

The described land and soil related attributes include altitude, slope characteristics, stone and rock coverage, erosion and stability characteristics, drainage characteristics, ground water level, biological activity, and humus form. Soil descriptions are done on the basis of augerings (1.2 to 2.0 m deep). Soil pits were dug at representative sites for more detailed soil analyses. Soil characteristics are described per horizon and include colour, mottling, texture structure, consistency cutans, rooting characteristics, and pores. Chemical soil properties determined are organic carbon, total nitrogen, available and total phosphorous, pH-H_2O and pH-KCL, exchangeable bases, aluminium and hydrogen, and cation exchange capacity (CEC). Physical parameters determined are texture, water retention characteristics (pF) and bulk density. Additionally, the clay mineralogy of a small set of samples was analysed. Some 250 soil augerings and 45 soil pits have been described (van Gemerden and Hazeu, 1999).

The vegetation is described on the basis of its structure and floristic composition, in the sense of the French-Swiss school (phyto-sociological approach, Braun-Blanquet, 1964). In each locality, as much as possible jointly with the soil survey, a vegetation relevé was made. All growth forms, except mosses, ferns, epiphytes and seedlings (due to difficulties in identification), are recorded in a plot of 100 m^2. In addition, all trees with diameter at breast height (dbh) ≥ 20 cm were recorded in the surrounding 1000 to 2500 m^2. Though not approaching the minimal area of tropical rain forest communities, this plot size is sufficiently large for classification purposes if all terrestrial growth forms of flowering plants and all size classes are included (Hommel, 1987; de Rouw, 1991). Plant identification was done in the field with the help of a field botanist and a local tree spotter. Plant material has been collected of unknown species and for verification purposes. A total of 175 vegetation relevés have been described.

Based on the variation observed within the area, preliminary classifications were drafted for landforms, soils and vegetation. To describe the landscape as a complex of these attributes, the relations between landforms, soils and vegetation types were studied by means of cross-tables. The aim of this exercise was to trace the parameters of the a-biotic environment, which may best explain the variation in vegetation types. Based on these analyses, the landforms, soils and vegetation classifications were slightly modified to attain an optimal ‘ecological’ fit. Equally important is that the classifications reflect attributes that are important in light of the land evaluation.

3.1. Shifting cultivation and logging

Shifting cultivation and logging are the most obvious types of land use. Through photo interpretation the areas where shifting cultivation takes place could be mapped. The aerial photographs, on which the landscape ecological map is based, were taken in 1983-85. Recent changes in vegetation cover can therefore not be accounted for. Field observations suggest, however, that although the shifting cultivation area has not changed drastically in size, the intensity of land use has increased. Based on the aerial photographs a subdivision is made into ‘areas relatively undisturbed by shifting cultivation (115 000 ha)’, ‘low intensity shifting cultivation area (30 000 ha)’ and ‘high intensity shifting cultivation area (20 000 ha)’. The relatively undisturbed areas are characterised by the (near complete) absence of agricultural fields. Within the low intensity shifting cultivation areas actual and recently abandoned agricultural fields cover less than

20% of the unit. Young secondary forest accounts for another 20%. In the high intensity shifting cultivation areas actual and recently abandoned field cover more than 40%. Additionally, more than 20% of the unit is young secondary forest.

Large-scale logging in the area started in 1985, just after most of the aerial photographs were taken. Unlike shifting cultivation activities, which are strongly concentrated in specific areas, the impact of logging on forest vegetation could not be mapped accurately. This will only be possible once more recent and highly detailed remote sensing material becomes available. Vegetation analysis (on reconnaissance scale) reveals that with time the differences between extensively logged-over forest and 'virgin' forest stands become quite subtle. In the present survey seven broadly defined plant communities are discerned. Each of the five types of relatively undisturbed forest in fact comprises both virgin stands and various regeneration stages of old secondary forest.

3.2. Landscape ecological map

The landscape ecological map has 34 mapping units and the outline of the legend is given in Table 1. The ecological zones and landforms are presented in Figure 2.

The overall orientation of the ecological zones is NNE-SSW and follows the general orientation of the geological structures in south Cameroon. The landscape of the TCP area changes considerably from west to east. Altitudes rise from approximately 40 to over 1000 m asl (above sea level). Dissected erosional plains, hilly and rolling uplands dominate the western part of the area whereas complexes of hills and mountains are found solely in the east. Going from west to east the soils change from Ebimimbang to Ebom and Nyangong thereby increasing in clay content. Valley bottoms are found throughout the area. The natural vegetation changes from low altitude evergreen forest with many littoral species to a submontane vegetation with characteristics of cloud forest. Human activities influenced this (climate) gradient by logging and shifting cultivation. Along the main access roads and in the vicinity of villages mosaics are found of actual fields, thickets on recently abandoned fields, young secondary forests and residual patches of full-grown tropical moist forest.

3.3. Landscape ecology

Five ecological zones are identified. The first subdivision is based on altitude (climate), the second on landform and soil characteristics, and the third on the (complex of) vegetation types and the degree of disturbance (van Gemerden and Hazeu, 1999). Overviews of the landforms, soils and vegetation types are presented in Tables 2 - 4.

The overall orientation of the ecological zones is NNE-SSW and follows the general orientation of the geological structures in south Cameroon. The landscape of the TCP area changes considerably from west to east. Altitudes rise from approximately 40 to over 1000 m asl (above sea level). Dissected erosional plains, hilly and rolling uplands dominate the western part of the area whereas complexes of hills and mountains are found solely in the east. Going from west to east the soils change from Ebimimbang to Ebom and Nyangong thereby increasing in clay content. Valley bottoms are found throughout the area. The natural vegetation changes from low altitude evergreen forest with many littoral species to a submontane vegetation with characteristics of cloud forest. Human activities influenced this (climate) gradient by logging and shifting cultivation. Along the main access roads and in the vicinity of villages mosaics are found of actual fields, thickets on recently abandoned fields, young secondary forests and residual patches of full-grown tropical moist forest.

Table 1. Legend landscape ecological map of the Bipindi – Akom II – Lolodorf region, south Cameroon and overall suitability for land utilisation types: conservation of botanical diversity; timber production in (semi-) natural stands and shifting cultivation (van Gemerden and Hazeu, 1999; Hazeu *et al.*, 2000).

Mapping unit	sc[1]	Soil [2,4]	Vegetation[3,4]	Botanical diversity[5]	Timber production[5]	Shifting cultivation[5, 6]	Surface	
							ha	%
Zone A: well drained soils; > 700 m asl								
- Mountains	u	Ny	1	1	4	4	10,064	6.0
- Isolated hills	u	Ny	1	1	4	4	879	0.5
Zone B: well drained soils; 500 - 700 m asl								
- Isolated hills	u	Ny	2a	1	4	4	3,043	1.8
	l	Ny	2a+4+5	2	4	4	772	0.5
- Complex of hills	u	Ny	2a	1	3-4	3-4	12,329	7.4
	l	Ny	2a+4+5	2	3-4	3-4	721	0.4
	h	Ny	5+4+2a	3	4	3-4	847	0.5
- Hilly uplands	u	Ny+Eb	2a	1	2-3	2-3	14,594	8.7
	l	Ny+Eb	2a+4+5	2	2-3	2-3	3,350	2.0
	h	Ny+Eb	5+4+2a	3	4	2-3	1,755	1.0
- Rolling uplands	u	Ny+Eb+Vb	2a+3	1	2	2-3	2,484	1.5
	l	Ny+Eb+Vb	2a+3+4+5	2	2	2-3	2,831	1.7
	h	Ny+Eb+Vb	5+4+2a+3	3	3	2-3	88	0.1
Zone C: well drained soils; 350 – 700 m asl								
- Isolated hills	u	Eb	2b	1	4	4	3,920	2.3
	l	Eb	2b+4+5	2	4	4	596	0.4
- Hilly uplands	u	Eb	2b	1	2-3	2-3	20,785	12.4
	l	Eb	2b+4+5	2	2-3	2-3	3,110	1.9
	h	Eb	5+4+2b	3	4	2-3	1,179	0.7
- Rolling uplands	u	Eb+Vb	2b+3	1	2	2-3	16,936	10.1
	l	Eb+Vb	2b+3+4+5	2	2	2-3	7,163	4.3
	h	Eb+Vb	5+4+2b+3	3	3	2-3	7,171	4.3
Zone D: moderately well to well drained soils, < 350 m asl								
- Isolated hills	u	Em+Eb	2c	1	4	4	2,543	1.5
	l	Em+Eb	2c+4+5	2	4	4	770	0.5
- Hilly uplands	u	Em	2c	1	2-3	2-3	17,222	10.3
	l	Em	2c+4+5	2	2-3	2-3	4,691	2.8
	h	Em	5+4+2c	3	4	2-3	2,033	1.2
- Rolling uplands	u	Em+Vb	2c+3	1	2	2-3	7,896	4.7
	l	Em+Vb	2c+3+4+5	2	2	2-3	3,650	2.2
	h	Em+Vb	5+4+2c+3	3	3	2-3	1,078	0.6
- Dissected plains	u	Em+Vb	2c+3	1	1-2	2	2,246	1.3
	l	Em+Vb	2c+3+4+5	2	2	2	1,835	1.1
	h	Em+Vb	5+4+2c+3	3	3	2	7,179	4.3
Zone E: poorly drained soils								
- Valley bottoms	u	Vb	3	2	4	4	1,261	0.8
	l	Vb	3+4+5	2	4	4	334	0.2

[1] Disturbance classes: u = undisturbed by shifting cultivation; l = low intensity shifting cultivation; h = high intensity shifting cultivation; see text for details.

[2] Ny = Nyangong soil; Eb = Ebom soil; Em = Ebimimbang soil; Vb = Valley bottom; see Table 2 for specifications.

[3] See Table 3 for specifications of vegetation types.

[4] Soil and vegetation types are ordered by decreasing coverage. Types that cover less than 10% of mapping unit are omitted.

[5] Suitability classes: 1 = suitable; 2 = moderately suitable; 3 = marginally suitable; 4 = not suitable.

[6] Suitability for shifting cultivation refers to areas up to 5 km from roads and villages. All other areas are not suitable (class 4).

Figure 2. Simplified landscape ecological map of the Bipindi – Akom II – Lolodorf region in south Cameroon (van Gemerden and Hazeu, 1999).

Figure 3. Land suitability map for conservation of botanical diversity (Hazeu *et al.*, 2000).

Table 2. Landforms of the Bipindi – Akom II – Lolodorf region, south Cameroon (van Gemerden and Hazeu, 1999).

Landforms	**Slope length**	**Slope**	**Relief intensity**	**Altitude range**	**Extent**
	m	**%**	**m**	**m**	**km^2**
Dissected erosional plains	50-200	5-15	20-30	40-280	110
Rolling uplands	100-200	10-20	10-40	350-500	480
Hilly uplands	150-300	10-30	30-80	120-700	690
Isolated hills	250-500	> 30	120-300	200-900	116
Complex of hills	250-350	20-40	80-200	350-700	139
Mountains - Outside slope - Inside slopes	 > 400 250-400	 > 30 30-60	 > 250 120-250	 > 500	 100
Valley bottoms	-	0-2	<10	40-700	15

Table 3. Soil types of the Bipindi – Akom II – Lolodorf region, south Cameroon (van Gemerden and Hazeu, 1999).

Soil type	**Depth**	**Drainage**	**Texture (clay topsoil)**		**Texture (clay subsoil)**	**FAO – UNESCO classification[1]**
	cm		**%**		**%**	
Nyangong	100- >150	Well	40-70	heavy clay	50-80	Xanthic Ferralsols
Ebom	100- >150	Well	20-40	sandy loam to sandy clay	35-60	Acri-xanthic Ferralsols
Ebimimbang	50- >150	Moderately well to well	9-25	sand to sandy loam	20-45	Acri-plinthic Ferralsols; Haplic Acrisols
Valley bottom	50- >150	Poorly to very poorly	5-30	loamy sand to sandy clay loam	Variable	Gleyic Cambisols; Dystric Fluvisols

[1] FAO (1988) and ISRIC (1994).

Ecological zone A occurs above 700 m asl and has well drained soils. Landforms encountered are mountains and isolated hills. The soils are of the Nyangong type (deep, very clayey). The predominant vegetation is submontane forest of the *Maranthes – Anisophyllea* community. The canopy of these forests is low (15 – 20 m), irregular and often climber infested. Epiphytic mosses are found at low heights. The forests of this type appear to have high natural dynamics as many traces of uprooted and broken trees are found.

Ecological zone B is located between 500 and 700 m asl and has well drained soils. Landforms encountered are complex of hills, isolated hills, hilly uplands and rolling uplands. Soils are Xanthic Ferralsols of the Nyangong type in the complex of hills and isolated hills. The soils in the hilly uplands and rolling uplands are an association of the very clayey Nyangong soils and the clayey Ebom soils. The predominant vegetation is primary and old secondary evergreen lowland forest of the *Podococcus –Polyalthia* community. The forest canopy is 30 – 40 m high and relatively dense (60 – 80%). Lianas are rare and mainly restricted to gaps. Emergents often surpass 55 m in height.

Ecological zone C occurs between 350 and 500 m asl and has well drained soils. Landforms encountered are isolated hills, hilly uplands and rolling uplands. The clayey soils belong to the Ebom type. Predominant vegetation is primary and old secondary lowland evergreen forest of the *Strombosia –Polyalthia* community. The physiognomy of the forest is similar to the above-mentioned vegetation community.

Ecological zone D is found below 350 m asl and has moderately well to well drained soils. Landforms encountered are isolated hills, hilly uplands, rolling uplands and dissected erosional plains. The soils are typically gravelly, sandy clay loam to sandy clay of the Ebimimbang type. Predominant vegetation is primary and old secondary lowland evergreen forest of the *Diospyros – Polyalthia* community. The physiognomy of the forest is again similar to that of ecological zone B.

Table 4. Vegetation types of the Bipindi – Akom II – Lolodorf region, south Cameroon (van Gemerden and Hazeu, 1999).

Community	**Status**[1]	**E**[2]	**C**[3]	**L**[4]	**Differential species group**
		m	**m**		
1. *Maranthes – Anisophyllea*	p / os	-	20	++	*Anisophyllea polyneura, Maranthes glabra, Scorodophloeus zenkeri*
2. *Polyalthia* community group	n.a.[5]	n.a.	n.a.	n.a.	*Greenwayodendron suaveolens* (= *Polyalthia suaveolens*), *Scaphopetalum blackii, Desbordesia glaucescens, Diospyros bipindensis*
2a. *Podococcus – Polyalthia*	p / os	55	40	+	*Hymenostegia afzelii, Duboscia macrocarpa, Podococcus barteri*
2b. *Strombosia – Polyalthia*	p / os	50	30	+	*Grewia coriacea, Sacoglottis gabonensis* (*Strombosia pustulata* abundant)
2c. *Diospyros – Polyalthia*	p / os	45	30	++	*Diospyros suaveolens, Picralima nitida, Dracaena spp.*
3. *Carapa – Mitragyna*	p / ys	-	40	+	*Hallea stipulosa* (= *Mitragyna stipulosa*), *Carapa sp., Trichilia heudelotii*
4. *Xylopia – Musanga*	Ys	-	20	+++	*Zanthoxylum gilletii, Xylopia aethiopica, X. staudtii*
5. *Macaranga – Chromolaena*	Ys	-	-	+	*Macaranga spinosa, M. barteri, Chromolaena odorata*

[1] p = primary forest; os = old secondary forest; ys = young secondary forest.
[2] average height of emergents; - = absent.
[3] average height of canopy.
[4] abundance of lianas: +++ = abundant; ++ = common; + = few.
[5] n.a. – not applicable.

Ecological zone E comprises valley bottoms throughout the area with poorly to very poorly drained soils. These soils are shallow to moderately deep and are stratified, i.e. alternation of sand and clay layers. Because of the high ground water table and water stagnation, the vegetation structure and composition are very distinct. The predominant vegetation type is swamp forest of the *Carapa – Mitragyna* community. The tree layer forms a canopy at 35 – 40 m. Trees are often stilt rooted, crooked, and branching at low heights. Lianas are abundant. Mosses and epiphytes are found all along the stems.

The ecological zones B, C, D and E also comprise secondary vegetation as a result of human activities. Not all landforms are subject to these activities as steep slopes are avoided both by logging companies and shifting cultivators. Shifting cultivation is mainly practised in the landforms hilly uplands, rolling uplands and dissected erosional plains. Logging is also mainly restricted to these landforms although occasionally logging has taken place in complexes of hills and isolated hills.

Two vegetation types are related to (recent) disturbances and reflect the age of the vegetation. They appear near villages and along the main access roads, and to a lesser extent in logged-over forests, throughout the three ecological zones, apparently regardless of altitude, soil type, or natural vegetation:

- On recently abandoned farmlands (i.e. up to five years after tending stopped) a very dense thicket is found: the *Macaranga – Chromolaena* community. The thicket has only two structural layers. The tree layer is very open and often dominated by *Musanga cecropioides*. The herb layer is characteristically dense and has *Chromolaena odorata* as the single dominant species.
- The *Xylopia – Musanga* community is generally (5) 10 – 15 years old. The tree layer is open (40 – 50%) and is only 15 – 20 m high. *Musanga cecropioides* is often dominating the canopy.

Often relics of the (undisturbed) forest are present but their external foliage cover is generally less than 10%. The shrub and herb layers are very dense and many thorny lianas and pioneer species are present.

4. LAND EVALUATION

The challenge of the land evaluation is to determine the suitability of each mapping unit for sustained use of the land. The evaluation procedure consists of four steps:

- Definition of land utilisation types (LUTs);
- Definition of the requirements of each LUT;
- Description of the mapping units in terms of qualities and limitations;
- Matching of requirements with qualities and limitations finally leads to suitability classes of the mapping units for the different LUTs.

Five land utilisation types are described for the Bipindi – Akom II – Lolodorf area:

- Conservation of biodiversity (flora and fauna);
- Collection of non-timber forest products by local population;
- Production of timber in (semi-)natural forest;
- Shifting cultivation;
- Plantation agriculture.

This list is by no means exhaustive but reflects the most important demands on land in the area (van Berkum, 1996; van Gemerden and Hazeu, 1999; Hazeu *et al*., 2000). The order of the land utilisation types reflects the increasing impact on the natural environment. The land evaluation method in its original form is more easily applied to the last two types as it was designed for purely agricultural purposes (FAO, 1983).

Systematic descriptions of the land utilisation types include objective, output, markets, labour and capital input, technology involved, infrastructure needs and scale of operations. The conditions necessary or desirable for a successful implementation and sustained practice of the land uses are described as requirements. Requirements are related to growth, to management, and to conservation and sustainability. The results of the land evaluation for conservation of botanical diversity, production of timber in (semi-)natural forest and shifting cultivation are discussed in the following sections.

4.1. Conservation of botanical diversity

Conservation of diversity within species, between species and of ecosystems is internationally recognised as a priority for management and nature conservation (e.g. Heywood and Watson, 1995; Lammerts van Bueren and Duivenvoorden, 1996). Biodiversity is thought to contribute to ecosystem functioning and its resilience to human induced changes. The main objective of this land utilisation type is to conserve the botanical diversity of the forest systems. Special focus is on threatened and endangered species. Conservation of biodiversity in (strictly) protected areas will be complementary to efforts made in non-protected areas. Ecological sustainable production of timber and non-timber products provide suitable habitats for many forest species (de Groot, 1992).

The FAO land evaluation method needs adjustment to apply to nature conservation. The suitability for nature conservation means priority of an area to be set aside as a conservation area for its value of biodiversity conservation. Requirements can consequently be interpreted as criteria to assess this conservation value. To determine the botanical conservation value three criteria are formulated: 1) species diversity, 2) occurrence of rare species, and 3) integrity or naturalness of the vegetation.

Species diversity is assessed using the contribution of each vegetation type to the total species diversity of the area. Species with frequency < 10% are omitted because their distribution among the vegetation types are not sufficiently well known. Although the information gathered in the reconnaissance survey does not give accurate estimates of the total species diversity per vegetation type, the data are expected to show diversity trends correctly. The species diversity figures are translated into a more subjective rating of the conservation value as far as species diversity is concerned. It was found that the primary and old secondary forest between 350 and 700 m asl have the highest species number. The submontane forest (≥ 700 m asl) and young secondary forest are slightly less divers. Swamp forests and recently abandoned fields are relatively poor in species.

Rarity, in the criterion occurrence of rare species, is interpreted in a phytogeographical sense.
All species (frequency ≥ 10%) are classified according to their geographical distribution (Keay and Hepper, 1954–1972; Aubréville and Leroy, 1961–1992; 1963–1998; Hawthorne, 1996). Six categories are defined:

1) Endemics (restricted to Cameroon);
2) Regional species (south Nigeria to Congo);
3) Species of Central Africa;
4) Species of West and Central Africa;
5) Species of tropical Africa;
6) Pantropical and cosmopolitan species.

It is recognised that to properly characterise the rareness of species also their abundance and distribution within their phytogeographic range should be evaluated. Unfortunately, this information is too scarce to be applied at present. For each vegetation type, the phytogeographic spectrum is drafted (Table 5). As expected, rare species prove to be most abundant in the primary and old secondary forests, including swamps. Species with a large to very large distribution area are most prominent on the recently abandoned agricultural fields.

The *naturalness* or integrity of the vegetation is assessed on the basis of the ecology of the species. All species (frequency ≥ 10%) are classified, on the basis of regional floras and checklists (e.g. Keay and Hepper, 1954–1972; Aubréville and Leroy, 1961–1992; 1963–1998; Hawthorne, 1996), as species of:

1) Primary forests;
2) Forests (in general);
3) Secondary forests;
4) Secondary vegetation (in general);
5) Secondary shrubland.

The categories are broad and partly overlapping, since relevant information in literature does not allow for a more accurate classification. For each vegetation type, the ecological spectrum is drafted. The ratio of forest species / secondary species indicates the naturalness of the vegetation and an ad-hoc classification of the conservation value on the basis of naturalness is made.
The per criterion and overall classifications of the botanical conservation value are presented in Table 6. The mapping units often consist of a complex of vegetation types and the overall botanical conservation value (i.e. suitability for conservation of botanical diversity) per land unit reflects the

ratio in which the vegetation types occur. In Table 1 the suitability rating per mapping unit is shown. In Figure 3 the land suitability map for botanical conservation is presented.

Table 5. Phytogeographic spectra of vegetation types in the Bipindi – Akom II – Lolodorf region (Hazeu *et al.*, 2000).

Vegetation type[1] **Distribution area**	**1**	**2a**	**2b**	**2c**	**3**	**4**	**5**
World / pantropical	3	1	2	3	3	1	12
Tropical Africa	6	7	9	12	9	16	19
West and Central Africa	39	43	42	40	46	50	55
Central Africa	19	14	17	15	15	12	3
South Nigeria to Congo	32	34	28	28	27	19	10
Cameroon	1	2	2	2	1	2	2
Conservation value (rarity criterion)[2]	1	1	1	1	1	3	4

[1] See Table 3 for specification vegetation types.

[2] Suitability classes: 1 = suitable; 2 = moderately suitable; 3 = marginally suitable; 4 = not suitable. 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. Species information is based on regional floras and checklists (e.g. Keay and Hepper, 1954 – 1972; Aubréville and Leroy, 1961 – 1992; 1963 – 1998; Hawthorne, 1996).

Table 6. Botanical conservation values of vegetation types of the Bipindi–Akom II–Lolodorf region (Hazeu *et al.*, 2000).

Vegetation type[1] **Criteria botanical conservation value**	**1**	**2a**	**2b**	**2c**	**3**	**4**	**5**
Species diversity	1	1	1	2	3	1	3
Occurrence of rare species	1	1	1	1	1	3	4
Integrity or naturalness	1	1	1	2	2	3	4
Overall botanical conservation value[2]	1	1	1	1	2	2	4

[1] See Table 3 for specification vegetation types.

[2] Suitability classes: 1 = suitable; 2 = moderately suitable; 3 = marginally suitable; 4 = not suitable.

4.2. Production of timber in natural forest

Timber is economically an important product of tropical rain forests. The annual production of Cameroonian forests is estimated at $2.8.10^6$ m^3 and represents one fifth of the country's export revenues, i.e. US\$ 320.10^6 (Eba'a Atyi, 2000). Approximately 55% are processed in Cameroon. The forest provides timber for the local and export markets. Although most forests in the Bipindi – Akom II – Lolodorf region have been logged, they still hold a large potential for timber production.

The objective of this land use is the sustainable production of timber for the national and export markets. Production will take place in a polycyclic silvicultural system with a felling cycle of at least 30 years. The timber production required for economically sustainable production is 7 – 12 $m^3 ha^{-1}$ (pers. comm., R. Eba'a Atyi). Labour requirement is high during silvicultural treatment and exploitation. Levels of technology and capital input are relatively high.

The overall suitability of the land mapping unit is based on criteria related to growth, to management and to conservation. The growth requirements reflect the potential of the land to produce timber. In the present land evaluation only the frequency with which timber species are found is considered. No data are available on diameter distribution and growth and yield. Insight in the recent logging history will only give some indication what areas are likely to produce timber on short term. The occurrence of timber species is evaluated similar to the occurrence of rare species in the land utilisation type conservation of botanical diversity. All species (frequency ≥ 10%) are classified according to their timber status. The following classes are used:

1) Superior grade timber species, i.e. species presently exploited (pers. comm., G.J.R. van Leersum);
2) High grade timber species, i.e. species occurring on the list of the state forestry service ONADEF, code 11 (see ONADEF, 1991);
3) Medium grade timber, i.e. ONADEF code 12;
4) Low grade timber species, i.e. ONADEF code 13 and species identified by the TCP project on lesser-known timber species as potential timber species (good technical qualities but not yet widely marketed) (Zijp *et al*., 1999).

A total of 68 timber species are included in the analysis of which 42 occur with frequencies higher than 10%. The scores per vegetation types have been adjusted for the frequencies with which the species occur (Table 7). The primary and old secondary forests between 350 and 700 m asl are best stocked with high-grade timber species. Swamp forest and primary and old secondary forests below 350 m contain slightly less high-grade timber species. Submontane forests (≥ 700 m asl) has low scores for high-grade timber species and only medium scores for mediocre timber species. The young secondary forest and thicket on recently abandoned fields are not included in the analysis, as they will not produce timber in the next 30 years. The values per vegetation type are adjusted to reflect the valuation of the mapping units.

Requirements related to management include terrain conditions and size of the management unit. The requirement terrain condition reflects the suitability of the land for mechanised operations. It is valued by the absence of steep slopes and swampy areas. The use of heavy machinery becomes troublesome with increasing slope. Slopes surpassing 30% are avoided in the present logging operations (pers. comm., G.J.R. van Leersum). The mountains, isolated hills and complexes of hills are not suitable for timber production because of too steep slopes. Swamps also hinder exploitation but are only included in the valuation if a large proportion of the mapping unit is covered. Rolling uplands and dissected plains also less suitable for exploitation due to a large portion of valley bottoms (10-19% of the mapping unit).

Table 7. Timber species per vegetation type in the Bipindi – Akom II – Lolodorf region (Hazeu *et al.*, 2000).

Vegetation type[1] / **Timber class**[2]	**1**	**2a**	**2b**	**2c**	**3**	**4**	**5**
Superior	2[4]	10	11	5	4	-	-
High	9	14	8	10	10	-	-
Medium	12	14	16	17	14	-	-
Low	18	22	18	27	23	-	-
Suitability timber production[3] **(requirement timber species)**	3	1	1	1	1	4	4

[1] See Table 3 for specifications vegetation types.

[2] See text for details timber classes.

[3] Suitability classes: 1 = suitable; 2 = moderately suitable; 3 = marginally suitable; 4 = not suitable.

[4] Values weighed by frequency in which they occur in the vegetation types. Vegetation types 4 and 5 not included in analyses.

The management unit should cover 30 000 ha for a small forestry enterprise and 60 000 ha to support a small to medium-sized sawmill (Eba'a Atyi, 2000). As disjunct areas are also of interest for this land use, this requirement is evaluated on the basis of the whole region.

The conservation requirement 'tolerance to soil erosion' could be estimated by the soil texture, slope, susceptibility to surface sealing and crusting, and land cover. In general, the areas most vulnerable to erosion after land use conversion, causing a decrease in soil fertility and a deterioration of the surface water quality, are those with steep slopes and coarse textured soils, e.g.

Ebimimbang type. The measured annual sediment yield from undisturbed forest was very low at about 60 kg ha^{-1} (Songkwe catchment near Mvié). Due to higher rainfall, the area along the Akom II – Lolodorf axis should also be somewhat more susceptible to erosion than the western lowlands or eastern highlands. Selective logging (Biboo-Minwo catchment) has a significant impact on erosion rates as indicated by a higher catchment sediment yield. Severely compacted skid tracks, roads and landings, which are the main sources of sediment, cover about 0.2% of the area. Erosion occurs locally on these tracks, but because of their location on rather flat terrain, the released sediment may not reach the stream and a large proportion of the sediment will be deposited within the catchment at short distance from the source. The observed sediment yield in the first year after logging was ten times higher (560 kg ha^{-1} yr^{-1}) than that of the forest covered catchment. This is still a low value in comparison to sediment yields observed elsewhere in the humid tropics (30-6200 kg ha^{-1} yr^{-1} for undisturbed natural forests, Wiersum, 1984). Furthermore, it is very likely that a decrease due to forest regrowth will be observed in the following three years to a value close to those of undisturbed rain forest areas (Waterloo *et al*., 2000). It is therefore concluded that soil erosion remains within acceptable limits on slopes of less than 30% and with a selective logging system. For water and soil conservation purposes, steeply sloping areas should be protected against the mechanical harvesting and extraction of logs. Standard soil and water conservation measures (maintaining buffer zones along rivers, proper planning of skid tracks, number of skidder passes, observation of forest recovery period lengths, etc.) may otherwise be sufficient to ensure that the forest land use remains sustainable from a hydrological point of view.

The suitability ratings per mapping unit are given in Table 1. In Figure 4 the land suitability map for timber production in natural forests is presented. Size of management unit is not included in the evaluation.

4.3. Shifting cultivation

The population in the area depends on agriculture for subsistence and cash revenues. The most widespread agricultural land use is shifting cultivation in which forest patches are cleared, burned and interplanted with ngon (*Cucumeropsis mannii*), groundnut (*Arachis hypogeae*), maize (*Zea mays*), cassava (*Manihot esculenta*), macabo (*Xanthosoma sagittifolium*), coco-yam (*Colocasia spp.*) and plantain (*Musa spp.*). Depending on the productivity, the tending and harvesting gradually stops after two to three years and the land is left fallow for 7 – 15 years. Annually about 1.3 ha is cultivated per household. The estimated surface in use per household (five members on average) is 10 ha. This figure includes fields, fallow land and cacao plantations (Fines *et al*., in prep.). Although Bakola forest dwellers practice shifting cultivation to some extent, they depend more on the trade of non-timber forest products and labour to acquire agricultural products.

The objective of the land use shifting cultivation is the sustainable production of agricultural crops by the local population. The produce is for subsistence and local markets. Labour input is high and capital input and level of technology are low. Fields are in general created near villages and main roads (up to 5 km distance).

The main growth requirements for shifting cultivation are drainage condition, soil depth and nutrient availability. The management requirements are workability and terrain condition. Tolerance to soil erosion reflects the requirements related to conservation. Shifting cultivation is a mixed cropping system and therefore the requirement of the most demanding crop will determine the evaluation. Crop requirements are based on Sys (1985).

Rainfall and temperature are near optimal for all crops. Groundnut and ngon are most sensitive to drainage and require deep (> 75 cm), well-drained soils. All soil types in the area meet these requirements except the valley bottom soils and to a lesser extent the Ebimimbang soils. The most nutrient demanding crops are plantain and maize. The Nyangong and Ebom soils are moderately to slightly limiting in this respect. The workability depends on the texture of the topsoil. Most crops prefer sandy to sandy loam topsoils making the Ebom and Ebimimbang soils the most suitable. The requirement terrain condition is based on slope and the presence of rock outcrops. Mountains, isolated hills and complexes of hills are in general too steep for productive shifting cultivation. Rock outcrops are not limiting, as in all mapping units they are not more than 2%.

The hydrological studies in the area indicate that erosion does not (as yet) present a major problem for shifting cultivation practices (Waterloo *et al*., 2000). In the shifting cultivation system, disturbance of the topsoil is relatively limited and bare soil is only exposed for a few months immediately following the burning after forest clearance. In addition, fields are generally located on the flatter parts in the area, with the surrounding hills remaining under forest cover. Moreover, fields are small and larger stems of trees remain on the field acting as surface water flow barriers. As such, erosion and sediment transport from these fields to the streams remained low as indicated by the sediment yield from a catchment affected by shifting cultivation (i.e. 105 kg ha^{-1} y^{-1}), which was only somewhat higher than that of undisturbed forest. The higher value may also partly be attributed to the steep topography of this catchment. Erosion may become a problem, however, when the fallow period is shortened, preventing full recovery from the previous cropping phase, or when fields are established on steeper slopes as a result of population pressures.

In Table 8, overall suitability for shifting cultivation is given per soil type. Combining these ratings with the limitations caused by slope (erodibility) leads to a final suitability of the land of each mapping unit (Table 1). In Figure 5, the suitability for shifting cultivation is presented on a map.

Table 8. Suitability for shifting cultivation of soil types in the Bipindi – Akom II – Lolodorf region (Hazeu *et al*., 2000).

Soil type[1] **Requirement**	**Nyangong**	**Ebom**	**Ebimimbang**	**Valley bottom**
Drainage[2]	1[9]	1	2	4
Effective soil depth				
- Actual soil depth[3]	1	1	1-2	1-2
- Coarse fragment content (topsoil)[4]	1	1	2	1
Nutrient availability				
- Cation exchange capacity (topsoil)[5]	1	1	1-2	1-2
- Base saturation (topsoil)[6]	3	1-3	1	1-3
- Organic matter (topsoil)[7]	1	1	1	1
Workability				
- Texture (topsoil)[8]	2	2	2	1
Overall suitability (soil parameters)[9]	2	1-2	2	4

[1] See Table 2 for specifications soil types. Requirements have three to four classes. Order follows overall suitability, see 9.
[2] well; moderate; imperfect; very poor.
[3] > 75 cm; 50-75; 25-50; < 25.
[4] < 3%; < 15; < 35; > 35.
[5] > 8 meq/100g; 4-8; < 4.
[6] > 35%; 20-35; < 20.
[7] > 1.5% C; 0.8-1.5; < 0.8.
[8] Sand to loamy sand; sand clay loam to clay; heavy clay.
[9] Suitability classes: 1 = suitable; 2 = moderately suitable; 3 = marginally suitable; 4 = not suitable.

In the previous sections the land evaluation for the land uses biodiversity conservation, timber production and shifting cultivation are discussed. The final suitability of some land utilisation types can only be judged on the basis of the whole map. For biodiversity conservation purposes the possibility to link small but suitable areas into one larger management unit by using less suitable

Figure 4. Land suitability map for timber production in (semi-)natural forest (Hazeu *et al.*, 2000).

Figure 5. Land suitability map for shifting cultivation (Hazeu *et al.*, 2000).

corridors will increase the potential of all mapping units involved. For timber production a similar upgrading can occur if different disjunct areas can be regarded as a management unit.

Land use objectives need not be mutually exclusive. Conservation of flora and fauna can up to a certain level be combined with controlled small-scale hunting and gathering. Timber production and hunting and gathering can easily be combined. On the other hand, the objectives of conservation of biodiversity or timber production and shifting cultivation are in conflict. On the basis of the information gathered in the land evaluation the sustainability of land use combinations can be examined.

5. LAND USE PLANNING

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 utilisation 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 *et al.* (2001) stipulate the steps necessary to 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 utilisation 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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SOCIAL CHANGE, EXPLOITATION AND MANAGEMENT OF NATURAL RESOURCES IN THE BIPINDI-AKOM II AREA

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SUMMARY

Planning is generally considered a prerequisite for achieving sustainability in forest management. Qualitative and quantitative data on the present situation are the usual and obvious sources of information for such plans. Yet this present situation is only the result-for-the-moment of various ongoing processes of change. Areas to be managed sustainably have their own dynamics, and forest managers lack the means to redirect or stop such processes. Consequently, if forest management plans are based on snapshot pictures of the current situation only, this will result in a number of unpleasant surprises during the implementation phase. Forest managers can reduce the number of such surprises by basing their forest management plans also on knowledge about processes of change. Social dynamics are an essential factor to be taken into account in this respect. The present analysis contributes to achieving this. Local exploitation of forest resources in the Tropenbos-Cameroon research area has undergone profound changes due to such processes as: commoditisation, introduction of new technologies, modification of peoples' residence patterns, and transformations of the normative frameworks regulating natural resources exploitation. These processes are critical variables in explaining current local exploitation of forest resources. As these very processes will also shape the future situation, any plan for sustainable management of forests in this area should take them into account.

Keywords: Bantu, Pygmies, social change, sedentarisation, tenure arrangements, land use planning, forest management, Cameroon.

1. INTRODUCTION

The master management plan developed within the Tropenbos-Cameroon Programme (TCP) is a form of strategic planning. The present paper substantiates that the TCP research area (see Figure 2 in van Gemerden *et al*., this volume) has been subject to constant change. Not only do these changes affect the ways in which forest resources are exploited, but also their relative importance if compared the other economic activities. It starts with a brief introduction on the various population groups in the Bipindi-Akom II area and their ways of forest exploitation. Its second section focuses on changing economic conditions, the introduction of new technologies, and changing human mobility respectively, and these will be considered in view of their impact on local forest exploitation and management. Attention will also be paid to the impact of plural regulatory forest management frameworks.

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Processes of social change were among the main research topics of the social scientific research within the Tropenbos-Cameroon Programme (TCP). Part of the research among Bagyeli pygmies focussed on socio-economic changes and their impact on local knowledge on and exploitation of forest resources. Another part of the research among Bagyeli pygmies concentrated on the dynamics of their local forest resources tenure in relation to processes of sedentarisation. Fieldwork among Bantu farmers focused on related themes. One part of this research paid particular attention to the influence of the market on Bantu exploitation and perceptions of the forest. The other part analysed dynamics of plural institutional and regulatory frameworks within which land and other forest resources are managed and exploited. Four social scientific researchers were employed for these studies; they were supported by their supervisors and by students. A variety of standard social scientific research methods were used, among which participant observation, semi-structured interviews (targeting either individuals or groups), questionnaires and archival research. Preliminary results were presented in many intermediate reports, articles, papers, and draft PhD thesis chapters. An integrated overview of the overall results of the four studies is presented in an additional report (van den Berg and Biesbrouck, 2000).

2. A HETEROGENEOUS STUDY AREA

The human population in the Tropenbos research area is heterogeneous. There are marked socio-political differences. First of all there is a differentiation between Bantu speaking farmers and Bagyeli pygmies. Bagyeli form a minority group (an estimated 4% of the total population). Most Bagyeli families live at some distance from the passable roads, in base-camps in the forest. Bagyeli camps are unevenly distributed over the research zone: they are concentrated in the northern part of the area, and in the western part towards the south. Bantu farmers live in villages along the passable roads. Their fields and fallow lands form strips on both sides of these roads. Several different Bantu languages are spoken in the area. In the northern part, Ngoumba and Fang speaking farmers are the most numerous. In the western and southwestern part, most farmers speak either Fang or Bulu. The population in the southeastern part, on the contrary, consists almost exclusively of Bulu speaking farmers.

Bagyeli camps are administratively connected to Bantu villages; sometimes several Bagyeli camps are linked to the same village. Symbolic kinship relations and intricate economic links relate Bagyeli to Bantu farmers. In the past, these relationships were clientelistic in nature with the Bantu acting as patrons. These patron-client relationships started to decline just before independence. Bantu found alternative opportunities for achieving status in the jobs related to the africanisation of the bureaucracy. Furthermore, the catholic mission commenced its activities aimed at reducing the exclusive and exploitative character of the ties between these groups. Meanwhile, Bagyeli received formal education; got directly involved in the market; and the catholic nuns fulfilled some of the functions of the former patrons. Bagyeli are still looked down upon and their power position remains rather weak *vis-à-vis* Bantu farmers and administrative authorities (van de Sandt, 1999).

Also within these groups there is internal differentiation. The elite of Bantu villages plays an important role in their development. This elite consists mostly of retired civil servants who moved back into their village of birth, and people who currently work in town and maintain the link with their paternal village. Bagyeli hardly ever become civil servants (let alone influential ones), so it is impossible to speak of a Bagyeli elite in this sense. Yet the first generation of Bagyeli receiving formal education fulfils a similar role. Those advocating local participation in forest management and expecting to find well-organised and coherent villages will be disappointed. Leadership and representation are problematic issues in the entire region, and the Bagyeli are no exception to this rule (van den Berg and Biesbrouck, 2000).

Another dimension of the heterogeneous character of the area is the economic differentiation between and within population groups. For the Bantu, agriculture is the most important economic activity. Two main types of agricultural activities can be distinguished in the area: a) the cultivation of food crops and b) cultivation of cacao. Main food-crops grown are cocoyam, plantains, and cassava. There are a number of secondary crops, among which cucumber, maize, groundnuts, and a few vegetables. Agricultural activities provide for food crops, and for substantial monetary incomes for both men (sale of cacao) and women (sale of food crops) (Tiayon, 1999a). Considerable differences exist between Bantu and Bagyeli as to the scale of the cultivation of food crops. Agriculture is much less important for Bagyeli; in general it provides them with only a minor part of their food, and contributes to their monetary income only in some exceptional cases (Biesbrouck, 1999b).

Hunting and gathering is the most important economic activity for most Bagyeli. Rodents and duykers are the most frequently caught, a large part of the catch is used for own consumption. Bagyeli also collect kernels, seeds of *Strophanthus* climber, bark, and honey. Part of these uncultivated forest products is exchanged with Bantu farmers for food crops or other things, another part is sold in order to be able to pay for some of the primary necessities of life (Biesbrouck, in prep; Nkoumbele, 2000). Bantu also practice hunting and gathering, but to a lesser extent, although some of them have specialised in the extraction of specific forest products (e.g. primates and rodents, several ingredients for palm-wine, bush-mango) (Tiayon, 1999a). Some Bagyeli are professional traditional healers. They combine medicinal bark and leaves from the forest with their special knowledge and powers (van de Sandt and Biesbrouck, 2000). The more famous among them attract patients from town, and this provides them with a substantial income. These traditional healers are particularly dependent on uncultivated forest resources because these provide ‘raw material’ necessary for the execution of their profession.

Among Bantu farmers in the research area there are regional variations in (perceptions of) pressure on land. Along the northern edge of the TCP area, and in the western part towards the south, the pressure on agricultural lands is high. In the north this is partly related to presence of a steep hill chain that limits agricultural expansion. In the western to southern part, this pressure is due to medium-scale plantations for cash crops. In most of the villages in the TCP area, the expansion of the agricultural area (see below) started long ago and the process seems to be tending towards its end. In these zones, many farmers currently prefer to create their fields on fallow lands in view of the practical constraints related to clearing of forest land (Tiayon, 1999a; Nounamo and Yemefack, 2001). This pressure on land is reflected in the enormous number of conflicts on land. The archives of the traditional courts of the village of Bidjouka, to give an example, showed 276 conflicts on land between 1973 and 1995. Sixty percent of these conflicts concerned fallow lands (Tiayon, 1999a). The Bulu farmers in the hilly eastern part of the area, however, do not experience similar restrictions to the expansion of the area under cultivation. As a consequence, agricultural expansion is still going on in eastern part of the region. Here, clearing high forest is still possible within easy reach of the village. Farmers actually do this, as ownership claims by the state make them feel insecure about future access to land for their offspring. They strengthen their rights to land by planting palm- and fruit trees (van den Berg and Biesbrouck, 2000). These regional differences are not only related to these geographical and economic characteristics, but also to demographic variations between villages, as well as to the length of human occupation of the area (Tiayon, 2001).

At least two intervening variables complicate this general picture (*ibid*.). First of all, as a result of the economic crisis, young people are nowadays severely restricted in their opportunities to (find or) keep a job in the towns. These youngsters return to their villages throughout the area. Especially young men hope to earn some money in the logging industry or the construction of the oil pipeline. Such jobs, however, are only temporary and limited in number. As a consequence, many of these youngsters start practising agriculture and / or exploiting forest resources (for consumption or market). Secondly, the availability of chainsaws greatly facilitates the heavy work of opening up the high forest.

3. PROCESSES OF SOCIAL CHANGE AND THE USE OF NATURAL RESOURCES

Which processes of social change have been going on in the past few decades, and which were the consequences for local exploitation of uncultivated forest resources?

3.1. Forest exploitation influenced by the market

As from 1986 many people in towns lost their jobs due to enterprises' bankruptcies caused by the economic crisis. Numerous were those who returned to the rural areas. In 1989, producer-prices for cacao dropped, only to recover again five years later. Cacao is the major source of income for most Bantu families. Meanwhile, imported goods had become more expensive as a result of the devaluation of the FCFA. Bagyeli were less affected by these economic trends if compared to Bantu farmers, for Bagyeli hardly produced cacao in the first place, nor did they hold any positions in the towns. Bantu people, on the other hand, had to look for alternative sources of income.

One would expect cacao-producers to shift their attention to cultivating food crops in order to sell the surplus. Research in the Bidjouka area, however, showed that this drop in incomes for cacao-producers generally did *not* lead to an increase of male involvement in production and sale of food crops. The cultivation of food crops and their sale on the urban markets has always been, and still is, essentially a women's affair (Tiayon, 1999a). Despite this, cacao farmers' attitudes towards production and marketing of food crops did change under these circumstances.

Young Bantu men, who re-migrated to their villages of birth after having lost their jobs in town, provide a first example. Some of them specialised themselves as hunters. In the Bidjouka area pressure on fauna grew as a result of this. Another option was the increased exploitation of certain types of forest vegetation, such as kernels (*Irvingia gabonensis*, *Coula edulis*, and *Panda oleosa*) and the seeds of the *Strophanthus gratus* climber. Some farmers increased the production of palm-wine and gained substantial incomes from selling this drink directly to local consumers. This palm-wine was also used and sold as the main ingredient for a palm-wine distillate (Tiayon, 1999a). This growing production of palm-wine for sale led to excessive exploitation of the bark of *Garcinia lucida* (used in the distillation process), and this occasioned an overexploitation of exemplars of this species. Eventually this may cause a scarcity or extinction of this species (Guedje, 1996; Guedje and Nkongmeneck, 2001; see also Ndoye *et al.*, 1998).

Furthermore, commercial timber exploitation enhanced local awareness of the forest as an area producing valuable resources for the market. Nowadays, the utilitarian perception of the forest tends to predominate among local populations (see, e.g., Tiayon, 1999a). The Ngoumba have been elaborated as an example of Bantu farmers perceiving the forest for agricultural purposes as well as a stock of valuable timber. This utilitarian perspective is, at least in part, a reaction to commercial timber exploitation by logging companies. The 'compensation' received by villages and paid by logging companies led to a multitude of conflicts between the two parties. In addition to this, such compensation also led to conflicts between inhabitants of adjacent villages on its distribution. The inhabitants of the respective villages wish to maximise the amount of compensation derived from 'their' forests, and this results in the villages becoming increasingly interested in demarcating their village forest. This tendency has been coined a *villagisation* of forests (Tiayon, 1999a). Furthermore, Bantu farmers contact logging companies in order for them to harvest the commercially interesting species found in their fields and fallow lands and pay the owner.

In the eastern part of Cameroon this tendency was strengthened by the 1,000 FCFA 'tax' paid to local communities for each cubic metre of timber leaving a sale of standing stock (*vente de coupe*) (Milol and Pierre, 2000). If the same phenomenon were to happen in the Tropenbos research area, it is expected that the *villagisation* trends will be reinforced, with heavy risks of social unrest due to boundary disputes.

3.2. Availability of new technology facilitates local forest exploitation

Chainsaws, cable wire, and rifles are rather efficient tools in exploiting natural resources. Over the past few decades, these technologies have either been newly introduced, or their use has expanded significantly.

The use of the chainsaw for agricultural purposes is a relatively new phenomenon in the area. Its introduction was largely related to logging practices, which made use of this technology. The temporary drop in cacao prices seems to have accelerated farmers' recourse to the use of chainsaws. In fact, among farmers this drop this created a need for alternative sources of income. The expansion of food production was hampered by the scarcity of labour, which was especially felt in the preparation of new fields. The introduction of the chainsaw greatly facilitated this task. However, due to its high price, only the wealthier people could afford to buy such a chainsaw. Those who were less fortunate try to make use of this facility either by making use of their social relations, or by paying these lumberjacks for their services. Currently, a local association (KTM) attempts to organise communal use of this chainsaw in many of the Ngoumba villages along the northern edge of the TCP area (Tiayon, 1999a).

Cable wire was already introduced during the colonial period. The material is relatively cheap, and it increases the efficiency of snares. This explains why currently the material is widely used by both Bantu and Bagyeli trappers. Despite this availability, many lines of snares in the forest consist of a mix of traps made from traditional materials and those made with cable wire (Nkoumbele, 2000).

The use of the rifle in local hunting practices dates even further back, namely to the trade economy. After the country's independence its use greatly intensified, especially in response to the development of the trade in bush-meat. Urbanisation led to an increasing demand for bush-meat, and the improved roads facilitated access to the urban markets. Despite these developments, rifles are not owned on a very large scale nowadays. This is because rifles are expensive, the acquisition of the required permit is hampered by the complexity of the administrative procedure, for most of the Bantu hunting is just a marginal economic activity, and mainly for auto-consumption. The relative scarcity of rifles, combined with the demand for bush-meat, has led to the creation of new temporary partnerships in hunting, centring around rifle-owners, and to practices known as commissioned hunting (Dkamela, 1999; Tiayon 1999a). This implies that the number of rifle-users largely exceeds the number of owners. Those hunting with a gun do not necessarily restrict their activities to the forest near their place of residence. Some forests are fuller of game than others, and hunters make use of their kinship and cordial relations in order to have access to other forests. This led to a regionalisation of some hunters' forest use (Tiayon, 1999a).

3.3. Sedentarisation and the spatial distribution of forest use

Human mobility is an important factor determining the spatial distribution of forest exploitation for local use. Sedentarisation of Bantu farmers started early in the colonial period and this concentrated forest use in specific areas. Contemporary Bagyeli, on the other hand, are anything but sedentary. Research on Bagyeli mobility showed how sedentarisation can have many faces. A comparison of several cases indicated that mobility has altered in various ways, resulting in several different current patterns of mobility. These changes in the various forms of mobility occurred independently from one another. Over the years, the time spent per year in temporary hunting camps has reduced considerably. Despite this, important differences still occur between families, for some of them spend considerably less time in their hunting camp than others. A similar statement can be made about the frequency of moves of groups of people towards other base-camps: nowadays a few Bagyeli families move between base-camps much less frequently than they did before the 1960s. In many other cases this type of mobility has also reduced, yet less dramatically[4]. A third form of mobility, indicating whether or not the base-camp is situated on the roadside, showed additional differences. In the 1960s, a governmental campaign aimed at Bagyeli settlement on roadsides. The majority of Bagyeli in the research area obeyed the government's resettlement policy, but they disliked the ensuing frequent contact with 'meddlesome' and 'haughty' Bantu farmers, and many Bagyeli soon returned to their base-camps in the forest. The Bagyeli families in Ndtoua and Nyamenkoum are exceptions in this respect, as these have managed to live on the roadside in the neighbourhood of villagers for several decades (Biesbrouck, 1999a; 1999b; Hanssen, 1995; Henning, 1997; Nkoumbele, 2000).

When Bantu farmers expanded the area under agriculture they drew on the space immediately neighbouring their current fields. This space used to be available for Bagyeli, so these were confronted with an increased pressure on the land in the immediate vicinity of their base-camps. In some cases Bantu withdrew the Bagyeli right of usufruct of these lands. Bagyeli were sent away from their base-camp and this caused mobility. However, in other cases Bagyeli mobility reduced, as the latter preferred to keep living in that specific base camp in order to defend their claims to the surrounding land (Biesbrouck, 1999a).

3.4. Plurality of normative frameworks (regarding forest exploitation)

All this happened in a situation figuring a plurality of normative frameworks regarding forest exploitation. At the local level, the exploitation of natural resources is predominantly conditioned by customary tenure arrangements, and not by state forest regulations as the latter are hardly implemented. Bantu farmers as well as Bagyeli hunter-gatherers developed such arrangements.

[4] Readers with a particular interest in this subject are referred to Biesbrouck (1999a; in prep.), who deals with this matter at length.

Bantu and Bagyeli discern different forestland types or categories of space. The residential area is a separate category; there is high pressure on these lands. Among Ngoumba, *Dzier* appears as a generic term including all land categories apart from human settlements It then consists of sub-categories such as *ngie* indicating the fields and plantations; *Mabvur* is the notion used in referring to fallow lands; *Pandé* is the concept utilised to indicate 'primary' forest (Tiayon, 1997; 1999a; 1999b). Bagyeli classification of forest space parallels that by Ngoumba, although there are slight differences in terminology (see Biesbrouck, 1999c). The Bulu call a field or plantation that is actually under cultivation *Afup*. *Ekotôk*, on the other hand, refers to fallow lands that are initially still used as storage for food-crops and a source of planting material. After a fallow period of approximately thirty years an area is designated as old secondary forest, *Mfôn afan* (van den Berg, 1996). 'High' or virgin forest, *Fut afan*, is the category of land in which the vegetation shows no sign of human impact, and according to local memory it has 'never' been transformed into agricultural land.

Various levels of social organisation are involved in local management of natural resources. In order to understand which of these levels applies, it is crucial to know on which type of forestland a resource is found, and whether or not particular investments have been made in the productivity of that resource. The House, households and individuals play important roles in the access to fields, fallow lands and cacao-plantations[5]. Throughout the TCP area, the House holds collective rights for its members over the fields and fallow lands that were inherited from previous generations; Tiayon calls this set a *patrimony*. Its head, together with the elders, distributes these lands among its constituent households. In daily practice, these households are the significant units in managing these lands. Agricultural land that was not inherited but that has recently been opened in high forest, however, is governed by the individual man. This man derives this right from the fact that he was the first to put his axe into this section of the forest and from the principle of first occupancy. In the Bidjouka region, such a man has the right to expect others even to refrain from transforming the forest immediately bordering his fields and fallow land into agricultural land, as this is considered to be his *Nkwong dzier* (the width of this area is at least 300-500 meters). Individual men generally start building their own patrimony after their marriage; as time passes by the number of his descendants increases, and this group will form a separate House (Ngo Mboua, 1996; Tiayon, 2001).

Tenure arrangements pertaining to land do not always correspond exactly with those regarding the uncultivated resources found on them. In other situations, however, tenure of land can affect tenure of other resources (Biesbrouck, 1999c; Ngo Mboua, 1996; van den Berg and Biesbrouck, 2000). Bagyeli use arrangements regulating the access to uncultivated forest products in the high forest *among* several right-holders. Elements occur of more or less individual control over natural resources. Some resources are appropriated by individual persons or a small group by means of personal efforts. Such investments turn collectively held resources into more or less private property: the person (or persons) who catches or gathers the product can decide what will happen to it (Biesbrouck, 1999c). Among Bantu farmers, the House controls access on valuable trees found on the *patrimony*, except for those trees that have been appropriated by an individual. The House also controls the access to the fauna found in fallow lands, and its members may grant others the right to exploit this. Individuals, however, control valuable trees on this patrimony in case they are the ones who

[5] The House is not a house in the usual sense of a building, for people belonging to the same House do not necessarily live in the same building. A House is a group of people recognising their social and political ties.

invested energy in enhancing its productivity. Individuals also control access to wildlife and fish on their own agricultural fields and plantations (van den Berg, 1995).

Meanwhile, national forest legislation pertains to the very same forest areas. During the colonial period, the state proclaimed itself the owner of the so-called *terres vacantes et sans maîtres*. Agricultural activities were taken as indicators of human occupation, notwithstanding the fact that at the local level claims over natural resources may be based on other activities as well. This legal manoeuvre brought forests containing valuable timber under the influence of the state. Current legislation still builds on this legal move, and this is at the basis of the state distributing permits for commercial logging (Biesbrouck, 1997).

Yet the distinction between the various normative frameworks is not entirely exclusive. Elements of state legislation also figure in local discourse on tenurial matters, even though detailed knowledge of the forest and land laws is generally lacking at the local level. Notwithstanding this, Bantu farmers, in their disputes on natural resources with other farmers or Bagyeli, legitimise their claims by referring to principles and regulations derived from either of these normative frameworks. As forest clearing is one of the most effective ways to secure rights to land in the long term, both in terms of local tenure and in terms of the current state legislation, existing feelings of insecurity of rights motivate farmers to strategically open up the forest (van den Berg, 1999). One can easily imagine that this plurality of normative frameworks allows for a rather chaotic exploitation of the forest.

4. IMPLICATIONS OF SOCIAL CHANGE FOR SUSTAINABLE FOREST MANAGEMENT

Demographic differences between Bantu villages, geographical particularities, as well as variations in the length of human occupation make the research area heterogeneous in terms of agricultural practices. There are regional variations in availability of land for agricultural expansion. In the Nyangong region, expansion of agricultural area into the forest is still possible. In most other areas, however, such expansion has become virtually impossible, as the forest is at quite some distance by foot. Those planning forest management should take such regional variations into account.

Apart from this, the extent of forest dependency differs between Bantu and Bagyeli, although these differences are not absolute. The forest is important for both groups, but to varying degrees and in different ways. For Bantu, the high forest is mainly a reservoir for agricultural land as well as a stock of valuable timber to be ‘sold’ to logging companies. For Bagyeli, on the other hand, as well as for some individual Bantu NTFP specialists, natural forests are their main sources of food and income.

Local forest exploitation is influenced by economic conditions and developments on the market, by feelings of insecurity of rights caused by the presence of external actors such as logging operators, and facilitated by the availability of new technology. The use of new technology in hunting both occasioned a regionalisation of hunting with guns and increased pressure on the fauna in some areas. As a consequence, those planning sustainable forest management should take great care in the definition of stakeholders in game, and in the delimitation of hunting zones.

Notwithstanding reductions in mobility, Bagyeli are still far from being as sedentary as their Bantu neighbours are. Often, this mobility takes place within the area over which Bagyeli hold rights based in local tenure, and this does not pose any problems in terms of externally initiated forest management. However, if they move out of their own area and start exploiting forest resources elsewhere, this could become a matter of concern. If future arrangements for sustainable forest management are based on a choice for zoning, it is to be feared that these will be made on current patterns of residence only. This result from notions on exploitation of resources developed in western, sedentary societies, taking geographical entities as a criterion rather than kinship. However, if applied rigidly in the southern Cameroonian context, such an approach leaves out related right-holders living elsewhere, who will certainly come and manifest their rights some time in the future. This could create problems with regard to controlling access to resources. Therefore, when developing such arrangements for areas inhabited by mobile peoples, provisions will have to be made for the rights and the responsibility for the behaviour of these 'distant' individual stakeholders. Furthermore, there is a possibility that 'others' (friends, distant relatives), through good relationships, have been granted the privilege of exploiting certain resources. In such a case it is said that this other 'passes on the name of' the person actually holding the right to allocate access. This latter principle is a locally acknowledged way of tracing ultimate responsibility for the exploitation. In a co-management setting, this principle may be a convenient mechanism to solve this problem in co-operating with mobile people.

In a situation of relative poverty, local utilitarian perceptions of the forest are at odds with western concerns for forest conservation. Extension activities are necessary as these might reduce the gap between these different logics. Yet it would be naive to assume that extension alone will solve this problem. Compensation should mitigate the restrictions put to future local forest exploitation.

5. CONCLUSION

Planning is generally considered a prerequisite for achieving sustainability in forest management. Qualitative and quantitative data on the present situation are the usual and obvious sources of information for such plans. Yet this present situation is only the result-for-the-moment of various ongoing processes of change. Areas to be managed sustainably have their own dynamics, and forest managers lack the means to redirect or stop such processes. Consequently, if forest management plans are based on snapshot pictures of the current situation only, this will result in a number of unpleasant surprises during the implementation phase. Forest managers can reduce the number of such surprises by basing their forest management plans also on knowledge about processes of change. Social dynamics are an essential factor to be taken into account in this respect. The present analysis contributes to achieving this.

Nowadays, the market and the availability of new technology have an impact both on local forms of forest exploitation and on products derived from its conversion into agricultural land. A combination of several events between the mid 1980s and the mid 1990s reduced farmers' incomes, while some of the costs rose. The desire to earn money intensifies the sale of natural resources. Farmers looked for alternative income generating activities. One of the options was to increase production of food crops for the market. Depending on the farming system structure, this implied the expansion of the area under cultivation. Another option was the increased sale of such uncultivated forest products as bush-meat and NTFPs. Meanwhile, new technology (such as chainsaws, rifles, and metal wires) had become available. This technology allowed for a more efficient exploitation of natural resources, and this enabled some people to realise these desires. Local pressure on the forest increased as a result of this. Bantu agricultural expansion went at the expense of space immediately neighbouring their current fields and fallow lands. This space used to be available for Bagyeli, but such arrangements were reconsidered under the changing circumstances. Bagyeli felt the pressure on land. This influenced Bagyeli mobility, yet the effect of this influence depended on the specific circumstances. All this happened in a situation figuring a plurality of normative frameworks regarding forest exploitation, a situation that allows for a rather chaotic exploitation of the forest.

These changes resulted in the current patterns of local forest exploitation. These trends will continue to play a role in the future, and they should therefore be taken into account when planning forest management. Yet one can never predict the exact course of the events. Socio-political and economic realities in Cameroon are rather complex, due to their internal dynamics, which is also a response to trends at the international policy level. In this situation, predicting trends even a decade ahead is particularly hazardous. Therefore, plans for future management should be flexible and allow for regular reopening of negotiations in response to changing circumstances.

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INTEGRATION OF ECOLOGICAL KNOWLEDGE IN SUSTAINABLE MANAGEMENT OF RAIN FORESTS OF SOUTH CAMEROON, WITH SPECIAL REFERENCE TO MYCORRHIZA ASSOCIATIONS

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SUMMARY

Knowledge on functioning of humid tropical forests is crucial in decision-making for ecologically sound forest management (SFM). However, ecological knowledge on components, processes, and interactions in tropical forests remains scanty. The Tropenbos-Cameroon Programme (TCP) is involved in monitoring various ecological parameters of the rain forest of south Cameroon, including species richness and distribution of plant functional types, symbiotic fungi, and vertebrate seed dispersers. Information about nutrient cycling and hydrological fluxes will be included in SFM. Application of ecological principles in SFM is illustrated using results of an investigation on diversity and distribution of mycorrhizal associations in rain forests.

All 97 timber species examined were mycorrhizal: 23 timber species formed ectomycorrhizae (ECM) and 74 formed vesicular-arbuscular mycorrhizae (VAM). The ECM habit was encountered in 13 genera belonging to three families: Gnetaceae, Uapacaceae and Caesalpiniaceae. Eleven ECM genera belong to the Caesalpiniaceae, ten to the tribe Amherstieae and one to the tribe Detarieae. VAM associations dominated young vegetation stands, but were also common in late-successional forest stands. In some patches of old or primary forest stands on clayey and sandy soils, ECM associations occupied a larger basal area throughout the TCP area. Elsewhere, ECM tree species occurred isolated in an array of VAM associations, suggesting habitat partitioning of both mycorrhizal inocula, and giving way to two forest types that differ in stand maturity, canopy openness, and quality and quantity of myco- and phytobionts. Contribution of ECM trees to basal area varied between about 20 and 70%. Numerous ECM fungal species (about 125 species already identified) occurred exclusively in ECM forest patches. Occurrence of forest sites with high ECM fungal and tree diversity can be regarded as indicator of the least disturbed sites. These sites are suitable for forest conservation.

Both mycorrhizal types reacted differently to shifting cultivation and logging activities. Logging practices reduced VAM abundance, and both decreased VAM and ECM activities and this negative impact could last for over a decade. Forest conversion into agricultural fields had a short-term positive influence on VAM abundance and activities but negative effect on ECM activities of the clumped tree *Tetraberlinia bifoliolata.* Thus, both mycorrhizal associations will differ in rate of recovery after large-scale deforestation with ECM associations more likely being wiped out and VAM associations slowly recovering. Consequently, sustainable management of valuable timber resources should include sustainable management of mycorrhizal communities. The same applies for the conservation and management of communities of climbers, seed dispersers, pollinators, and litter and wood decomposers.

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1. INTRODUCTION

One of the most pressing environmental concerns at the dawn of the third millennium is certainly the degradation of habitat and loss of biodiversity in tropical rain forests. Current estimates indicate that at least 100,000 ha of Cameroonian forests are disappearing annually due to agricultural clearings and timber exploitation, causing, in addition, a threat to extinction of wildlife (Anonymous, 1991). In response to the destruction of rain forest habitats and loss of biological diversity, awareness is increasing to developing of methods and strategies to protect biodiversity and ecosystem services of rain forests while maintaining a socially, ecologically, and financially acceptable flow of forest products and services for present human use and generations to come, coined in the concept sustainable forest management (SFM). However, besides social, economical, and technical difficulties, lack of ecological knowledge on forest dynamics has constrained the application of sustainable forest management and conservation practices for a century (Bertault *et al*., 1992).

Contemporary practices to manage and protect natural forests in tropical countries generally consist of planning to set aside a given portion of natural forest areas to national parks and ecological reserves where little or no human exploitation is allowed. However, a small number of ecological reserves are not likely to insure the preservation of the multitude of plant and animal species in tropical rain forests as well as the diversity of habitats for wildlife. In addition, the practice of low-intensity selective harvesting on forest lands, seen as another hypothetical scheme for timber resource conservation could have detrimental impacts, which are not accounted for, on forest soils and tree species without immediate economic value.

Sustainable forest management requires ecological knowledge on structure and specific composition of key forest components. Floristic variations within the same forest patch are linked to complex interactions of climate (precipitation, temperature, light microclimate), soil conditions (topography), and soil chemical, physical, and biological factors such as forest dynamics, biology of reproduction, and seed predation. But qualitative and quantitative information on the components, processes, and interactions in humid forests, and impacts on forest land use practices (FUP) remain scanty. Eleven projects of the Tropenbos-Cameroon Programme (TCP) are involved in gathering data on various ecosystem components and the structure of the rain forest of south Cameroon as well as the influence of FUP on these components and processes. This paper provides an overview of the TCP multidisciplinary approach to ecological knowledge and its implications for SFM, followed by the significance of fungi in FUP, and integration of ecological data of mycorrhizal community dynamics in SFM planning.

2. RELEVANCE OF ECOLOGICAL KNOWLEDGE IN SUSTAINABLE FOREST MANAGEMENT

Ecological knowledge to be integrated in SFM planning should include data on keystone taxa and on essential ecological parameters. It should lead to an understanding of the structure and functioning of rain forests and to prescribed applications of ecological principles on which SFM should be based. Population and community structure and dynamics in forest ecosystems depend on:

- Recognition of the interrelationships among and mutual dependence of various populations of forest taxa;
- Quantitative information about species richness, abundance, and biomass of organisms, their population dynamics (migration, birth, growth, mortality), and transfer and cycling rates of carbon, nutrients and water within forest ecosystem components;
- Acceptance that the human population is a component of all terrestrial ecosystems.

In this paper, the following aspects of the rain forest of south Cameroon are discussed: distribution and diversity of plant species and growth forms and their effects on FUP, phytomass and nutrient cycling, vertebrate seed dispersers, and diversity and distribution of symbiotic fungi. Assessing these components is essential for the fine analyses and interpretation of forest population dynamics and for modelling natural regeneration and growth of forest trees.

Wildlife plays important roles in seed dispersal and dissemination of trees within forest ecosystems. In fact, the nature and composition of fauna and flora are often interdependent. The major contribution of forest elephants (*Loxodonta africana cyclotis*) in the dissemination of large fruit species (Alexandre, 1978) is well known. Many other faunal elements (mammals, birds, insects, etc.) participate in forest tree seed consumption and dispersal and play a fundamental role in forest dynamics and spatial repartition of tree species. Intensive FUP will inevitably lead to decline or disappearance of certain animal species. Disappearance of large, old and hollow trees might lead to disappearance of hornbills, another major group of seed dispersers. But data are almost completely lacking on the consequences of such impacts on the species composition.

Climbers form an important component with major impacts on tree falls during forest exploitation. 90% of liana species are found in tropical rain forests (e.g. Fox, 1968). A few species of lianas are particularly abundant in disturbed forests, whereas many species are present in primary forests but in low abundance. Their role in soil litter build up can be considerable. The diameter distribution seems to follow models of nearby trees, which explains their impact on forest structure during tree felling. In South-East Asia it has been reported that climber cutting before harvesting reduced felling damage on the remaining tree stand (Fox, 1968). Hence, a study of climbers and the effect of climber cutting prior to logging should provide important information for ecologically SFM (see also Parren and Bongers, 2001).

Forest litter is the vegetation / soil interface that insures soil fertility maintenance. In tropical Ultisols and Oxisols, bio-geochemical cycles play a considerable role in concentrating available nutrients in humus in closed-canopy forests. But turnover rates of the nutrients in closed-canopy forests and the recovery rate in disturbed forest patches have not been quantified, at least in Cameroon. Such information is needed to ensure continued soil organic matter production and protection of the soil against direct solar radiation, which speeds up mineralisation. Thus, the following parameters are monitored: above- and below-ground phytomass, net primary production (stems, branches, leaves, flowers, fruits, roots,) as well as their annual variations, and mineral nutrients in the different fractions and in litter.

Floristic diversity is only one aspect of the epitomic biological diversity of tropical forests: of more than three millions living species inventoried, higher plants represent at most 20% (Whitmore, 1990), but more likely considerably less if recent estimates of insect and fungal diversity are taken into account. Soil fauna (termites, ants, earthworms, nematodes, collembola and mites) and micro-organisms (fungi, bacteria, actinomycetes, cyanobacteria, algae and protozoa) represent a considerable proportion of rain forest diversity, forming the forest below ground, often ignored in forest biodiversity. Among beneficial soil micro-organisms, particular soil fungi associate with roots of most higher plants to form mutualistic associations called mycorrhizae. The role of mycorrhizal associations in the regeneration and growth of tree species in tropical rain forests may be critical since the mycorrhizal condition is indispensable for (almost) all tropical tree species. However, these crucial soil biotic components have not been included in projects designed to foster SFM in tropical Africa before TCP started. The TCP mycorrhiza project (F6) will provide basic data on species richness and composition of mycorrhizal fungi and practical implications of FUP on their associations with important timber species. This information is required to interpret species composition and dynamics in undisturbed forest, and is relevant to the management of forest regeneration after exploitation or shifting cultivation, and to the use of indigenous tree species in enrichment planting, plantation forestry, and agro-forestry systems.

3. SIGNIFICANCE OF FUNGI IN FOREST LAND USE

Fungi are essential functional components of forest ecosystems. Their roles in the functioning of rain forest resources include litter and wood decomposition, parasitism of plants, animals and other fungi, and mutualisms (e.g. lichens and symbiotic fungi). Fungi provide food web resources for invertebrate and vertebrate animals, including humans. As a consequence of the various ecological roles, fungi contribute to species and habitat diversification. Fungal species of different functional groups are bio-indicators of the quality of forest habitat and can serve as criteria for SFM.

Saprotrophic fungi decay litter and wood, thereby transforming cellulose and lignin into carbon dioxide and releasing mineral nutrients. They also degrade lignin of the microbial biomass, another important nitrogen source. Part of the non-decomposed material is converted into stable organic matter that guarantees long-term soil fertility. Infection of trees by heterotrophic fungi in the process of killing trees and decomposition after death, leads to softening of their interiors into snags and logs, which are subsequently inhabited by wildlife and a variety of other organisms that are characteristic for pristine rain forests. Saprotrophic and parasitic fungi increase wildlife habitat. Gaps in the canopy develop when diseased trees die and fall, and shade intolerant pioneer plants flourish in these openings, thereby increasing plant species diversity. Mushrooms are important as food for wildlife, and are consumed by small mammals, molluscs, and insects, which are, in turn, primary prey for larger predators. Finally, mushrooms provide protein-rich resources for humans. This treasure has been recognised by local forest dwellers, who recognise more than 50 species of edible mushrooms.

These fungi provide essential ecosystem services and are critically important to the function of healthy ecosystems, but they are difficult to study, especially in natural settings, and their sheer numbers are overwhelming.

Mycorrhizal fungi form long-lived symbioses with the roots of higher plants and serve as mediators of nutrient transport from soil to plant. Their major role in tropical rain forests consists in improved access of mycorrhizal roots to soil nutrients, especially slowly mobile nutrients such as phosphorus. This increased nutrient uptake is due to the extension of the root-absorbing system of host plants by the external mycelia of mycorrhizal fungi, beyond the so-called root depletion zone. Mycorrhizae also protect the roots of host plants from microbial pathogens, create stable soil aggregates and thus prevent soil erosion, increase drought resistance of young seedlings, increase seedling survival, decrease the need for fertiliser inputs, and stimulate the production of growth-promoting substances (Harley and Smith 1983; Sampangiramaiah, 1990). Hence, mycorrhizal fungi are key components of both plant and soil development. Availability of mycorrhizae has been hypothesised to be a determinant of tree species composition in early phases of forest recovery (Janos, 1985) and of tree species composition on P-deficient soils of humid forests (Newbery *et al*., 1988). Exudates and hyphae of mycorrhizal fungi form a major link between above-ground producers and soil food webs, providing an energy source for a wide range of bacteria, protozoa, arthropods, and microfungi. Many large edible mushrooms, such as chanterelles (*Cantharellus* species) and boletes (*Boletus* species) are sporocarps of mycorrhizal fungi.

Most soils in the tropics are strongly acid and highly clayey, high in exchangeable aluminium but low in available P and micro-nutrients (Sanchez and Salinas, 1981). Under such conditions, fertiliser uses would be the norm and widespread in agriculture. However, for financial reasons fertilisers are hardly used by resource-poor tropical smallholders, with nevertheless acceptable crop yields. This may stem from the fact that most tropical crops are mycorrhizal.

4. INTEGRATION OF KNOWLEDGE ON MYCORRHIZAL DYNAMICS IN SFM

Until recently, it was thought that in the tropics mycorrhizal associations are dominated by the vesicular-arbuscular mycorrhizal (VAM) type, and that ectomycorrhizal (ECM) associations are rare and occur in small to large clumps, mainly in sandy, poor and heavily nutrient-leached soils where they confer a competitive advantage to their host plants (Alexander, 1989). In the rain forest of Korup National Park, Cameroon, observation of cyclic mast fruiting of three emergent ectomycorrhizal (ECM) Caesalpiniaceae trees was thought to be possibly related to enhanced phosphorus cycling (PACER hypothesis) (Newbery *et al*., 1997).

Within the TCP research area, all tree species examined formed mycorrhizae. Of the 97 species investigated, 74 species formed only VAM associations and 23 species formed ECM associations, five of which also harboured VAM structures. The ectomycorrhizal habit was encountered in 13 genera in only three families, Caesalpiniaceae (with 10 genera in tribe Amherstieae, most of which are locally known as Ekop and one genus in tribe Detarieae), Uapacaceae and Gnetaceae (Table 1).

Table 1. Diversity of ectomycorrhizal plant families and genera in the Tropenbos-Cameroon Programme area.

Family	Genus	Pilot name
Caesalpiniaceae	*Afzelia*	Doussie
	Anthonotha	Enak
	Berlinia	Ebiara
	Brachystegia	Ekop naga, Ekop evene
	Didelotia	Ekop gombe
	Gilbertiodendron	Abem
	Julbernardia	Ekop blanc
	Monopetalanthus	Ekop mayo
	Paraberlinia	Ekop beli
	Tetraberlinia	Ekop ribi
	Touabouate	Ekop zing
Uapacaceae	*Uapaca*	Rikio
Gnetaceae	*Gnetum*	Okok, Eru

Note: With the exception of *Afzelia* (tribe Detarieae), all ECM genera in the Caesalpiniaceae belong to the tribe Amherstieae.

Mycorrhizal associations of the VAM type dominated all vegetation stands, with the exception of some old or primary forest stands, where ECM associations formed canopy dominants, forming ECM forest clumps. Among ECM tree species, *Afzelia* species rarely occurred in ECM forest clumps, while *Anthonotha* and *Berlinia* often appeared in clumps, though in few stem numbers. In early successional stands, ECM plant species often belonged to species of *Uapaca*, *Berlinia*, *Anthonotha* and *Gnetum*. In fallow dominated by *Chromolaena odorata*, the only ectomycorrhizal plant taxa were *Gnetum* species. Elsewhere in the landscape, no ECM taxa could be observed. Relative abundance in stem number and basal area of ECM phytobionts varied with site from about

20% to 70%. The largest numbers were recorded in Bityili and the lowest in Ebom, with Ebimimbang and Nyangong being intermediate (Table 2).

Table 2. Relative stand composition of ectomycorrhizal (ECM) tree species at four undisturbed forest sites of the Tropenbos-Cameroon Programme (two-hectare plots).

Sites	**Dominant ECM tree**	**Stem**	**Basal area**
		%	%
Ebimimbang	Ekop	22	35
Ebom	Abem	7	19
Nyangong	Rikio	26	34
Bityili	Ekop, Abem, Rikio	71	79

Both mycorrhizal forest types substantially differed in terms of stand maturity, canopy openness, and abundance and diversity of myco- and phytobiont species. VAM forest patches were found in open canopy forests in relatively young stands: such stands are rich in tree species and without or with very few (if isolated ECM trees are present) ECM fungal species. In contrast, ECM forest patches formed a closed-canopy in relatively old forest stands; they were rich in fungal species and showed a more limited number of plant species. They constitute the only habitats for ECM fungal and tree species. Both partners are interdependent; one can not survive without the other. A large number of ectomycorrhizal fungal species were found associated only with ECM Caesalpiniaceae, Uapacaceae, and Gnetaceae (Table 1). It is expected that after completion of the F6 projects some 150–200 ectomycorrhizal fungal species will have been identified. A provisional key of ECM fungal species that is already available contains 125 species (Table 3). Species-rich fungal genera are *Amanita*, *Russula*, and *Lactarius*, and members of the Boletales and Cantharellaceae, whereas the genera *Scleroderma*, *Cortinarius* and *Inocybe* contain only limited species richness. The only ectomycorrhizal fungi that are locally consumed are *Lactarius gymnocarpus* and a few *Cantharellus* species.

Table 3. Species richness of ectomycorrhizal fungi at the Tropenbos-Cameroon site (preliminary list, species identified up till December 1999).

Family	**Genus**	**Number of species**
Sclerodermataceae	*Scleroderma*	2
Russulaceae	*Russula*	30
	Lactarius	11
Cantharellaceae	*Cantharellus*	10
	Craterellus	2
Gomphaceae	*Gomphus*	1
Hymenochaetaceae	*Coltricia*	1
Clavulinaceae	*Clavulina*	1
Amanitaceae	*Amanita*	30
Cortinariaceae	*Cortinarius*	3
	Inocybe	8
Paxillaceae	*Paxillus*	2
Boletaceae	*Phylloporus*	1
	Boletellus	1
	Strobilomyces	4
	Phlebopus	2
	Gyrodon	1
	Gyropus	2
	Rubinoboletus	1
	Tubosaeta	3
	Chalciporus	1
	Boletus	4
	Pulveroboletus	2
	Tylopilus	1
	Leccinum	1
Total		**125**

Mycorrhizal inoculum potential (MIP) refers to the capacity of infective propagules (spores, dead root fragments, colonised organic matter, soil hyphal networks) of mycorrhizal fungi present in soils of a given habitat to become established within the roots of host plants, giving rise to colonisation (infectivity) and to provide benefits to the plant (effectivity).

Spore density and percent root colonisation (PRC) of VAM fungi were significantly decreased by forestry practices (skid trails and landings, see Table 4). VAM fungal population density and activity recovered only slowly in skid trails invaded by the facultatively VAM pioneer tree *Musanga cecropioides* (Table 5). VAM fungal populations were increased by agricultural practices, both in agricultural fields and in fallow of *Chromolaena odorata*. Seedling growth in soils with differences in VAM inoculum potential showed the same pattern: slow growth of timber tree seedlings on soils from skid trails, bare landings, and landings with *Musanga*, and good growth on soils from agricultural fields and *Chromolaena* fallow. In cases where seedlings grew poorly, inoculation with grass inoculum could boost seedling growth substantially, suggesting that scarcity of VAM inocula could limit forest regeneration.

Table 4. Spore numbers and percent root colonisation of vesicular-arbuscular mycorrhizal fungi in different vegetation types (averaged across sites, percent root colonisation of *Distemonanthus benthamianus* grown in intact cores).

Disturbance stages	**Spore density**	**Root colonisation**
	number/g dry soil	%
Late successional stands	12 c	30 c
Early successional stands	21 b	34 c
Skid trails	8 c	18 d
Landing	5 c	14 d
Field before burning	21 b	49 b
Field after burning	39 a	28 c
Fallow of *Chromolaena odorata*	38 a	62 a

Notes: Means followed by the same letter in the same column are not significantly different at 5% level of significance.
Forestry practices include skid trails and landings.

Table 5. Recovery rate in populations and activity of vesicular-arbuscular mycorrhizal fungi along differently aged skid trails.

Ecological mycorrhizal parameters	**Age of skid trails (years old)**				
	1	3	6	10	15
Spore density (number/g dry soil)	11 ns	10 ns	5 ns	6 ns	7 ns
Root colonisation (%)	5 c	15 b	23 a	24 a	26 a

Notes: Means followed by the same latter in the same column are not significantly different at 5% level of significance; ns = not significant at 5% level of significance.
6, 10 and 15 years old skid trails were invaded by the early successional tree *Musanga cecropioides*.

Ectomycorrhizal inoculum potential (EIP), assessed as PRC of roots of *Tetraberlinia bifoliolata*, was generally absent in soils from agricultural fields, fallow of *Chromolaena odorata*, and sites of logging practices. Little EIP persisted in fallow with *Gnetum* species, and in early successional stands, owing to the presence of some ECM host tree species and the *Gnetum* liana. It was only in late successional forest stands and especially in forest clumps that EIP was high (Table 6). Seedling growth of ECM trees in soils in which EIP was high was significantly better than in soils without ECM inoculum.

Table 6. Ectomycorrhizal inoculum potential in different vegetation types (percent colonisation of root tips of *Tetraberlinia bifoliolata* grown in intact soil cores; average of three cores across three sites).

Disturbance stages	LS	LC	ES	FP	FI	FA	FG
Root colonisation (%)	31	54	8	0	0	0	2

Notes: LS = late successional forest stands; LC = ECM forest clumps; ES = early successional forest stands; FP = forestry practices, including skid trails, bare soil and re-vegetated *Musanga* landing; FI = agricultural fields; FA = fallow of *Chromolaena odorata*; FG = fallow with *Gnetum* species.

5. DISCUSSION: RECOMMENDATIONS FOR SUSTAINABLE FOREST MANAGEMENT

The distribution of ECM and VAM associations throughout the TCP area indicates two major mycorrhizal forest types of contrasted structure and species composition. Hence, VAM and ECM forest patches require different management and conservation requirements. At the level of the forest management unit, the localisation of individual ECM trees in VAM forests during management inventory should be given special attention, owing to the specific regeneration requirements of their seedlings for ectomycorrhizal inoculum, and for the conservation of the locally unique ECM inoculum. Hence, small forest refugia around ECM trees should be set aside within to be logged forests to provide shelter for rare forest species communities and those with specific regeneration and growth demands.

At the landscape level, it is likely that, due to poor seed and spore dispersal, ECM associations will not survive large-scale deforestation, contrary to VAM associations. Occurrence of forest sites with high ECM fungal diversity can therefore be regarded as indicator of least disturbed sites and such sites deserve special attention for forest conservation.

Logging practices reduced abundance and activities of VAM fungi on skid trails and landings and their negative impacts persisted for a long time. On the other hand, a positive influence of forest conversion to agricultural fields on VAM populations was suggested. Most soils were nearly devoid of ectomycorrhizal inoculum except for soils from clumps of ECM Caesalpiniaceae and old forest patches. Therefore, FUP that allow persistence of mycorrhizal fungi on site until new trees become established should be adopted, notably reduced trafficking and proliferation of landings during logging activities. Critical aspects of tropical mycorrhizal ecology with strong sustainable management implications at the scale of forest management units will consist in the initial assessment of mycorrhizal inoculum potential of forest stands recommended for plantation enrichment with poorly naturally regenerating tree species or trees that are threatened with extinction. If the target enrichment sites are old skid trails and landings, the findings of this study imply that the management strategy should boost VAM infectivity by inoculation of nursery soils. In addition, future SFM will require to know in advance the extent of mycorrhizal dependency of currently harvested timbers to ensure a strong natural regeneration of their saplings and juveniles. If agricultural fields are accidentally created within a FMU, it would require to look for ecologically adapted VAM communities for a successful reforestation.

A primary objective for managing mycorrhizal fungi on a landscape level consists in creating or maintaining sufficiently large and connected habitats to sustain viable populations of all species. Within this goal, managers may wish to ensure a steady supply of readily accessible habitats that produce abundant mycorrhizal structures after exploitation, before the next harvest cycle. Three aspects of habitat that influence mycorrhizal communities with most relevance at the scale of landscape are major differences in forest type, differences in successional stage within a given forest type and microhabitat diversity within each forest type and successional stage.

During management inventory, forest types, successional stages, and unique microhabitats harbouring high levels of mycorrhizal fungi, need to be identified, mapped, and inventoried for sustainable use and conservation of rain forest biological and functional diversity. The same holds for the sustainable use and conservation of communities of other organisms, such as higher plants, climbers, seed dispersers, pollinators, and litter and wood decomposers.

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SHIFTING CULTIVATION PRACTICES AND SUSTAINABLE FOREST LAND USE IN THE EVERGREEN FOREST OF CAMEROON

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SUMMARY

Studies were conducted conjointly on forest management and farming systems in order to achieve sustainability of the forest production in the Tropenbos-Cameroon research site. Results on some aspects of farming systems are here presented. They show that a farm in the evergreen forest of Cameroon is composed of many subsystems interrelated and influenced by external biophysical and socio-economic parameters. According to 92% of the farmers interviewed, the cropping subsystem remains the first priority activity. In this cropping subsystem, 80% of the farmers considered shifting cultivation involving food crop fields and fallow as their first priority land use type. Four major crop associations highly linked to the preceding fallow type were identified in the food crop fields. Today, 76% of food crop fields in the area shift within fallow of different ages in a rotational system. Only 24% of agricultural fields expand towards undisturbed forest for cucumber (*Cucumeropsis mannii*) production and for establishment of semi-industrial farms by elite. The population pressure, the type and objective of crop production, the limited labour, and the access to new land have prompted more farmers to abandon the traditional expansive shifting cultivation and to adopt the rotational system. The latter consist of shifting in a total area of less than 10 hectares, clearing short length fallow. This reduction in fallow length leads to degradation of topsoil morphology and physical soil properties, and to drastic reduction in plant species diversification. For a sustainable management of the forest zone of southern Cameroon, solutions must be found to two main problems: (1) the shortening of the fallow length leading to soil productivity degradation and (2) the unsustainable non-prosperous subsistence shifting cultivation destroying the forest ecosystem. Solutions in the form of recommendations deal with soil productivity improvement and conservation and the move from subsistence to income generating farming.

Keywords: shifting cultivation, farming systems, soil degradation, sustainability, forest land use, Cameroon.

1. INTRODUCTION

Shifting cultivation is the dominant farming system practised in the tropical forest zone of Cameroon for food crop production. Information on this type of land use in the moist evergreen forest of South Cameroon is very sparse. The Tropical Forest Action Plan (MINAGRI, 1989) does not foresee a significant agricultural pressure on forest land in southern Cameroon. However, the present trends in shifting cultivation practices, under increasing local population growth and influence of market economy as result of local infrastructure development (rural electrification, road construction, etc.), may well lead to agricultural land expansion and a threat on forest management and conservation.

The objective of the Tropenbos-Cameroon Programme is to develop methods and strategies for natural forest management directed at sustainable production of timber and other products and

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services. In order to achieve sustainability of the forest production in the area, sustainability of crop production must be studied conjointly, since shifting cultivation systems represent a threat to forest as well. It was in this regard that a study was carried out on farming systems in order to provide a comprehensive description of the shifting cultivation system practised in the area and an insight on soil fertility degradation related to such agricultural practice.

This paper presents a brief description of the practice of shifting cultivation, discusses its relationship with logging activities and changes in soil and plant species composition, its sustainability and that of the forest land use as a whole.

2. THE STUDY AREA

The research area covers the whole Tropenbos-Cameroon Programme (TCP) site located 70 km east of Kribi between 2° 47’ - 3° 14’ North, and 10° 24’ - 10° 51’ East. The physiography is of undulating landscape with relief intensity increasing from west to east and southeast. The altitude varies from 180 to 900 m. The climate is of the equatorial type (Köppen, 1936), characterised by two rainy seasons and two dry seasons. The mean annual rainfall is 2000 mm and the mean annual temperature is 25°C. The vegetation is one of the low and mid-altitude evergreen Atlantic forest (Letouzey, 1985). Soils are derived from metamorphic rocks belonging to the basement complex, traversed in some parts by old intrusions of plutonic rocks (Champetier de Ribes and Reyre, 1959; Champetier de Ribes and Aubague, 1956). From west to east, cristallophyllian series (with ectinites and migmites) change to the calco-magnesian complex of Ntem (with leuco-mesocrate gneiss and pyroxenic granites). Excepted some wetland soils encountered in few inland valleys, soils of the site are mainly Ultisols and Oxisols (van Gemerden and Hazeu, 1999) as classified in the USDA system (Soil Survey Staff, 1992). Ultisols are dominant in dissected plains of low altitude (180 – 350 m) area of the Bipindi region. These soils cover about 30% of the research area. Oxisols are encountered in higher altitude (>350 m) regions of Akom II, Lolodorf and Ebolowa. They cover more than 65% of the whole area.

3. METHODOLOGY

The methodology consisted of the collection of secondary data through consultation of existing documents, interview of key informants, and the collection of primary data through surveys conducted in the research area. The participatory approach was used in the field for exploratory survey in the whole site. Cases studies were used for a more detailed characterisation of farmer’s priority setting and strategies for soil fertility management.

Four sub-site areas were selected for soil degradation studies. The sub-site selection was based on the physiographic units described by van Gemerden and Hazeu (1999). The soil degradation study involved many aspects related to soil survey, on-farm studies and analytical studies as well. Soil sampling for bulk density and aggregate stability analyses were carried out at two depths of 0-10 and 10-20 cm, in shifting cultivation fields, skid tracks, fallow and undisturbed forest. Aggregate stability was determined at the TCP laboratory in Kribi by the water-drop method (Imerson and Vis, 1984). Bulk density was determined at IRAD laboratory in Nkolbisson by soil oven dry technique (at 105°C). Skid track raw data utilised in the Analysis of Variance were obtained from Waterloo *et al*. (2000), who used a similar method of sampling. For routine laboratory analyses, composite soil samples were collected with auger at five spots on a diagonal basis in each type of field and type of land use, at three depths (0-10, 10-20 and 20-50 cm). The analyses concerned pH water and KCl (1:2.5 ratio), organic Carbon (Walker and Black method), total Nitrogen (Kjeldahl digestion), available Phosphorous (Bray II method), exchangeable bases (extraction with 1M NH4OAc), Cation Exchange Capacity (extraction with 1M NH_4O at pH 7), Exchangeable acidity (leaching with 1M KCl and titration by 1M NaOH), particle size distribution (pipette method). The trend of agricultural field expansion was studied based on aerial photographs and field size measurements from selected farmers.

Data were analysed statistically using Systat software. Cumulative frequency was performed for priority setting. Analysis of variance (ANOVA) was performed for changes in soil properties under various fields and land use types.

4. SHIFTING CULTIVATION IN THE FARMING SYSTEM

4.1. Farm as a system

Generally, the production systems of a farm (Farming Systems) in the evergreen forest of Cameroon is composed of the subsystems Household, Cropping, Animal, Soil, and Non-agricultural activities such as Hunting, Fishing, Off-farm activities, etc. (see Figure 1). These subsystems are interrelated and are under the influence of external biophysical and socio-economic parameters such as climate, road and market infrastructures, market price, land tenure law, credit availability, etc.
According to 92% of the farmers interviewed, cropping subsystem activities (Crop production) are the first priority activities, followed by animal husbandry, then fishing, palm wine tapping, wild fruits collection, hunting, and oil palm exploitation (Table 1). In the cropping subsystem, shifting cultivation involving food crop fields and fallow is the first priority land use type according to 80% of the farmers, followed by perennial plantations, then home gardens (Table 2).

Table 1. Farmers' priority activities

Major Activities	**Rank**	**Frequency of farmers ranking responses**	**Reasons of Importance**
		%	
Crop production	1	92	Diverse consumption & revenues
Animal husbandry	2	29	Guests reception, dowry, ceremonies
Fishing	3	35	Local consumption, less revenue
Palm wine tapping	4	45	Consumption and unstained revenues
Wild fruits collection	5	22	Seasonal consumption and revenues
Hunting	6	32	Diverse consumption and revenues
Palm oil extraction	7	48	Simple local consumption

Sample size n = 200

Table 2. Farmers' priority land use in a farm

Land use type	**Rank**	**Frequency of farmers ranking responses**	**Reasons of Importance**
		%	
Shifting cultivation	1	80	High consumption and revenues
Perennial plantations	2	56	Decreasing revenues
Home garden	3	72	Various consumption with low revenues

Sample size n = 200

4.2. Spatial Land Use on the Farm

Farm land use for crop production begins with small gardens adjacent to the house, where the farmer maintains an ecosystem of plants and animals composed of useful domesticated forest trees, local and introduced fruit trees, annual/biannual and perennial food crops (Table 2), and chickens, goats, pigs, sheep and ducks (Table 3). Perennial plantations with oil palm and cocoa - the major export cash crop - lie further away.

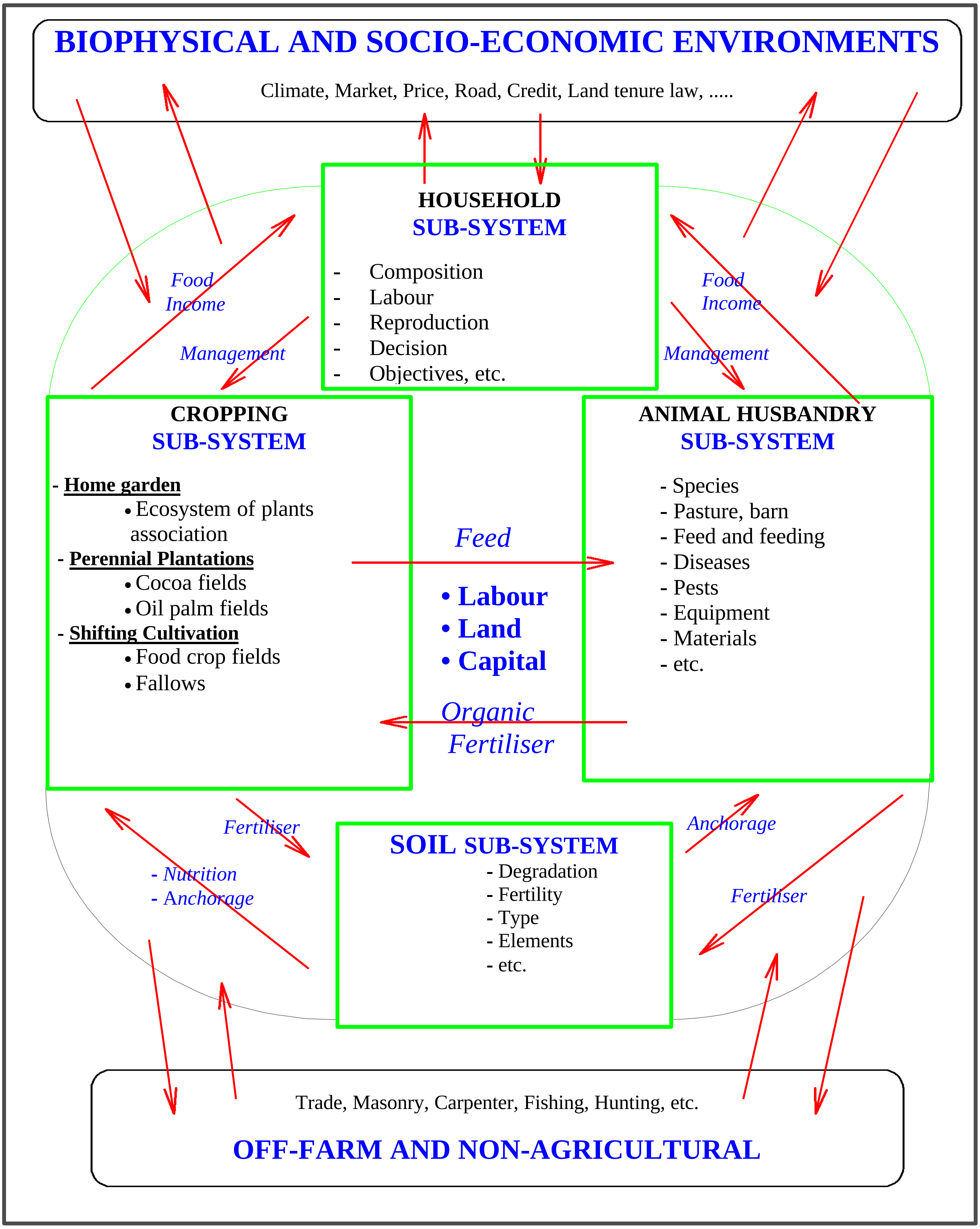

Figure 1. Subsystems of the farms in the forest zone

Farthest from the house, at the forest's edge, food crop fields are found where more than 20 species of crops (cassava, cocoyam, banana/plantain, cucumber, groundnut, maize, sweet potatoes, fruit trees, sugar cane, pineapple, vegetables, etc.) are grown in association alternates with short and/or long length fallow. Crops represented in higher density in the association are termed major crops (cassava, cocoyam, banana/plantain, cucumber (*C. mannii*), groundnut, maize, yam). Crops represented in lower density are termed minor crops (vegetables, fruit trees, sugar cane, pineapple, etc.).

Four major crop associations, highly linked to the type of preceding fallow, have been identified:

- Cucumber (*C. mannii*) / cocoyam / plantain / maize (from a cleared and burned forest fallow);
- Groundnut / maize / cassava / cocoyam / plantain (from a cleared and burned bush fallow);
- Groundnut / maize / cassava / cocoyam (from a cleared and burned Chromolaena fallow);
- Cucumber (*Cucumis sativum*) cocoyam / plantain / maize (from a cleared and burned bush fallow).

Minor crops are more or less found in all these associations.

Table 3. Farmers' priority reared animal species

Priority species		**Rank**	**Frequency of ranking %**	**Reasons of importance and constraints**
Pilot name	Scientific name or race			
fowl (chicken)	*Gallus sp.*	1	37	Local consumption during guests' reception and ceremonies; pests are frequent.
pig	African local race	2	39	Guests reception and ceremonies; pests are frequent; divagation
goat	Guinean thin race	3	40	Wedding and traditional ceremonies; diarrhoea; divagation
sheep	Djalonke	4	43	Wedding ceremonies and guests' receptions; divagation.

Sample size : n = 200

4.3. Shifting Cultivation and Agricultural land Expansion

Today, the shifting characteristic of this cropping system is defined in two directions:

- The first direction is that of shifting within fallow plots of different ages. This constitutes a rotational system, which is normally the more stable part of the system. It concerns mainly food crop fields and 76% of food crop fields in the area rely on this rotational system.
- The second direction is that of agricultural fields expanding towards new lands under undisturbed forest. This is the pure expansive system, which constitutes more threats to forest conservation and sustainable management systems. This system (24% of the food crop fields) is practised mainly for cucumber (*C. mannii*) production and for the establishment of semi-industrial farms by the elite. For this system an average of 2200 m² of new forest land is opened by each household per year in the TCP area. This average surface corresponds to about 300 m² per inhabitant. Ebimimbang plains and Mvié uplands have highest rate of forest encroachment per year and per household with values of 2450 m² and 2650 m² respectively. These higher rates can be explained by the fact that their landscape is more accessible for agricultural practices, and that these areas have been under commercial logging many times.

From the Landscape Ecological Survey of the study area based on aerial photograph of 1984/1985, over a total area of 51 180 ha were used for low to high intensity agriculture. This agricultural area represented about 31% of the total area (Table 4). The expansion of agricultural fields in the TCP area is a function of many factors such as the population growth, the increasing roads network, the landform accessibility, etc. From 1984 to 1997, the proportion of land under agricultural use changed from 31 to 40.3%. This corresponds to an average annual expansion of 0.71% of the total land area, for an absolute value of 1,267 ha.

Table 4: Extent of the areas influenced by shifting cultivation in 1984 and 1997 (adapted from van Gemerden and Hazeu, 1999)

Intensity of shifting cultivation	**Extent**			
	ha		%	
	1984	1997	1984	1997
No to hardly any	116 170	99 472	69	59.7
Low to High intensity	51 180	67 652	31	40.3

4.4. Fallow types

The limited labour and access to new land have prompted more farmers to abandon the traditional and expansive shifting cultivation and adopt the rotational system. The latter consist of rotating in a total area of less than 10 hectares, where the farmer clears each season, either Chromolaena fallow (age: 3 to 5 years), either bush fallow (age: 7 to 9 years), or forest fallow (age: more than 10 years). The above classification of fallow based on vegetation age is the farmers' definition. It is difficult for farmers to recall the precise age of a fallow. The corresponding local words for the different types of fallow are *Afan* for virgin forest or forest fallow, *Nnom ekotok* for bush fallow, and *Ekotok Ngoumgoum* for Chromolaena fallow. The type of fallow cleared is highly linked to the major crops to be grown. Virgin forest and forest fallow (*Afan*) are cleared to grow *ngon* (*C. mannii*) with associated crops. Bush fallow (*Nnom ekotok*) is cleared to grow *ngon/seng'le* (*C. sativum*) and groundnut with associated crops, or to grow groundnut and plantain with associated crops. Chromolaena fallow (*Ekotok Ngoumgoum*) is cleared to grow groundnut and associated crops. The choice of the virgin forest or forest fallow to clear is based on the presence of some tree species indicating good or bad soil fertility (see Tables 5 and 6).

Table 5. Some plant species used by farmers as indicators of good soil fertility

Local or Pilot name	**Scientific name**	**Family**	**Frequencies of farmers responses**	
			Number	Relative frequency
				%
Eteng/Ilomba	*Pycnanthus angolensis*	Myristicaceae	49	16.3
Doum/Fromager	*Ceiba pentandra*	Bombacaceae	38	12.7
Akom/Fraké	*Terminalia superba*	Combretaceae	36	12.0
Essombo	*Rauvolfia macrophylla*	Apocynaceae	24	8.0
Asseng	*Musanga cecropioides*	Moraceae	20	6.7
Ekouk	*Alstonia boonei*	Apocynaceae	20	6.7
Others	-	-	113	37.6
Total			300	100

Table 6. Some plants species used by farmers as indicators of poor soil infertility

Local or Pilot name	**Scientific name**	**Family**	**Frequencies**	
			Number	Relative frequency
				%
Elon / Tali	*Erythrophleum ivorense*	Caesalpiniaceae	44	18.6
Alan	*Hylodendron gabonense*	Caesalpiniaceae	28	11.8
Adjom	*Afromomum citratum*	Zingiberaceae	21	8.9
Ebay	*Pentaclethra macrophylla*	Mimosaceae	16	6.7
Eyen	*Distenomanthus benthamianus*	Caesalpiniaceae	14	5.9
Others	-	-	114	48.1
Total			237	100

In the rotational system, the length of the fallow period gets shorter. Most farmers are now clearing short fallow such as Chromolaena fallow (Table 7).

Table 7. Farmers' priority fallow types

Fallow Types	Rank	Frequency of farmers ranking responses	Reasons of importance
		%	
x <= 3 years	3	60	Good for few crops; less difficulties tilling.
Chromolaena fallow 3 < x <= 5 years	1	64	Less labour for clearing; Enough fertility to grow many crops.
Bush fallow 7 < x <= 9 years	2	46	Good fertility recovery; but labour for clearing and difficulty tilling because of tree stubs.
Forest fallow x >= 10 years	4	36	Labour demanding for clearing. More difficulties tilling because of tree trunks and stubs. Few crops grown, mainly *Cucumeropsis mannii*.

Sample size : n = 200

4.4.1. Commercial logging and agricultural farming activities

Shifting cultivation and commercial logging are the two main man activities in the study area, which contribute to deforestation and represent threats to forest conservation. Although logging is mainly an industrial and temporary activity of Logging Companies, it has a strong influence on the shifting cultivation of rural population in the area. The relationship between the two activities is highlighted in the following aspects:

- Roads and skid tracks opened by logging activity are used by farmers to create new farms in the virgin forest for shifting cultivation. This is confirmed by the pattern of agricultural land distribution along the roadsides.
- The presence of Logging Companies always improves the food crop market system in the villages and the neighbourhood. This forces farmers to increase their production by increasing the farm size.
- Logging and farming activities are both contributing to degradation of soils. Bulk density and aggregate stability of the top A-horizon of Oxisols were significantly higher ($p<0.05$) in soils under agriculture and on skid tracks compared to the undisturbed forests (Table 8).

Table 8. Bulk density and Aggregate stability variation with land use type

Character	Land Use type			
	Shifting cultivation fields	Skid track (Waterloo *et al*., 2000)	Fallows	Undisturbed forest
Bulk density (g/cm^3)	1.10 - 1.24 **a** (n = 28)	1.27 - 1.30 **a** (n = 46)	1.05 - 1.11 **b** (n = 32)	0.99 = 1.09 **b** (n = 24)
Aggregate stability (Number of water drop)	50 -70 **a** (n = 18)	30 - 60 **a** (n =25)	100 - 180 **b** (n = 18)	> 180 **b** (n=12)

N.B. **a** and **b** are significantly different at $p<0.05$

4.4.2. Causes and effects of the reduction in fallow length

For the poor farmers of southern Cameroon, the prime functions of fallow within the shifting cultivation system are production (food crops, fishing, hunting, medication, crafting and construction) and soil productivity reconstitution. The land inventory carried out in the area (van Gemerden and Hazeu, 1999) showed that only dissected plains and uplands mapping units were mainly used for shifting cultivation. These units suitable to agricultural activities represent only less than 50% of the total area. Sixty four percent of the farmers are today considering and clearing short length Chromolaena fallow as their first priority fallow. This reduction in fallow length leads to continuous degradation of soil, poor yields, and biodiversity losses.

4.5. Causes of fallow length reduction

4.5.1. Agricultural land shortage and land tenure

In the TCP area, less than 50% of the total area are accessible for crop production because of their flatness or their gentle sloppiness. But in the traditional land tenure system, the land claim is by kin group according to first clearing of the forest (Nounamo and Yemefack, 1997). Access to land is limited because user rights are not given to farmers not belonging to the family. These family rights to land limit people's access to more land and restrict each member of the family to only their own fallow land.

4.5.2. Population pressure
The rural population growth was moderate due to constant urban migration. But with increasing city jobless today, young people are coming back to the village for agricultural occupation. Actually the population growth due to backward migration (16.5%) and birth rate (7.3%) is increasing needs for arable land, leading to the decrease in fallow periods.

4.5.3. Type and objective of crop production
The choice of the type of fallow to clear is also a function of the crop to be grown and the land availability. The choice of the type of crop to grow is a function of production objectives (income, consumption, or both), of the availability of the market and of the easy evacuation of the produce. Cassava, maize, cocoyam, and groundnut are the first priority crops of the farmers because they are cultivated for revenue and consumption. Their production requires the clearing of the more suitable fallow, which in this case is short length Chromolaena and Bush fallow. Old fallow and undisturbed forests are mainly cleared for *Ngon* (*C. mannii*) production, or for establishment of semi-industrial farms by the elite for the production of high income generating crop.

4.5.4. Soil Al-toxicity reduction
Short fallow, especially Chromolaena fallow, produces an important biomass for burning. The burning releases soil ashes which act as a lime and significantly ($p<0.05$) increases soil pH, reduces Al-toxicity, increases phosphorous and exchangeable bases (specially Calcium), and reduces C/N ratio. Farmers prefer to clear more young Chromolaena fallow lands to grow groundnut. These young fallow lands are more suitable for groundnut production because of their relative richness in available phosphorous.

4.5.5. Labour shortage to clear forest land
Food crop production is mainly women activity. The use of hired labour is rare and is not easily affordable. The most labour demanding activity in food crop production is tree felling and land clearing. The cost to clear 1 ha of forest fallow now averages to 40,000 to 50,000 F CFA. Farmers who cannot afford to clear forest fallow will restrict themselves to clearing short length Chromolaena fallow.

4.6. Effects of fallow length reduction
4.6.1. Soil morphology degradation
The topsoil (3-5 cm) A_1 horizon is a characteristic horizon for climax tropical rain forest soils. It is a humic horizon, very rich in fine roots, very friable, very porous, with a granular subangular structure induced by the fine rooting system. It is within this A_1 horizon that farmers plant with zero-tillage, cucumber (*C. mannii*) and maize (*Zea mays*) after the clearing of old forest. After these crops are harvested, systematic clearing, burning and tilling take place for groundnut and cassava field establishment. The A_1 horizon disappears under this systematic tilling. It reappears when the land is left under fallow for more than 10 years. Figure 2 shows the development of this horizon with the age of the natural fallow.

4.6.2. Chemical soil properties changes
In the two main soils (Ultisols and Oxisols) of the study area, the top 20 cm are significantly ($p<0.05$) affected by shifting cultivation practices involving short fallow systems.

Organic matter: As the length of fallow reduces, the organic carbon decreases, though slightly, and the C/N ratio diminishes significantly (Figure 3):

- Available Phosphorous: The available phosphorous is generally very low in the soils of the whole study area. It is less than 5 PPM in the first 20 cm of the soil profile. But, the decrease in fallow period length increases very significantly ($p<0.01$) its availability in 0-10 cm of the surface layer. The availability of phosphorous in the cropped land is multiplied at least by a factor three after burning of the vegetal material as compared to the values obtained in the virgin forest. The highest values are obtained when the cropped land is opened from a short fallow land. The availability of phosphorous is reduced by the increasing age of the fallow. After about eight years of natural fallow, the situation becomes similar to that of the virgin forest.
- Cation Exchange Capacity (CEC), Bases Saturation Percentage: The CEC is low in all the soils of the area (less than 14 $Cmol^{+}$/g of soil). It is relatively higher in 0-20 cm layer of Ebom and Nyangong soils. The fallow age has low influence on the CEC, but the general tendency is a decrease in CEC and ECEC in short fallow and cropped land. Bases Saturation Percentage (BSP) increases under shorter fallow. This increase of BSP is more sensible in Ultisols (Ebimimbang soils) with significant differences ($p<0.05$) between cropped land and the virgin forest (FV).

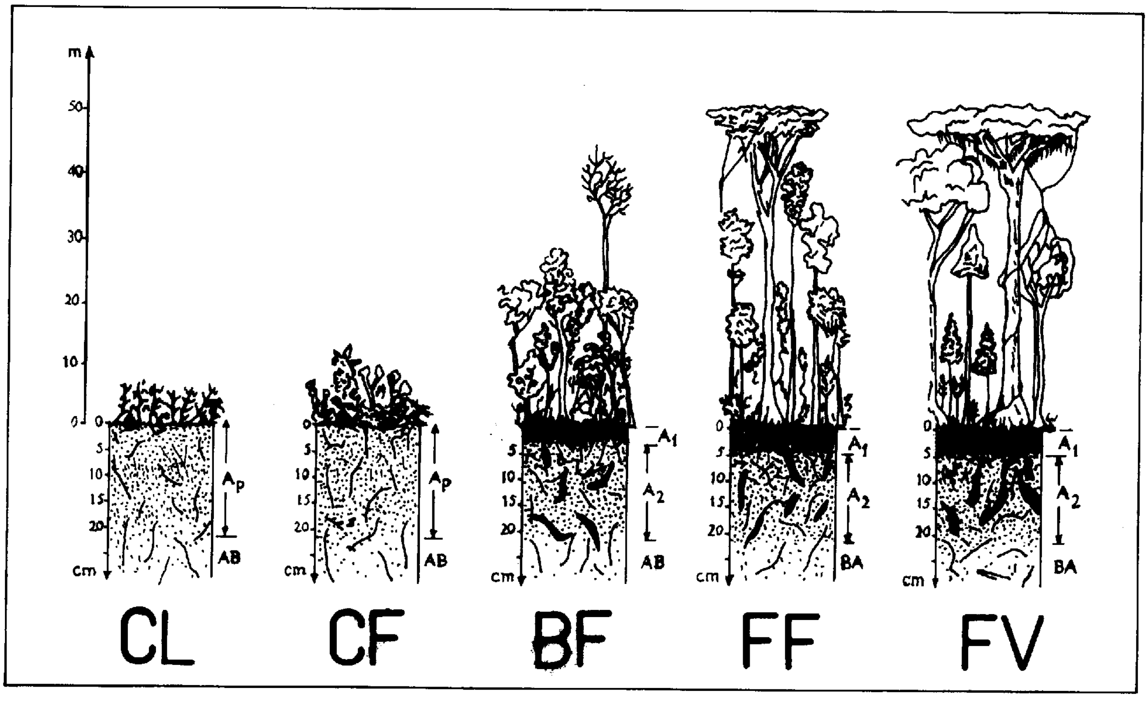

Figure 2. Development of the topsoil layer with the age of the natural fallow (after Yemefack and Nounamo, 1999).
CL = Crop Land (based on groundnut-maize-cassava); CF = Chromolaena Fallow (3 to 5 year old);
BF = Bush Fallow (7 to 9 year old); FF = Forest Fallow (more than 15 year old); FV = Virgin Forest (control).

- pH and Exchangeable Bases: pH and Exchangeable Bases increase very significantly ($p<0.01$) when land is taken into short fallow practice. They decrease progressively with the fallow age increase. This increase in pH and Exchangeable Bases is ascribed to the effect of ashes from burned vegetation biomass at the beginning of the cropping period, which act as lime fertiliser. The contribution of Calcium in these variations of pH and Exchangeable Bases is about 85%.

- Exchangeable Aluminium: In Oxisols (of Ebom, Mvié and Nyangong) the decrease in fallow length reduces the availability of exchangeable aluminium and therefore the Al-toxicity (Figure 3).

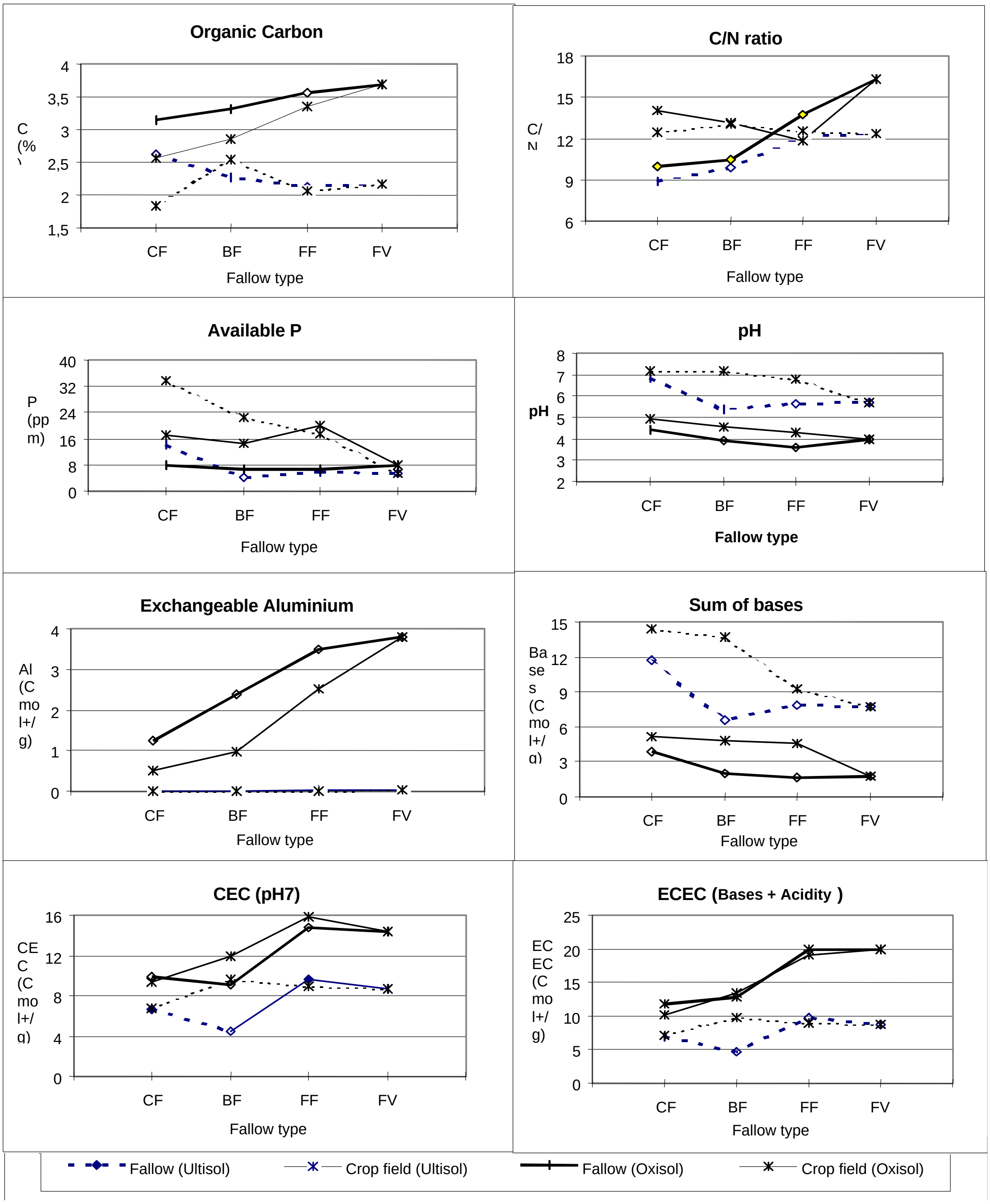

Figure 3: Chemical soil properties (0-10 cm) variation within the shifting cultivation system between fallow type and the adjacent crop field.

4.6.3. Physical soil properties changes

Figure 4 shows that the clay content decreases slightly in young fallow while coarse sand content and bulk density increase significantly ($p<0.05$). These changes are the consequences of the disappearance of A_1 -horizon under short fallow.

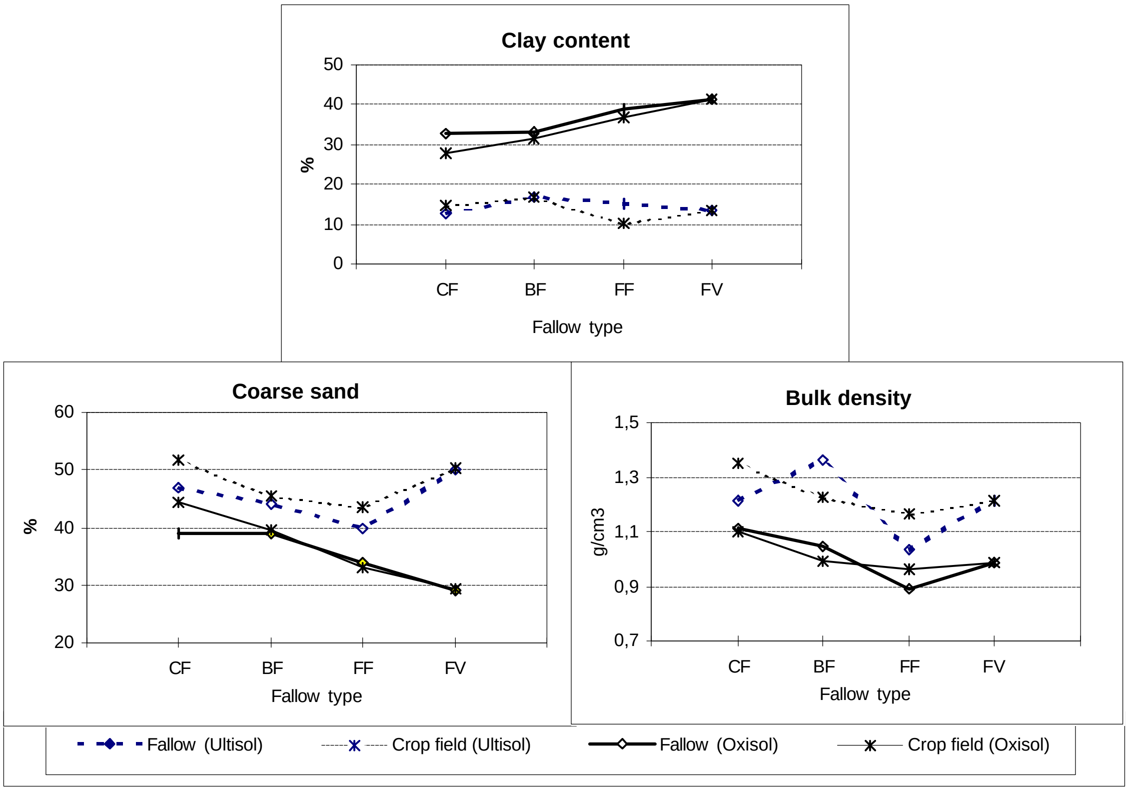

Figure 4. Physical soil properties (0-10 cm) variation within the shifting cultivation system between fallow type and the adjacent crop field.

4.6.4. Soil regeneration, forest growth and species diversification

From clearing a piece of forestland for cropping to the formation of a secondary forest during the fallow period, soil constituents undergo important changes. But the effects of these changes vary from one property to another. The results on the effects of fallow reduction study groups roughly the soil properties in two categories according to their behaviour vis-à-vis the fallow length. The pH, exchangeable bases, exchangeable acidity and available phosphorous are improved under short fallow systems. In contrast, the morphological development of A_1 subhorizon, organic matter, soil texture, and bulk density are relatively degraded under short fallow.

Ashes from burned vegetation biomass at the beginning of the cropping period act as lime fertiliser and influence significantly some chemical soil properties. This liming effect of ashes is reduced by crop harvesting, leaching of cations, and sheet erosion due to heavy and strong rainfalls on bare soil at the beginning of the cropping season. According to many authors (Tulaphitak *et al*., 1980; Prat, 1990), the most important loss of ash nutrients during the cropping period in shifting cultivation takes place in the period between burning and soil surface covering by crops. This process of soil exhaustion continues during the whole cropping period. After two to three years of cropping the land is abandoned for natural fallow.

The beginning of the natural fallow phase constitutes an era of new vegetation dynamics. The natural vegetation grows rapidly, partly from new seedlings, partly from root systems inherited from the previous fallow. The erosion and leaching processes are considerably reduced by the vegetation cover. Besides, the biotic processes between the new vegetation and the soil surface are intensified. Nutrient elements released from litter decomposition are either used immediately by the vegetation in place or added directly to the topsoil. The increase in nutrients content of the topsoil and the humus content occurs simultaneously. The vegetal population develops a dense fine root criss-crossing system in this topsoil horizon to better ensure plant nutrition. This results in the formation of A_1 horizon. This A_1 horizon, although very humic, is very thin (3-5 cm) and its contribution to the organic carbon content of 0-20 cm layer is not enough to provide significant differences between various cover types. In this process of natural reforestation, a number of physical soil properties seem to really benefit from these changes. Also, the soil structure and the porosity of the topsoil layer are highly influenced by erosion and the development of the A_1 horizon. The fine rooting system in this A_1 horizon changes the subangular blocky structure of the eroded topsoil into a porous granular structure.

In this process of natural forest regeneration, species richness of some timber species is highly influenced by the fallow age (Bongjoh and Nsangou, 1999). Species richness was higher in the understorey than in the nearby fallow fields. In general, clearing forest for cultivation reduces drastically scope for species diversification.

5. THE SUSTAINABILITY OF THE PRESENT FARMING SYSTEMS

Shifting cultivation is an agricultural practice where a short period of mixed cropping alternates with a long period of natural fallow. The role of the natural fallow in the system is to recycle nutrient elements for soil fertility restoration and to suppress weeds, pests, and diseases (Nye and Greenland, 1960). As long as there is enough land, the population pressure is low, the road infrastructures are poor, prices for agricultural products are low, and the market is limited, this shifting cultivation will remain an efficient system of soil management. This holds only for subsistence farming since it is difficult to find prosperous shifting cultivators in the evergreen forest of Cameroon.

Soil can recover its optimum equilibrium under natural fallow only if this fallow is left undisturbed for at least ten years after cropping area (Yemefack and Nounamo, 1999). This shifting cultivation system can then be replaced by a “Rotational Fallow System” in which a farmer comes back to a piece of fallow land only after ten years. But, with the actual practice in the area, farmers are more and more shortening the fallow length because of unsuitable land tenure rights, market driving production and soil chemical gains from burned vegetation biomass. More farmers (64%) are clearing Chromolaena fallow (3-5 years) or Bush fallow (7-9 years) for food crop production. In these conditions, the cycle of weed, pests and diseases control, and nutrient replenishment is broken. Physical and organic soil fertility are drastically reduced, the vigour of the forest regrowth also. This renders the shifting cultivation practices unsustainable.

The sustainability of the shifting cultivation practice is a dilemma. On one hand, farmers must produce more for consumption and revenue gain in order to move from poverty subsistence farming to security guarantee and poverty alleviation. On the other hand, shifting cultivation involving clearing long fallow land must be practised to efficiently restore soil productivity after cropping.

For a sustainable management of the forest zone of southern Cameroon, solutions must be found to two main problems: (1) the shortening of fallow length leading to soil productivity degradation, and (2) the sustainable but non-prosperous subsistence farming practice destroying the forest ecosystem:

- Soil productivity conservation: researches have to be carried out on possibilities to intensify crop production within this rotational system. This intensification can be achieved by prolonging the cropping period without complete degradation of soil fertility or by shortening the fallow period by applying improved fallow technologies. To extend the cropping phase, a solution can be found in the Integrated Nutrient management methods defined by Janssen (1993), based on combined application of mineral and organic fertilisers. Improved fallow and agro-forestry technologies are available at ICRAF.
- Prosperous farming: shifting cultivation should move from subsistence farming to income generating farming to guarantee food security and alleviate poverty of the local population. This can be possible if the following subsystems are improved or adopted: land tenure rights and laws, market system, integrated low input and short fallow agricultural system, improved fallow, integrated cropping system and improved animal husbandry, and diversification of farmers' crop. A survey carried out in the area (Table 9) shows the willingness of the farmers to adopt changes in the actual farming system.

Table 9. Farmers' predisposition to innovations in the area.

	Activities				
	New crops	Integration of improved animal husbandry	Agricultural intensification	Bee keeping	Other innovations
Frequencies of responses (%)	97	78	75	60	97

n = 200

6. CONCLUSIONS AND RECOMMENDATIONS FOR SUSTAINABLE FOREST LAND USE

6.1. Conclusions

The study has produced information amongst which the following are to be highlighted in order to provide reliable tools for the sustainable management of the forest zone of southern Cameroon:

- The cropping system is far the most important activity system for the farmers of the area. Animal husbandry comes second in their ranking.
- Dissected plains of Ebimimbang area and undulating uplands are the most important land mapping units for this cropping system.
- Some tree species are used as indicators of suitable or unsuitable lands.
- The food crop production is mainly for the subsistence of the household.
- Due to land shortage, land tenure rights, population pressure, etc., farmers are replacing the expanding shifting cultivation by rotational short fallow.
- Seventy six per cent (76%) of food crop fields rely actually on this rotational system, which consists of rotating in a total area of less than ten hectares.
- Nevertheless, agricultural land is expanding into forest because of the needs for *C. mannii* production. The *C. sativum* variety adapted to short fallow fields may be a good substitute for *C. mannii*. Some farmers are already introducing it.
- Current rate of agricultural land expansion into virgin forest is greater at Ebimimbang and Mvié areas, and the average for the whole area is 2200 m^2 per household per year.
- An optimum fallow length is at least ten years.

- Needs are raised to intensify this agricultural system, either by improving the natural fallow system or to extend the cropping period using external input such as organic manure or other fertiliser, with the aim to guarantee food security of the local people.
- Non-Timber Forest Products should also be taken into account in the agricultural system. Research must find ways to domesticate them.

6.2. Recommendations

For a sustainable land use of the forest zone:

- Cropping practices must be considered as the prime activity that involves more users of the forest resources.
- This agricultural system must move from subsistence farming to income generating farming. For that, the following subsystems must be improved: market and road system, animal husbandry, etc.
- Crop diversification should be considered.
- Only improvement of the actual system is required, not a complete change of the whole system.
- Research ahead must develop and test sedentarising technologies to improve farmers' unsustainable subsistence shifting cultivation and to link these technologies with socio-economic policies providing disincentives for further deforestation.
- The Government must be sensitised on the necessity to review land tenure rights and laws.

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FOREST MANAGEMENT PLAN, AN IMPLEMENTING INSTRUMENT FOR SUSTAINABLE TIMBER PRODUCTION

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SUMMARY

A Forest Management Plan (FMP) is a tool for forest management, nowadays designated for sustainable production of timber and other forest products. The Cameroonian forest law stipulates the drawing of a FMP for each production forest. Since 1993, the Tropenbos Cameroon Programme (TCP) has carried out research into selected aspects of forestry. It is to produce scientifically sound knowledge, which can serve as a basis for forest management planning, and which will be used among others to write a forest management plan for a production forest within the TCP research site. The TCP research, which will serve these purposes, is introduced.

Keywords: forest management, production forest, research programme, Cameroon.

1. INTRODUCTION

While early people used the forest mainly for hunting and gathering, human needs *vis-à-vis* the forests have multiplied as the population has grown. Human demands for benefits derived from forest nowadays easily exceed limits posed by sustainability, not only because of the increasing demand of forest resources, but also because of ill-considered forestland use. The future of the tropical forest has therefore become a major concern among the general public and so does the concept of sustainable forest management. Tools have been developed or are still under development in order to meet this issue of sustainable forest management. The Tropenbos-Cameroon Programme (TCP) on its part had made it a point of duty to contribute to the Cameroonian government's implementation of a new forest policy, whose aims is to shift emphasis from the single timber tree to the entire forest ecosystem. Forest management plans (meant for production forest) can be a support of the mentioned policy as it is stipulated in specific regulatory instruments on forestry and wildlife management elaborated by the government of Cameroon.

The Tropenbos-Cameroon Programme is a problem-oriented research programme, and its implementation is expected to provide tools (methods and strategies) for a sustainable production of timber and other forest products and services. This paper addresses the issue of forest management plans, which are important tools in the process of securing the multiple functions of the forests. It is presented as a frame, within which other papers (van Leersum *et al*., 2001; Parren and Bongers, 2001; Bibani Mbarga and Jonkers, 2001) give more details on the contribution of TCP.

2. THE QUESTION OF SUSTAINABLE FOREST MANAGEMENT

Sustainable forest management can be referred to as "the process of managing permanent forest land to achieve one or more clearly specified objectives of management with regard to the production of a continuous flow of desired forest products and services without undue reduction of its inherent values and future productivity, and without undue undesirable effects on the

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physical and social environment" (ITTO, 1992). It is a complex issue, integrating many interrelated components.

Sustainable forest management therefore aims at ensuring multi-purpose management of the forest so that it can fulfil its multiple functions now and in the future. Its overall capacity to provide goods and services are preserved. For the Cameroonian situation, a shift in emphasis from the single tree to the entire forest is needed.

A forest, which is sustainably managed, will consequently provide timber on a sustainable basis. It will at the same time fulfil its socio-economic (contiguous supply of fuel wood, other timber products, and NTFPs to communities living in and around the forest), socio-cultural (spiritual and religious values, heritage value, educational value, etc.) and ecological (nutrient cycling, watershed protection, soil protection, stability and local and global climate, habitat of plants and animals) functions. Appropriate management systems, requiring relevant technologies for forest regeneration and harvesting practices are prerequisites to achieve this aim.

3. CAMEROON GOVERNMENT EFFORTS

The Cameroonian forest sector has gone through profound institutional and legislative reforms. This has resulted in a certain number of actions, some of which are referred to in this paper. These are legal regulations on forestry and wildlife (MINEF, 1997), the National Zoning Plan (Côté, 1993) and guidelines developed for forest management plan drawing (MINEF, 1998a; 1998b).

3.1. Legal regulations on forestry and wildlife

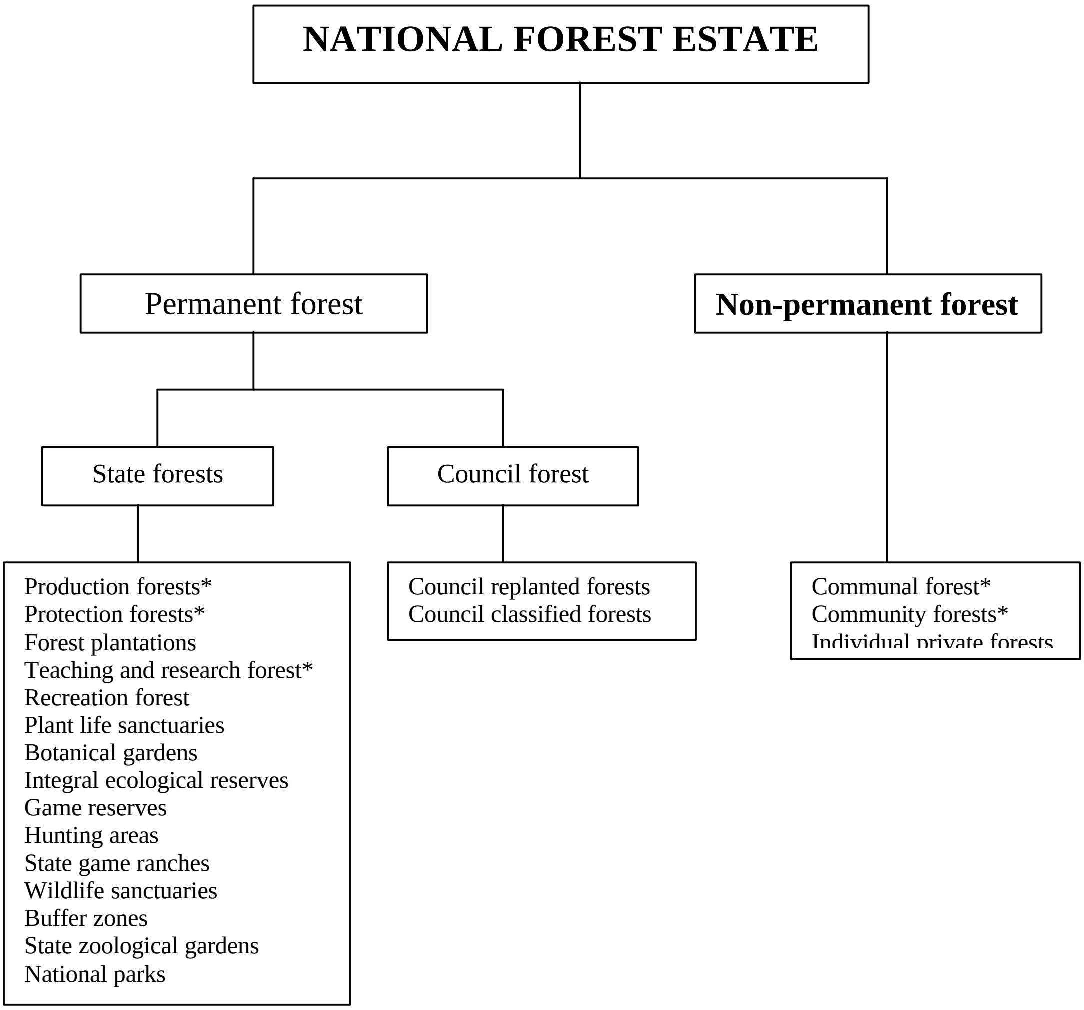
The new forest law of 1994 (Law N° 94-01 of 20 January 1994) is the legal framework for the implementation of the National Forestry Action Programme, as well as an integral part of the government strategy to ensure sustainable conservation and use of its forestry, wildlife and fisheries resources, and of the various ecosystems. It lays down regulations with a view to attaining the general objectives of Cameroonian New Forest policy. Its implementing instruments are made of three common (Decrees N° 86-230, 96-237-PM and 96-238-PM) instruments and of three specific regulatory (Decrees N° 95-531-PM, 95-678-PM, and 95-678-PM).

3.3.1. National Zoning Plan

The National Zoning Plan is an indicative framework for land use in the whole country. It acts as tool for the planning, orientation and exploitation of natural resources within the southern forested area. According to the provision of the Legal Regulations (Law N° 94-01), permanent (State forests and Council forests) and non-permanent (Communal forests, Community forests and forests belonging to private individuals) forests are distinguished here (Figure 1). These two categories of forests are likely to be found in the Tropenbos-Cameroon Programme site.

3.3.1. Guidelines for the Drawing up of Forest Management Plan for Production Forests

Permanent forests shall be managed in such a way that their production capacity will be maintained. It is in this respect that the concept of forest management plans is presented in the law (N° 94-01). According to its Section 29, "A management plan shall be drawn up for State forests defining, in accordance with the conditions laid down by decree, the management objectives and the rules for each forest, the means needed to achieve the said objectives, as well as the conditions under which the local population may exercise their logging rights, in accordance with the provisions of the classification instruments".



* Types of forests likely to be found at the TCP research site

Figure 1. The National Forest Estate in Cameroon

The above-mentioned guidelines entitled *"Guide d'élaboration des plans d'aménagement des forêts de production du domaine forestier permanent de la République du Cameroun*" (MINEF, 1998b) were developed to coach the implementation of this Section 29 provision. It falls within the framework of the forest production strategy and goes a long way to enhance sustainable forest management. The procedure to draw the forest management plan as planned by the guidelines includes:

- Data collection on biophysics of the forest;
- Study of the socio-economic environment of the forest;
- Evaluation of the state of the forest;
- Presentation of the proposed management system;
- Provisions for the participation of the populations to the forest management;
- Definition of the duration of the plan revision planning;
- Plan of operations;
- Financial and economic assessment of the management plan.

TCP is carrying out research in selected forestry aspects (see Foahom and Jonkers, 1992) both to develop elements to be integrated in the process of drawing a FMP, as well as to contribute to the improvement of the guidelines for writing a FMP. The actual research results will be implemented in a model forest management plan, as it will be written by TCP for a production forest in the TCP research area. The eventual implementation of this plan offers good opportunities for studies evaluating this model and the guidelines behind it.

4. THE CONTRIBUTION OF TCP

Much is still unknown about tropical rain forests. This can be the reason that many uses afterwards have to be classified as being wrong. We still need to know for example how it reacts after the disturbance. It is based on these and many other questions, that the TCP research projects were prepared (see Foahom and Jonkers, 1992). Hence, TCP is an interdisciplinary research programme dealing with sustainable production of timber and other forest products and all forest services by Cameroonian rain forest. It is expected to generate information needed for a better understanding of this forest ecosystem and of its uses and users. Some of its research questions or results aim at providing elements or material to be included in (the framework of) forest management plans.

The TCP study site covers a total area of about 165 000 ha; in which an area of 18 000 in one block (11% of the total area) is found suitable for production forest. A model forest management plan will be drawn for this production forest.

The following technical aspects, which are important parts of an FMP and are studied extensively by TCP, are discussed below: appropriate land use planning, reduced impact logging, improved silvicultural techniques and participatory approach.

4.1. Appropriate land use planning

The forest ecosystem is a source of multiple functions. Unfortunately, forests were not always perceived according to this multiple-use vocation. The different users - who can also be referred to as stakeholders - have each an isolated perception of the use of the forest. This kind of behaviour unavoidably leads to conflicting interests which consequently are not always properly managed. The challenge is to harmonise contradictory users' needs (Foahom, 1998), which can be summarised as:

- Local dwellers rely mainly on forest products and on agriculture; shifting cultivation and slash-and-burn agriculture are the most wide spread agricultural systems in tropical forests (Jumuar, 1991; Jepma and Blom, 1991; Cleaver, 1992);
- Many governments of developing countries depend heavily on the export of tropical wood;
- Tropical forests are recognised as a real reservoir of biodiversity and other non-consumptive benefits.

Not only it is expected to produce more forest products on less land (by shifting from extensive harvesting systems to intensive use of small proportions of forestland), to allocate more land for other uses, but also all uses, inclusive that for forestry should be guided by long-term objectives. Hence, all land allocation should be based on careful land use planning. This applies to all forms of land use, including timber production. Land inventory and evaluation (van Gemerden and Hazeu, 1999; van Gemerden *et al.*, 2001; Hazeu *et al.*, 2000) therefore form important components of the TCP research activities.

4.2. Reduced impact logging

The search for improved logging practices has become a matter of great concern and many publications have been devoted to it (e.g. Hendrison, 1990; Bertault and Sist, 1995; Blate, 1997; Webb, 1997; van der Hout and van Leersum, 1998). The development of sound harvesting techniques in order to reduce logging damage is one of the prerequisites for sustainable forest management. The concept of reduced impact logging was therefore developed. Reduced impact logging is defined as a practice that *"comprises new techniques and new concepts of organising* *and planning timber harvesting, with primordial objective of damage reduction, and with a proximate goal of improving the efficiency of the operation"* (van der Hout and van Leersum, 1998).

It is based on this issue that the Tropenbos-Cameroon Programme devoted an important part of its research activities to the development of a rational timber harvesting system, with emphasis on restriction of logging damage and improvement of efficiency (van Leersum *et al*., 2001). The study took into consideration the most important phases of timber harvesting process, which include inventory, pre-felling logging activities, felling, and skidding.

4.3. Improving silvicultural techniques

Silvicultural practices for timber production are management techniques, aiming at transforming natural or degraded forests with a low density of desirable timber trees into forest with a higher productivity level. Without going into detail, let us refer to Lamprecht (1989), who described four levels of transformation intensity, depending on how important is the change to the natural system:

- *Low-intensity* transformation (just a slight change in the production capacity of the system);
- *Low-to-medium* intensity transformation;
- *Medium-to-high* intensity transformation;
- *High* intensity transformation, which leads to a system completely different from the original one.

The decision to adopt any of the four levels closely depends of the state of the original forest, i.e. from the situation of the forest before treatment. The highest intensity level is applied to a natural stand either devoid of timber tree species, or of very poor quality in this respect, or to completely degraded forests. Artificial regeneration is here applied even if in degraded forest natural succession can still allow slow and partial recovery to take place - provided that there is no other human intervention and that intact forest containing the original forest biota is available nearby as a genetic source. Silvicultural systems developed for the three other levels if intensity of the treatment are designed to stimulate the growth of desired species already present, in order to improve the forest productivity.

Part of the TCP effort is precisely to develop a polycyclic management system for timber production in the evergreen rain forests of Cameroon. It is in this respect that one of its research projects is in the process of developing a silvicultural system appropriate for the local conditions of the Cameroon evergreen rain forests in general, and for production forests in particular (Bibani Mbarga and Jonkers, 2001). Production forests within the meaning of the Law N°. 94-01 of 20 January 1994 belong to permanent forests (Figure 1), situated in the permanent forest estate (MINEF, 1997).

Several attempts have been made and methods developed to find an extensive system of natural regeneration of tropical forest ecosystems (Jonkers, 1987; Ola-Adams, 1997; Ofosu-Asiedu, 1997). The one under development at the TCP is adapted from methods developed in Ivory Coast (Maître and Hermeline, 1985; Maître, 1986) and Suriname (de Graaf, 1986; Jonkers, 1987). It is an extensive and polycyclic system (in contrast with uniform systems) aiming at improving production and maintaining the multiple use and diversity of the forest after exploitation and treatment. It is a close to low-to-medium intensity transformation of the forest ecosystem, qualified by Lamprecht (1989; 1993) as a *near-to-nature* system. It relies on natural regeneration, in contrast with artificial regeneration.

4.4. Participatory approach

Claims on forest resources come from many stakeholders whose needs are often contradictory, which may lead to conflict situations. Persons belonging to the same group of stakeholders may have the same needs and objectives towards the forest, whereas persons from different groups may have different ones. Management of forestry resources therefore implies accommodating the objectives and needs of different groups, in such a way that their legitimate claims *vis-à-vis* the forest are taken care of. This will not always solve the unavoidable conflicts between groups. It is a matter of managing those conflicts through mediation processes until – hopefully – all stakeholders agree on a certain scenario. The mediation involves negotiation and co-operation among stakeholders, based on different but possible scenarios to be developed for the forest area to be managed.

Particular attention must be paid to local communities, because sustainable use of forest resources is most likely to occur if they participate in managing those resources on which they depend. Their involvement in the stages of planning and implementation of forest management process is a matter of great concern. The how of this involvement is one of the research questions addressed by TCP.

TCP social studies led to a certain number conclusions. In this respect, issues that emerged, and which needed to be considered as of critical importance were identified (von Benda-Beckmann *et al*., 1997). Without going into specifics, as more detailed analyses are given by Tiayon *et al.* (2001) and Parren *et al.* (2001), the main issues are:

- The issue of community. Communities in the area appear to be of diffuse nature; a situation likely to weaken the position of local populations in the negotiating and decision process when managing forests;
- Issues of leadership and negotiation power of both Bagyeli and Bantu groups, which are also linked to the above-mentioned problem;
- Techniques of exploitation and the pressure of local communities on forest resources;
- Local perceptions of the activities of logging companies and their relation to the State;
- Law and rights issues, notably on the difficult articulation of local rights and the claims of the state as expressed in the 1994 forest law.

5. CONCLUSION

This presentation attempted to highlight the issue of Forest Management Plan (FMP) in relation to the wider range of research activities of the Tropenbos-Cameroon Programme. It has limited itself to the frame of this FMP, a frame to be filled out by specific findings of the TCP through more detail analysis of issues of reduced impact logging, improved silvicultural techniques, involvement of local population, appropriate land use planning. Their proper handling appears to be important prerequisites that will enable sustainable forest management.

The Forest Management Plan, which is derived from the Master Management Plan, is a tool for Sustainable Forest Management. While the Master Management Plan deals with sound land use planning in order to reduce the conflicting needs of forest users and to use the forest according to its capacity of fulfilling its multiple functions (Jonkers *et al*., 2001; Fines *et al*., 2001), the Forest Management Plan applies to production forest designated for the sustainable production of timber and other forest products.

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LOGGING METHODS APPLIED IN SOUTH CAMEROON AND WAYS FOR THEIR IMPROVEMENT[1]

G.J.R. van Leersum[2], F. Ngibaot[2], E.A. Laan[2] and W.B.J. Jonkers[3]

SUMMARY

The logging research of the Tropenbos-Cameroon Programme aims at designing a rational timber harvesting system with emphasis on restriction of damage, improvement of efficiency of operations and a sound interaction with the local population in the area. The study started with an inventory of current logging practices and linked these practices to the damage levels and patterns in the area. Potential adaptations to the current logging method were then identified and tested in the forest. Finally, a field comparison between the experimental logging method and the conventional logging method was executed. The study has gained insight into the extent and the nature of damage caused by conventional logging as well as the current utilisation rates of felled timber. Less than 0.5 trees/ha were felled and logging damage was therefore limited to 5% of the ground surface. About 30% of the felled timber are left in the forest. Some elements of Reduced Impact Logging, such as directional felling and improved planning and supervision, can reduce logging damage, wastage and negative effects for the local people, but other elements, such as liana cutting and winching, are less suitable under the prevailing conditions.

Keywords: reduced impact logging, forest management, tropical rainforest, Cameroon.

1. INTRODUCTION

Efforts have been made in many countries to reduce logging damage in rainforests. Early publications by Mattson Marn and Jonkers (1981) and Hendrison (1990) indicated that considerable damage reduction can be achieved by introducing proper planning procedures and rather simple modifications in existing logging methods. In the 1980s and 1990s, there was a growing awareness of the need to manage rainforests in a sustainable way, and this led, among others, to more attention for reduced impact logging (RIL). Many studies were executed in Asia, Australia and Latin America (e.g. Crome *et al.*, 1992; Blate, 1997; Johns *et al.*, 1996; Webb, 1997; van der Hout, 1999; Bertault and Sist, 1995; Pinard and Putz, 1996; Cedergren *et al.*, 1994), and all these advocate similar changes in logging methods. Furthermore, FAO (1996) published codes of practice for logging operations.

In Africa, RIL has so far received less attention. In Cameroon, two RIL studies have been executed. One study was executed in the semi-deciduous forests in the eastern part of the country (Durrieu de Madron *et al.*, 1998). The Tropenbos-Cameroon Programme (TCP) started in 1994 with RIL research in the littoral forest of south Cameroon. This project aims at designing a rational timber harvesting system with emphasis on restriction of damage, improvement of efficiency of operations and a sound interaction with the local population in the area.

Basic questions to be answered before arriving at changes to the current method were the following:

- How is the forestry sector and logging organised in Cameroon;

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- What is the nature and the extent of the actual disturbance due to logging;
- What is the nature and extent of actual timber losses;
- Which elements of the world wide developed model harvesting system apply in the littoral forest of Cameroon?

2. FOREST MANAGEMENT PLANNING

The forestry situation in Cameroon is changing rapidly. Until recently, gazetted permanent production forest was almost non-existent, and timber production was in fixed-term concessions of one to five years. Since 1999, short-term concessions are no longer issued and large permanent forest management units are being established, for which forest management plans have to be made. Concepts for such plans have been developed, and are being elaborated further. With evolving insights in the complexity of managing Cameroon's forests, management plans are becoming increasingly complex. From a purely timber production oriented plan, the concept now develops into a detailed scenario including the rights and obligations of all actors concerned during the preparation and execution of the plan (ONADEF 1991; 1992; 1997; 1998).

In Cameroon, forest management planning should include land-use planning to determine the exact boundaries of permanent production and protection forest in consultation with the local people. After marking the boundaries, annual logging coupes will have to be planned in time and space and the annual yield has to be determined, based on a forest inventory and again in consultation with the population. To allow people to hunt and to preserve the fauna, an annual coupe should not cover a large continuous area and completely surround a village, but rather consist of logging compartments that are not adjacent to one another. For further information on the social aspects of forest management, see van Dijk (1999), Tiayon *et al.* (2001) and Parren *et al*. (2001).

Thereafter follows the operational planning of logging and other forestry activities within the first annual coupe. A specification of how logging should be executed has to be part of forest management planning, based on adequate rules and regulations. In Cameroon, until recently, the official 'Guidelines for logging enterprises' (MINAGRI, 1988) hardly posed restrictions on skidding and felling other than minimum felling limits. Over the last decade, the Government of Cameroon has made substantial advancements and recently, more severe restrictions on logging techniques were proposed (ONADEF, 1998). The practical implications of this new set of guidelines are subject of debate and further testing.

3. CONVENTIONAL LOGGING

In order to assess the need for improvements in logging methods, the operations of one of the better organised logging companies in Cameroon and the resulting damage were studied. The fieldwork for this investigation was done in 1995 and 1996 in a forest, which had probably never been logged before.

3.1. Logging operations

Before logging starts, the company arranges compensations for possible damage to agricultural fields and other losses and inconveniences with the villagers. The operations start with a 100% inventory. Only trees, which the concessionaire wants to harvest, are enumerated and plotted on 1 : 5 000 maps. These trees are always very large, and produce timber of export quality. Their average diameter is 116 cm and their average bole volume 13 m^3. Maps are used for harvest and marketing planning, for truck road alignment and for felling, and occasionally also for skidding.
Felling is done in teams of two or three men. The felling technique is simple, and trees are usually felled in the direction of their natural lean. The direction is rarely but successfully altered in case of possible damage to agricultural fields. Trees are subsequently crosscut and

topped without any information on log lengths desired further down the production chain. Felling productivity is three trees per effective working day per feller.

Skidding is carried out with D7 bulldozers and Caterpillar 528 skidders. The D7 constructs trails to felled trees and prepares logs for skidder transport to the landing. Trail construction is mostly from felling gap to felling gap and is seldom guided by inventory maps. Logs are skidded one at a time, and skidding on steeper slopes than 20% is avoided. The large log sizes and difficult terrain lead to a production of only five logs per skidder per day on average. At the landing, logs are further crosscut to improve their appearance and facilitate transport. Log transport is by trucks with a loading capacity of 25-35 tonnes over gravel roads.

Logging administration and reporting comprises recording of the daily production per crew. The system serves for payment of bonuses and monitoring of stocks in the forest and on the landing. The administration forms for felling, skidding, and transport are poorly attuned. As tree and log numbers on the various forms do not correspond, these records cannot be used for monitoring the production chain.

3.2. Logging damage

Logging damage was studied in twelve 25-hectare plots, randomly chosen within a 2500 ha working coupe. Only 5% of the area incurred disturbance as result of logging (Table 1). This can be soil compaction or vegetation clearing by logging machines, or damage caused by falling trees. Disturbance is so low because only 0.3 trees/ha were felled, which is substantially less than the 0.7 harvestable trees/ha recorded in the inventory and also less than the average logging intensity in Cameroon.

Table 1. Logging damage in twelve 25 hectares plots

Logging activity	**Damage level**
	% area disturbed
Felling	1.4%
Skidding	1.1%
Road/landing construction	2.7%
Total	5.1%

The main reason for the low production is that many parts of the forest were not entered because of steep slopes, poor stocking, and/or presence of agricultural fields. It is therefore not surprising that damage per plot varied considerably, ranging from 0% in as many as 7 of the 12 plots to 25% in the plot with the highest felling intensity (1.8 trees/ha felled). Another reason for the low volume harvested per hectare was that the concessionaire had temporarily increased the minimum felling diameter and reduced the list of species to be marketed.

It is remarkable that half of the damage was caused by truck road and landing construction, which occupies usually a minor fraction of a logged forest. This is because the terrain is highly dissected, and roads were built on each of the many ridges in order to keep skidding distances short. Furthermore, roads were made very wide to allow quick drying after rains. Log landings were also oversized, and unnecessary landings were made, that is, landings without connecting skid trails. The crews had been instructed to create landings every 500 meters, which was observed rigidly. About 30% of the damage due to roads and landings could have been avoided.

Avoidable skidding damage includes dual trails, shortcuts, and trails not leading to a felled tree and needless manoeuvring in felling gaps. About 20% of the skidding damage could have been avoided, and was caused by:

- Rain and unstable, water saturated ground conditions. Skidding continues in bad weather until the output is almost zero, leading to rapid deterioration of the trails, which can sometimes be used for only one passage.

- Lack of supervision. Machine operators can set their own standards of work. As long as they produce enough logs, their supervisors remain on the landing and inspect only logs that reach there.
- Lack of environmental awareness among operators and supervisors. Few operators see a need for damage reduction, and most feel that the forest will recover anyway.
- The unfavourable balance between machine capacity and the large sizes of the logs impede a smooth operation of the logging machines in the forest.

Needless manoeuvring in felling gaps proved a major source of avoidable damage, causing 10% of the total skidding damage.

Reducing felling damage by making felling gaps overlap is not feasible, as distances between felled trees are generally too large. The large distances between harvestable trees also reduce the need for careful planning of felling directions to facilitate skidding, as it is always possible to approach logs under the best possible angle. Directional felling may be useful for preserving future crop trees and trees producing non-timber forest products, however.

3.3. Timber recovery

Reducing timber wastage is an aim of RIL, as it makes the operation economically more attractive. Timber losses were therefore investigated.

The conventional inventory method overlooked on average 15% of the harvestable timber, but fellers generally found the overlooked trees, thus making up for this poor inventory performance. The quantity of timber delivered at the sawmill was 70% of the amount felled. Most losses occurred during felling (21%). As much as 7-10% was lost because good-quality top parts of the stems were cut off and left in the forest. Tree rot was responsible for 6-7% of timber loss. Other felling losses consisted mostly of "inferior" timber such as conical butt ends and hollow or poorly shaped trunks.

Losses due to skidding (4%) consisted mainly of good-quality logs left along trails. At landings, another 4% loss occurred, mainly due to cutting off both log ends to give the timber a better appearance. Some good logs were left at landings due to oversight.
Losses during trucking were negligible.

Underlying causes for timber losses during logging from a management point of view are threefold:

- Supervision of logging activities is only carried out at the landing. Poor administrative procedures and reporting impede adequate monitoring of what goes on in the forest. Timber losses remain untracked and the company’s supervisors do not assess the abuse of machines, the need for training among operators, wastage and logging damage.
- Likewise, remuneration and incentives for forest labourers are based on quality and quantity of timber arriving at landings and not on otherwise easily obtainable indicators for the quality of their work such as the volume recovered per tree harvested.
- The sawmill and sales branch of the company simply want only the best timber from the forest, leading to extraction of only the very best parts of the tree, in other words: creaming within the creaming of the forest.

4. REDUCED IMPACT LOGGING

Potential adaptations to conventional logging, aimed at damage reduction, were identified and tested individually. Thereafter, a field comparison was made between conventional and modified logging. This experiment was only partially analysed at the time of writing.

Furthermore, the impact of liana cutting on logging damage was assessed in a 28 ha experiment. Liana cutting nine months before felling was compared to a control treatment.

4.1. Summary results

4.4.1. Liana cutting
Liana cutting did not have a noticeable effect on felling damage, in spite of the large numbers of lianas present (see Parren and Bongers, 2001).

4.4.2. Harvest inventory and skid trail alignment
With the available level of topographic precision, detailed tree inventory data are not sufficient to plan logging operations in difficult, irregularly dissected terrain. Enlarged topographic maps used to plot inventory results are too inaccurate for ‘precision forestry’ purposes. When designing a skid trail system, a double field check is needed before marking trails. Even then, frequently used trails deteriorate, forcing the machines to deviate from the intended pattern. Alignment of skid trails based on detailed inventory maps was tried. The outcome was that the skid trail pattern is determined mainly by terrain conditions. However, involving local villagers in skid trail alignment with the aim to protect sites important to them is a promising option, and so is the use of topographic information from aerial photographs, remote sensing or radar imagery. Geographic Information Systems can also be of use (Durrieu de Madron *et al*., 1998).

4.4.3. Felling
Directional felling proved to be technically feasible. Only the very few trees without a clear natural lean are difficult to fell in a desirable direction. Directional felling can serve to protect potential crop trees (PCTs) and trees yielding non-timber forest products. This is done by felling the tree into the patches of young stands, which are scattered over the forest.
Table 2 shows that directional felling leads to fewer trees damaged and destroyed. Both felling methods led to comparable gap sizes.

Table 2. Gap size and number of trees (>10 cm dbh) damaged and destroyed per tree felled

Features and damage categories	**Conventional**		**RIL**	
	Total	**Mean per felled tree**	**Total**	**Mean per felled tree**
1. All felling gaps				
Number of trees felled	47		46	
Number of trees damaged		27.4		18.3
Number of marketable trees injured		3.0		1.6
Number of marketable trees fatally injured		2.1		1.3
2. Single tree gaps only				
Number of gaps	43		34	
Average gap size (m²)		764		720

Although the relative damage reduction is substantial, the reduction in absolute terms is modest. The main reasons are the scattered spatial distribution of trees to be preserved and the horizontal visibility, which is usually 30 meters or less while the bulk of a felled tree's crown penetrates the crown layer at a larger distance. The exact position of a relatively small PCT is thus difficult to assess and a proper felling direction to choose. Felling into patches of young forest then appears the only general damage reducing technique a feller could apply.

4.4.4. Skidding
Skidding offers little scope for improvement along lines developed outside Africa. Reduction of tertiary skid trails through winching and pre-felling alignment of trails on the basis of a detailed harvest inventory were considered promising techniques in this respect, and have been tried. Table 3 summarises the results of the field comparison with the conventional method.

Winching over long distances was seldom possible because of log weights and volumes, obstruction by the bucked, conical butt end and hilly and slippery terrain. Winching over short distances is already common practice, especially when the tree is slightly out of reach for a bulldozer or a skidder. In the experiment the winching distance resulted is even smaller than normally practised.

Table 3. Average winching distance and portion of plot area damaged under conventional and RIL skidding.

	Conventional	**RIL**
plot size (ha)	33	33
number of trees harvested/ha	1.3	1.3
winching distance (m)	9.1	7.9
skidding damage (%)	4.3	3.9

Supervision of skidding operations has immediate positive effects on damage reduction. Restrictions related to rainfall also has a positive impact on damage, but leads to output reductions in all production phases that may outweigh the benefits.

5. DISCUSSION

Logging damage has been measured in the concession of a comparatively well-organised enterprise, which applies planning and control. Although logging methods have improved little in recent years (see Evans, 1990; Gartlan, 1990), comparison of this operation with the full range of RIL elements is unlikely to show dramatic differences under the current low harvest intensities. About 20% of the skidding damage and 30% of the felling damage can be avoided, meaning that logging damage can be reduced from 5% to 3-4%. No doubt a comparison with practices of poorer organised enterprises puts RIL in a more favourable position.

Still, there is a need to reduce damage, not only to preserve future crops, but also to reduce negative effects for the local population and wildlife (see also Parren *et al*., 2001). The concepts and activities to achieve this are not new, with the exception of involving the local population directly in forestry activities. Better communication, reporting, and supervision will diminish damage and improve the utilisation rate of felled timber.

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LIANA DIVERSITY AND THE EFFECTS OF CLIMBER CUTTING IN SOUTHERN CAMEROON

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SUMMARY

In southern Cameroon, an experiment was set up to test whether pre-felling climber cutting could reduce logging damage. The abundance of lianas and their re-sprouting capacity after cutting was assessed. Logging damage was considered as tree mortality and tree damage in the felling gaps and the sizes of the created gaps after felling.
Liana diversity was high with at least 21 families present. However, taxonomic problems were evident in this insufficiently studied region. Lianas were very abundant: on average nearly 5000 individuals of which over 100 large ones per ha. Only a limited number of lianas died after cutting. Re-sprouting capacity was high but variable among species. Pre-felling climber cutting did not significantly affect felling gap size and tree mortality and damage. Damage to trees was not severe in most cases. Small trees were most prone to destruction and serious damage.
Pre-felling climber cutting had no significant effect on resulting gap sizes, tree mortality and damage levels. It can be concluded that in Cameroon, overall climber cutting does not contribute to damage reductions at felling sites.

Keywords: lianas, climber cutting, logging damage, tropical rain forest, Cameroon

1. INTRODUCTION

In tropical rain forest, lianas compete with trees and interfere with their growth. Many foresters regard them as a nuisance and the cutting of liana stems has thus been an important operation in forest management. Lianas are also believed to affect logging damage. In general, when a tree is felled in a forest, this tree may pull down several trees and damage others. This is partially a direct effect of the falling tree: it falls on top of other individuals. But large woody lianas may also play a part. These lianas ascend to the forest canopy by a primary host and often explore available space and light resulting in growth from tree crown to tree crown (Putz and Chai, 1987; Clark and Clark, 1990; Balfour and Bond, 1993; Pinard and Putz, 1994). In their expansion they intertwine several tree crowns. Vidal *et al*. (1997) for example found in Amazonia that on average 3 crowns (range 1-12) were connected by a single liana. Large and thick lianas can 'tie' tree crowns together and form an important structural component of the forest canopy. Felling a tree laden with lianas thus may cause considerably more damage to surrounding trees and create larger gaps than a similar tree without lianas. Climber cutting prior to logging therefore seems to be worthwhile as a silvicultural treatment to reduce logging damage. Studies in SE Asia (Fox, 1968; Appanah and Putz, 1984) and in the Amazon Basin (Vidal *et al*., 1997) have shown positive effects.

The basic idea behind pre-felling climber cutting is that it reduces the binding forces of the lianas: lianas dry out, get rotten and die. Information on the actual effects is scarce however. To what extent do these lianas really die? Are the strength properties reduced adequately after drying, or rotting? Liana leaves contribute significantly to total leaf production (Hladik, 1974; Putz, 1983; Bullock, 1990; Burghouts *et al.*, 1994) and massively fall-off after climber cutting

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operations. Tests on strength of alive and dead lianas are to our knowledge not available in the literature.

Even after cutting liana stems, the rooted parts often show a tremendous vigour. These living stems will mostly re-sprout within three months after they have been cut. The same (but to a lesser extent) accounts for the liana debris that falls on the forest floor and can re-sprout (Appanah and Putz, 1984). These re-sprouting lianas will look for support and reach out for their favoured environments such as forest edges (canopies) and gaps. Lianas add significantly to vascular plant species diversity as their contribution ranges from 12 percent in Puerto Rico (Smith, 1970) to 31 percent in Ghana (Hall and Swaine, 1981). What the effects are of climber cutting on liana diversity is hardly known yet but should be considered as the treatment might exterminate certain taxa from the forest.

Damage at the felling site of a tree can be seen as the combined effects on the size of the felling gap, the number of trees that die, and the amount and quality of the damage to trees and the effect of skidding in felling gaps on soil compaction. This total damage is the combined result of e.g. the size and type of trees felled, climber abundance, initial stand density and harvesting method. The damage at the felling site should be separated from the damage along the skid trails and at the landings. This study deals with the damage related to tree felling only, within the framework of a larger study on the development of reduced impact logging systems in southern Cameroon.

In general, forest exploitation in West and Central Africa can be characterised as being highly selective, in the sense that only the best and largest stems of a small number of species, in demand on the world market, are felled. Densities of these species are typically low and as a result, in most areas on average only one to two stems per hectare are removed (Debroux and Karsenty, 1997). The average harvest level in Cameroon is about 5 m^3 per ha and indicates that logging is very selective (Gartlan, 1992). The African forest is also known for its high liana abundance. In the past, climber cutting was described over vast areas on the African continent but proper evaluation never took place (Parren and de Graaf, 1995).

The aims of this study were to assess whether climber cutting would be effective to reduce felling damage. The following questions were studied:

- what is the floristic composition of the liana community;
- how abundant are lianas in the forest studied;
- to what extent climber cutting results in the death of the lianas and what is their re-sprouting capacity;
- what is the effect of pre-felling climber cutting on the felling gap sizes, and on the number of dead or damaged trees?

2. STUDY SITE

This study was conducted in a logging concession 100 km east of Kribi, Cameroon (3°N, 10°E). The concession area covers over 2000 km^2. The study area was located in the northeastern part near the village Ebom, in a part that never had been logged before. The mean annual rainfall is 2000 mm with two distinct wet seasons (March – May and August – November), associated with the movement of the intertropical convergence zone over the area (Waterloo *et al*., 2000). The study area is located on a Pre-Cambrian shield resulting in clayey soils and classified as a Xanthic or Plinthic Ferralsol. The topography ranges from undulating to rolling with isolated hills with elevations between 350 m and 600 m above sea level (Waterloo *et al*., 2000). Research plots were located in more or less flat terrain. The forests of the area are evergreen and can be characterised as late secondary forests of the Biafrian type (*sensu* Letouzey, 1968) with a more or less closed canopy layer between 25-40 m with emergent trees surpassing 60 m in height towering above. Climbers are abundant in the canopy and in gaps where light conditions favour their growth. The omnipresence of *Pycnanthus angolensis* (Welw.) Warb. and *Lophira alata* Banks ex Gaertn.f. indicates that the forest is of a secondary nature (see also Letouzey, 1968, p. 153).

3. METHODS

The experiment consisted of 33 one-ha research plots. In 5 control plots, no logging and no silvicultural treatment was applied. The remaining 28 plots were all logged and in 16 of them pre-exploitation climber cutting was applied (May 1995). Felling was carried out nine months later (February 1996). Climber cutting was applied in the 1-ha research plot and in a surrounding buffer zone of 8 ha. Harvest levels were set at one large tree[3] per ha resembling normal exploitation practise in the region. The baseline of the 1-ha plots was placed perpendicular to the natural inclination of the tree to be felled some 20 m from the stem foot to make sure that the entire tree would fall within the plot.

3.1. Floristic composition

A quantitative floristic inventory was conducted between November 1994 and January 1996 using 26 of the 33 plots. During field inventory, lianas were identified at their local Bulu name and at a later stage (February 1997) herbarium vouchers of each Bulu name were collected and identified in the field (by G. Caballé, Montpellier, France), and at Herbarium Vadense in Wageningen, the Netherlands. Rattan identification was only possible to genus level as a revision of the West- and Central-African rattans is presently being made (T.C.H. Sunderland, pers. comm.). A 100% inventory of lianas and their field identification was executed before experimental climber cutting was applied. In some plots, voucher herbarium material was collected including wood samples. Vegetative collections were made and taxa had often to be placed in genera or families as fertile material was mostly well out of reach. Fertile material was also looked for and collected in felling gaps in the area. Collections have been deposited at the herbarium of the Tropenbos-Cameroon Programme in Kribi and at Herbarium Vadense (WAG) in Wageningen, the Netherlands. Additional wood collections have been deposited in the Royal Botanic Gardens Kew (K) and with G. Caballé in Montpellier.

3.2. Liana abundance and re-sprouting

Liana stems over 2 cm in diameter at breast height were counted in all 33 one-ha plots (using 10 x 10 m subplots). All lianas cutting through the imaginary surface at breast height were counted and their diameter at breast height (dbh) measured. Lianas smaller than 2 cm in dbh were only counted per subplot. During field inventory lianas over 2 cm were identified at their local Bulu name and at a later stage herbarium vouchers were collected and identified as stated above. In 8 one-ha plots, a selection of 184 liana individuals were cut and tagged for subsequent monitoring. Re-sprouting capacity and mortality were assessed regularly for a period of 22 months after climber cutting. Re-sprouting capacity was expressed as the total number of spots where new sprouts developed on the main stem. This does not concern the actual number of sprouts, as at every spot several sprouts can develop.

At the beginning of the rainy season, 1-m long climber cuttings were placed on the forest floor to find out their re-sprouting capacity. The experiment concentrated on two dominant groups of lianas, distinguished by the local Bulu as (a) *Avom* consisting of the genera *Landolphia* and *Dictyophleba* of the Apocynaceae and (b) *Atuk* comprising the genera *Neuropeltis* and *Calycobolus* of the Convolvulaceae and *Icacina* of the Icacinaceae. Of each group, 1-m cuttings were collected in four diameter classes (< 3 cm, 3-6 cm, 6-9 cm and > 9 cm) with 20 cuttings per class. These were divided and placed on the forest floor in two different environments, in a

[3] over 60 cm diameter at reference height

felling gap and in closed canopy forest, and monitored for re-sprouting during a period of three months.

3.3. Felling gap sizes and residual stand damage

Climber cutting before logging was expected to result in considerably smaller gaps as a result of removing the binding effects, and in lower tree mortality and tree damage levels compared to logging without such treatment. To properly interpret damage levels, pre-logging data should be compared with post-logging data because trees crushed by the crown are not always found (personal observation; Mensah, 1966). To examine this, a total of 161 harvestable trees over 60 cm diameter at reference height (drh) in the 1-ha plots and their buffer zones. Of these, 81 trees had climber cutting applied in their plots and 80 trees were located in untreated plots. Gap size was determined in all these plots using the gap definition of Runkle (1981; 1982). Runkle considers trees as part of the surrounding forest canopy when they have a drh of over 25 cm (and in general reached a height of over 20 m). Runkle's gap size was calculated using the gap centre as a starting point. Direction and distance from the gap centre to the bases of all surrounding canopy trees was measured. The gap size was calculated as the surface of the area enclosed by the bases of the surrounding canopy trees. Runkle's definition is a useful method for measuring gap size at forest floor level (van der Meer *et al.*, 1994).

In 28 felling gaps, tree mortality as well as bark and crown damage to trees over 10 cm drh were assessed. The damage assessment classification was similar to the one applied in Suriname under the CELOS harvesting system (Jonkers, 1983). Stem damage was classified as no stem damage, severe bark damage when at least one third of the circumference of the stem (or over 20 cm) or over a length of at least 2 m was damaged. When it was less, it was classified as minor bark damage. Severe stem damage included stems that had split and unstable trees resting on others. Crown damage was classified as no damage, minor when less than half of the crown was broken off, severe when more than half of the crown was broken off, or as very severe when the whole crown was broken off.

4. RESULTS

4.1. Floristic composition

The survey of the 33 one-ha plots resulted in a total of 33 different Bulu names for both the lianas and the rattans together (see Appendix I). The relation between Bulu name and botanical name was rather weak. These 33 Bulu names represented a total of 21 plant families. Some 27 plants we were able to identify to species level while 15 just to genus level. Three genera were even represented in two Bulu names.

Some Bulu names were monospecific such as Fazo'o (*Tetracera alnifolia*), Angos (*Maniophytum fulvum*) and Ndik kussa (*Cissus dinklagei*). This specificity is probably based on their ethnobotanical meaning since Fazo'o means 'sponge', as it contains potable water. *Strychnos* species are ethnobotanically separated in a poisonous and a non-poisonous group. The two poisonous species are called Ndik assol and the fruits are used as medicine. The two non-poisonous species (Mfas) are used for their wood: Mfa means 'handle of a cutlass'. *Ancistrocarpus densispinosus* (Nsa bekoye) is typical in having abundant spines (as the botanical name indicates). The Bulu name Nsa bekoye means spiny fruits eaten by monkeys (Nsa = banana with spines, bekoye = monkey). Non-specific ethnobotanical names such as the Bulu name Ndik sole ('liana with ants') have a more general meaning and include species of several genera and families. The same applies for the general name Ndik assas, meaning 'liana

4.2. Liana abundance and re-sprouting capacity

Lianas are abundant in the area (Table 1). On average there were 408 lianas ≥ 2 cm dbh (SD = 200, n = 33) and 4370 smaller ones per ha (SD = 2264, n = 33). The abundance varied considerably, however, from 187 to 1092 for the large lianas and from 1890 to 10451 for the small ones, roughly a factor 5 between the lowest and the highest density. Really large lianas that could influence damage levels were quite common as well as, on average 113 lianas ≥ 5 cm dbh (SD = 58, n = 33) and 10 lianas ≥ 10 cm dbh (SD = 6, n = 33) were present per ha.

Table 1. Liana abundance in 33 1-ha plots, Ebom, Cameroon

Dbh (cm)	Mean	SD	MIN	MAX
	N/ha			
< 2	4370	2264	1870	10451
≥ 2	408	200	187	1092
≥ 5	113	58	39	293
≥ 10	10	6	1	25

In May 1995, 184 liana individuals ≥ 1 cm dbh were labelled shortly after they had been cut. In total, 53 morpho-species were distinguished (33 genera and 19 families). Liana mortality increased over time from 34% after 6 months, to 50% soon after logging (11 months after climber cutting), and 70% after almost 2 years (see Table 1). We noticed a slow die-off in most species: first the sprouts closest to the cutting surface died and later those closer to the stem foot. At the end of the monitoring period fungal attack was clearly causing wood rot of the entire stem. The total number of locations along the liana stem with sprouts declined also over time (Table 2). The decline was less than expected based on the number of surviving lianas because these were the more vigorous ones, having many sprouting spots.

Table 2. Liana performance after climber cutting: mortality, survival and re-sprouting capacity of 184 individuals > 1 cm dbh

Status	months				
	0	6	11	15	22
Dead	0	63 (34%)	92 (50%)	108 (59%)	128 (70%)
Alive	184	121	92	76	56
Total sprouting spots	n.a.	427	403	313	208

n.a. = not applicable

Some liana genera were more flexible and resistant with respect to cutting, while others were very vulnerable (Table 3). Genera belonging to the families Conneraceae, Dilleniaceae, Euphorbiaceae and Papilionaceae had survival rates of at least 50%. Genera in the Annonaceae, Apocynaceae, Celastraceae and Icacinaceae had extremely low survival rates.

In both the felling gap and the closed canopy forest the 1-m cuttings did show neither any rooting nor sprouting after three months. This was contrary to the expectations. In the gap, the cuttings had completely dried and in the closed canopy forest, the cuttings had to a large extent decomposed.

4.3. Felling gap sizes and residual stand damage

Although all felled trees were large canopy trees with diameters of more than 60 cm at reference height, the resulting felling gaps were very variable in size, ranging from 103 $m^2$to 1385 m^2 (Figure 1). Most gap sizes were between 300 and 900 m^2 (mean 565 m^2), irrespective of whether climber cutting had taken place before felling. The logging gaps without climber cutting were more variable and extreme in size. Sizes of felling gaps with previous climber cutting (mean 550 m², N = 81) were not significantly smaller than felling gaps without climber cutting (mean size distributions of the gap sizes were not significantly different. This was contrary to the expectation.

Tree size, tree height, and crown size and form are expected to influence the resulting gap size, as well as the density of the surrounding tree stand, and numbers and strength of lianas binding the trees together. As our 161 trees included 25 species, and species are expected to be different with respect to size and form, this was expected to have a large influence on felling gap size. To reduce this variability the analysis was repeated for the 48 Azobé (*Lophira alata*) felling gaps.

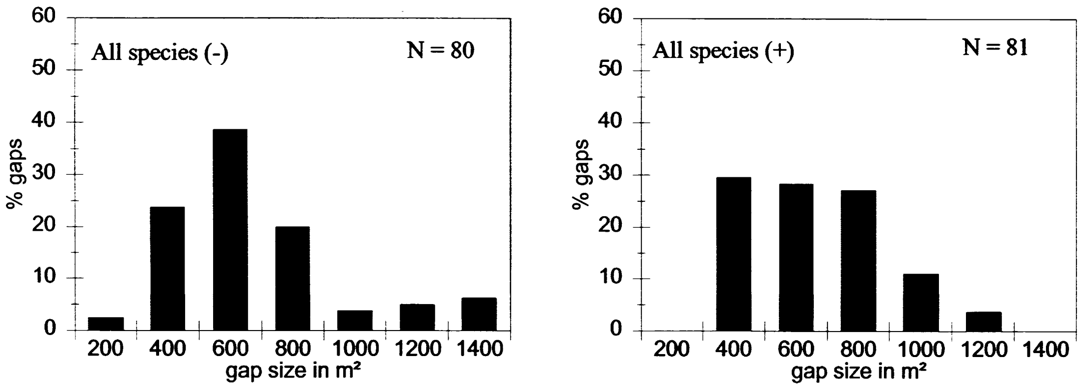
Surprisingly, the result was the same: no difference between gap sizes that result from logging with (n = 27) or without (n = 21) previous climber cutting.

Table 3. Vulnerability of liana genera after climber cutting.

Morpho-species	Family	(1)	(2)	(3)	(4)
Rourea	Conneraceae	4	3	75	5
Millettia	Papilionaceae	4	3	75	3.7
Agelaea	Conneraceae	13	9	69	3.8
Dictyophleba	Apocynaceae	3	2	67	1.5
Maniophytum	Euphorbiaceae	8	5	63	5.4
Iodes	Icacinaceae	9	5	56	1.8
Tetracera	Dilleniaceae	9	5	56	2.8
Salacia	Celastraceae	8	4	50	8.3
Artabotrys	Annonaceae	6	2	33	2.5
Acacia	Mimosaceae	3	1	33	4
Combretum	Combretaceae	4	1	25	2
indet. sp1	Icacinaceae	22	1	5	4
Landolphia	Apocynaceae	15	0		
Ancistrocarpus	Tiliaceae	3	0		
Cissus	Vitaceae	3	0		
Icacina	Icacinaceae	3	0		
Strophanthus	Apocynaceae	3	0		
Piper	Piperaceae	3	0		
Strychnos	Loganiaceae	3	0		
Simiristis	Celastraceae	2	2		5.5
indet sp1	Papilionaceae	2	2		3.5
Frisodielsia	Annonaceae	2	2		3.5
Mussaenda	Rubiaceae	2	1		3
indet. sp1	Annonaceae	2	0		
Cnestis	Conneraceae	1	1		5
Lonchocarpus	Papilionaceae	1	1		2
Dalbergia	Papilionaceae	1	1		2
Pyrenacantha	Icacinaceae	1	1		2
Loesenerilla	Celastraceae	1	1		1
Acridocarpus	Malpighiaceae	1	1		3
Calycobolus	Convolvulaceae	1	1		1
Neuropeltis	Convolvulaceae	1	1		4
indet. sp1	Apocynaceae	1	0		
Uncaria	Rubiaceae	1	0		
Sabicea	Rubiaceae	1	0		
Mucuna	Papilionaceae	1	0		
indet. sp1	Euphorbiaceae	1	0		
Afrobrunnichia	Polygonaceae	1	0		
indet. sp1	Celastraceae	1	0		
unknown		1	0		

Note: (1) the initial number of individuals monitored, (2) the number of lianas alive and with sprouting spots after 22 months, (3) the percentage of individuals surviving and (4) the mean number of sprouting spots for alive individuals after 22 months

As result of the felling of individual trees, on average 12 other trees died, but variation again was large. The averages were not different between trees felled with previous climber cutting (mean = 12.3, SD = 6.9) and without (mean = 12.5, SD = 6). Most dead trees were small or medium sized (Figure 2), and climber cutting had no significant effect on the size distribution. Between 16 and 20% of all affected trees belonged to the diameter class that includes potential crop trees (30-60 cm drh). This applies for mortality as well as residual damage in treated and untreated plots. Damaged harvestable trees (> 60 cm drh) made up 9% of all affected trees in treated and untreated plots and mortality of among those trees was as low as 2% for treated and 7% for untreated plots. Apart from trees that died, on average 20 trees were damaged per felled tree. In total, 33 trees were affected for each felled tree.



previous climber cutting (-).

In the field, 10 different types of damage were distinguished, but for analysis some of the damage classes were grouped into composite classes. In general the damage caused at the felling operation was not excessive. Minor stem and crown damage was most common and made up 80% of all damaged trees in untreated plots (class 1). Severe stem damage (class 2) and serious crown damage (class 3) were proportionally represented at the felling sites for both treatments. The most striking aspect was that among trees *with* previous climber cutting, the incidence of torn-off crowns was three times that in the untreated plots (class 4), with 30% of the affected trees showing such fracture (Figure 3). This was completely contrary to the expectations. Small trees (class 10-30 cm drh) were most prone to serious damage: roughly two-third of the total number of damaged trees were in this size class. To this size class belong most individuals and so damage levels are proportionally more abundant in this class too. The mean diameter for all damaged trees was 27.3 cm (N = 625 trees) for treated plots and 29.3 cm (N = 366 trees) for untreated plots.

5. DISCUSSION

5.1. Floristic composition

The present study deals with the ecological effects of logging with an emphasis on the role of lianas in the forest. In that context, abundance and distribution of lianas was more important than an exact knowledge of species composition. Therefore, local names were used initially and these were linked to botanical names later, as was done by Rollet (1974) over 103 ha in Venezuela and by Lescure *et al.* (1983) at a single ha in French Guyana. Because of the often non-specific characterisation of lianas in the Bulu language used in the study area, and due to the incomplete floristic knowledge of the lianas in the Lower Guinea forest, a considerable underestimation of the number of species present is likely. As the research area is most probably located in or near a forest refugium (Hamilton and Taylor, 1991; Reynaud-Farrera *et al.*, 1996; Maley, 1996), plant species diversity is expected to be very high. It will be rewarding to look more in detail to liana species.

A floristic inventory including lianas (> 3 m height) was done in northeast Gabon (Hallé *et al.*, 1967). In an area of just 800 m^2, they found 96 individuals representing 15 families and 26 (morpho)species. Even though plant taxonomists executed that study, there were 24 unidentified liana individuals belonging to 10 families. Since their lower cut-off limit is much lower, species and families will be included which do not attain the sizes of lianas included in our survey. We plea for further botanical studies on lianas in this overall region.

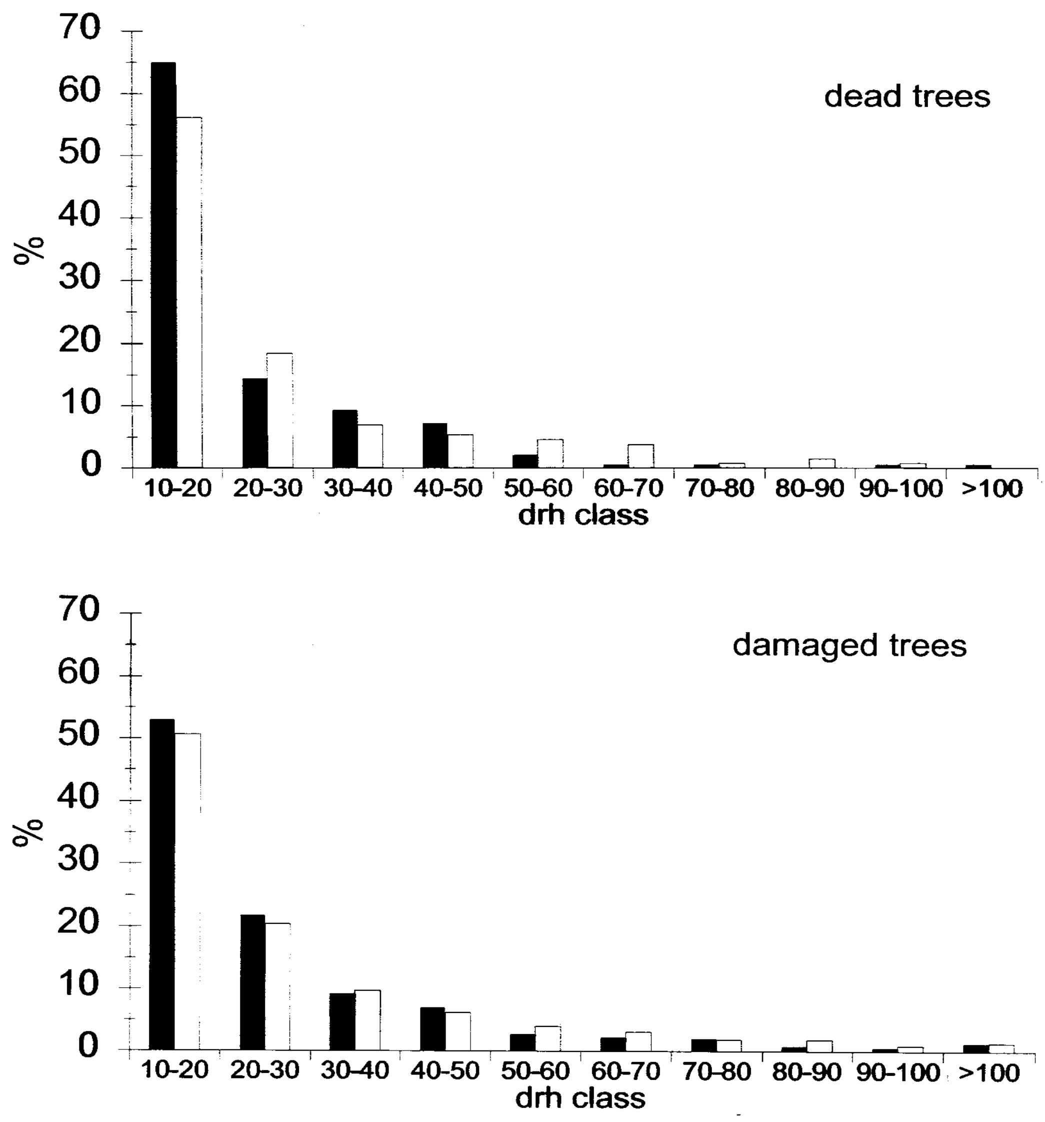


Figure 2. Diameter distribution of stand damage after felling of trees with (black) and without climber cutting (blank). Seventeen felled trees with climber cutting resulted in mortality of 194 trees and residual stand damage of 414 trees, 11 felled trees without treatment resulted in mortality of 130 trees and residual stand damage of 225 trees over 10 cm drh.

5.2. Abundance of large lianas

In the forests studied, lianas are abundant compared to many other forest sites (Gentry, 1991; Hegarty and Caballé, 1991). Especially the number of small lianas is high, but with respect to climber cutting and its effects, the number of large lianas is of prime importance. These forests harbour many large liana stems of over 5 cm dbh (113 liana stems ha^{-1}), but this is not exceptional compared to other continents. Appanah and Putz (1984) in Pahang, Malaysia (13 ha inventoried) found equal numbers of liana stems over 5 cm dbh in their forest. In Para State, Brazil, Vidal *et al*. (1997) estimated that some 100 large lianas per ha (only 0.42 ha inventoried) were present in mature forest. Jonkers (1987) in Suriname found slightly lower numbers for large lianas (mean 71 per ha, 1.8 ha inventoried). In a forest at Ituri, Congo, Makana *et al*. (1998) found some 67 large lianas per ha (3 ha inventoried), but in a monodominant forest type only 24 large lianas per ha (3 ha inventoried) were found. That classifies these African forests even as poor concerning large lianas. Unfortunately hardly no comparable density data were found for really large lianas of over 10 cm dbh except for Suriname (Jonkers 1987) were almost equal numbers were found (av. 9 lianas, 1.8 ha inventoried). Still these large lianas may be the main cause for tearing off entire crowns of surrounding trees. Unfortunately little is known of their densities and their effects at felling sites.

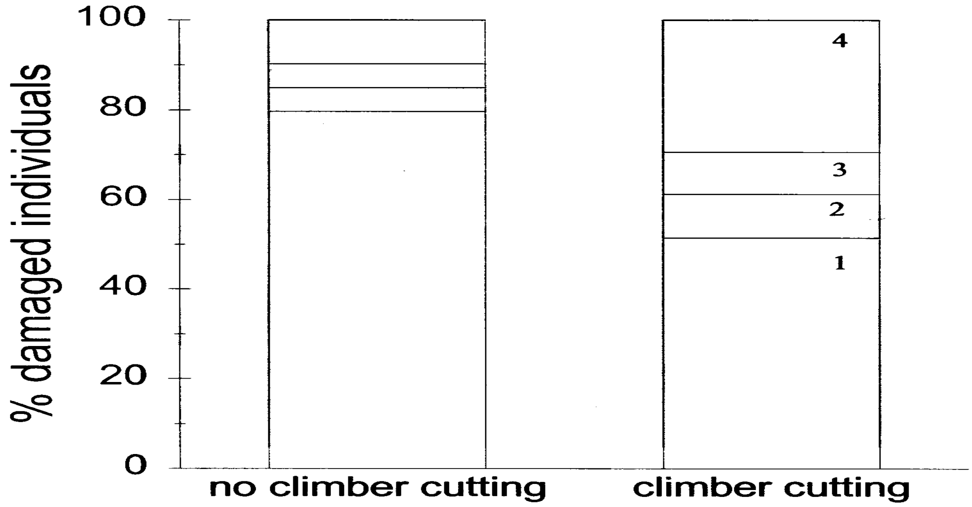


Figure 3. Type of damage for trees in an operation with (N = 379) and without (N = 226) previous climber cutting. Damage classes are minor crown and stem damage (1), severe stem damage (2), serious crown damage and hardly any stem damage (3), no crown anymore (4).

5.3. Sprouting of lianas

The goal of climber cutting is to eliminate or diminish the strength of the liana, leading to a smaller binding force between trees and tree crowns. We used mortality of lianas after cutting as an indication of weakening. For a large group of lianas, mortality was low, and thus the effect is not very obvious, at least during the period of observation (22 months). We cannot prove a positive relation between mortality and a decline of strength of the lianas, as knowledge on strength properties of alive and dead lianas is lacking.

The fact that cutting had a strong effect on some species while others were very resistant can partly explain the results found for the 1-m cuttings. Because the Bulu names do not correspond with one species or genus, the expectations were equivocal. *Avom* can be both *Dictyophleba* (high survival) and *Landolphia* (low survival). The same accounts for *Atuk*, which can be both *Neuropeltis* and *Calycobolus* (high survival) and *Icacina* (very low survival). The choice of species thus was not the right one. We suggest studying a large number of botanical well-defined ones in this respect. A study by Appanah and Putz (1984) is a nice example in this respect (32 species), but this was performed without taking the diameters of the cuttings or the environment (gap or understorey) into account.

5.4. Climber cutting effects on gap size, tree death and damage

This study shows that climber cutting had no effect on the size of felling gaps, contrary to the expectations. Of course many factors influence gap size and with a small number of gaps we would not have expected a difference. When studying 161 trees however, one would expect that the large number would filter out the variation due to non-controlled factors. That this was not the case is an indication that lianas play a minor role in this respect. An important drawback of this study, however, may be that we did not record the actual number and sizes of lianas on trees to-be-felled and the liana links to surrounding trees in the upper canopy. Several of the trees might not have had lianas on them at all, thus blurring the difference between the groups. Vidal *et al*. (1997) did select individual trees based on the difference in liana load and found that felling trees with many liana connections resulted in twice as large canopy gaps as those of liana-free felled trees.

This study shows that climber cutting has only a small effect on the number of trees that die or that are damaged during the felling operation. The study did not include effects of skidding operations. This is a surprising result as it was expected that the number of affected trees would be reduced when climbers were cut some time before the felling of the tree. Even more striking was that complete crowns were torn off three times as often after climber cutting, completely opposite to the expectation.

In general crown damage is more frequent than stem damage. Damage assessments in Sabah, Malaysia (Nicholson, 1958), Penang, Malaysia (Appanah and Putz, 1984) and Ghana (Mensah, 1966), following Nicholson's (1958) damage classification, all showed that there was more crown damage than bark damage and that the damage was predominantly of trees in smaller diameter classes. A similar pattern was found in Para, Brazil (Uhl and Guimarães Vieira, 1989). These results are consistent with those of the present study. We suggest that climber cutting will be applied on a tree-by-tree basis only, and after a judgement of the liana load.

Overall damage levels in our study are in concurrence with studies in Ghana (Mensah, 1966) and Gabon (White, 1994), but in contrast to studies in Malaysia (Nicholson, 1958; Appanah and Putz, 1984) and Brazil (Uhl and Guimarães Vieira, 1989) where they found much higher levels. This is probably related to the difference in extraction intensity of 1-2 trees ha^{-1} in Africa versus 8-11 trees ha^{-1} in Southeast Asia and Latin-America.

5.5. Is climber cutting cost effective?

The feasibility of a systematic large-scale climber cutting operation depends on the cost and effectiveness of this treatment. Climber cutting was executed by villagers who are used to cut trees and lianas and were given instructions to cut all lianas over 1 cm dbh. An area of in total 90 ha was covered and the time required was recorded. The cost of cutting was expressed as the number of man-days spent per ha. The average time required cutting all lianas over 1 cm dbh at breast height in a 9-ha plot with a team of 13 labourers was approximately 1 day (with 5 hours efficient working per day). This is equivalent to 0.7 man-days per ha. At a daily wage of F CFA 1000 (US$ 1 = approx. F CFA 600) this would equal approximately US$ 1 per ha. This amount does not include the costs of transport, supervision and other additional costs, which probably are considerably higher. Compared to the costs of the whole logging operation, this is very modest and should not be a reason for refraining from climber cutting.

Although the costs of climber cutting are low, this study shows that it is not worthwhile to do a general climber cutting in the way it was done. We believe that climber cutting, if at all applied, should be more selective and on a tree-by-tree basis. We suggest that during the logging inventory the liana situation of every potentially-to-be-felled tree should be verified. Only where really large lianas are present on a tree these should be cut. Ideally we should know what big woody lianas have the greatest strength properties, both alive and dead, to enable to be more selective with climber cutting. This would require some additional research. Depending on the total planning climber cutting could be combined with the inventory at least one year before the felling operations begin.

6. CONCLUSIONS

- More attention should be focussed on botanical studies of lianas in West and Central Africa.
- Lianas are abundant in the forests studied.
- Post cutting mortality and re-sprouting capacity is highly variable among species/genera and thus the effects are species dependent.
- Pre-felling climber cutting has at best a weak effect on the size of felling gaps, on the number of dead trees and on the damage to remaining trees.
- The effectiveness of pre-felling climber cutting is very doubtful in Cameroon.

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Appendix I. Botanical identification of Bulu names for lianas (≥ 2 cm dbh) and rattans present in 33 one-ha plots of lowland moist forest, Ebom, south Cameroon[4].

Bulu name	Botanical name	Family	Herbarium specimen
Abomendjang	Piper capense	Piperaceae	P16
Adjoe bekoye	Friesodielsia grandiflora	Annonaceae	P23
Aka	Lacosperma sp.	Calamoideae	
Angos	Maniophytum fulvum	Euphorbiaceae	
Atuk	Neuropeltis sp.	Convulvaceae	E547, E573
Avom	Dictyophleba ochracea	Apocynaceae	E583
	Dictyophleba stipulosa	Apocynaceae	P59
	Landolphia sp	Apocynaceae	P13
Bika		Calamoideae	
Enaye	Strophanthus thollonii	Apocynaceae	P47
Enaye ndjoto	Alafia lucida	Apocynaceae	P48
Fazo'o	Tetracera alnifolia	Dilleniaceae	P9, E537
Fofot ndik	Chassalia sp.	Rubiaceae	P26
	Musseanda arcuata	Rubiaceae	P50
Mendolo ndik	Phyllanthus sp.	Euphorbiaceae	P25
Mfas	Strychnos cuniculina	Loganiaceae	P1
	Strychnos urceolata	Loganiaceae	P20
Mfop	unknown	Calamoideae	
Nkam	Landolphia sp.	Apocynaceae	
Ndik assol	Strychnos camptoneura	Loganiaceae	E542
	Strychnos dolichothyrsa	Loganiaceae	P54
Ndik assas	Macaranga schweinfurthii	Euphorbiaceae	P19
	Lavigeria macrocarpa	Icacinaceae	P44
Ndik bilat	Salacia alata	Celastraceae	P28, E554
Ndik ele	Salacia sp.	Celastraceae	E576
	Dichapetalum angolense	Dichapetalaceae	P7
	Rourea thomsonii	Conneraceae	P17, P18
Ndik kussa	Cissus dinklagei	Vitaceae	P10, E550
Ndik missong		Rubiaceae	P21
Ndik ndamba	Dictyophleba ochracea	Apocynaceae	P41, P57
Ndik ngokop	Iodes africana	Icacinaceae	P12, E579
	Dalbergia saxatilis	Papilionaceae	P52
Ndik nguess	Strychnos aculeata	Loganaceae	E551
Ndik sole	Campylostemon sp.	Celastraceae	
	Mussaenda sp.	Rubiaceae	P30
	Vitex sp.	Verbenaceae	P55
Ngosso	Combretum sp.	Combretaceae	E570
	Clerodendrum sp.	Verbenaceae	P31
	Uncaria africana	Rubiaceae	E549
Nlong	Eremospatha sp.	Calamoideae	
Nsa bekoye	Ancistrocarpus densispinosus	Tiliaceae	P22
Nsinik	Entada scelerata	Mimosaceae	P32
Oko matele	Rhigiocarya racemifera	Menispermacea	P24, P39
Onono mstin		Calamoideae	
Opkwam	Landolphia sp.	Apocynaceae	P5, P27
Otutu	Salacia sp.	Hypocrataceae	P51

[4] Duplicates of herbarium specimens of the collectors M. Elad Epah (E) and M.P.E. Parren (P) are deposited at the Tropenbos-Cameroon Programme in Kribi, Cameroon and at Herbarium Vadense (WAG) in Wageningen, the Netherlands

SILVICULTURAL MONITORING IN PERMANENT SAMPLE PLOTS IN EBOM FOREST, SOUTHERN CAMEROON

R. Bibani Mbarga[1] and W.B.J. Jonkers[2]

SUMMARY

The present paper deals with a study in a rain forest in south Cameroon. The study is part of the Tropenbos-Cameroon Programme (TCP). Its purpose is to develop a silvicultural system for natural forest management directed at a sustainable production of timber, other products and services. Silvicultural methods and techniques adapted to the local conditions will be formulated and tested. The impact of logging and silvicultural interventions on growth, regeneration and mortality of tree species are being recorded and analysed. The study will also provide data for a growth and yield model, which will at a later stage be used to predict long-term stand development.

Since the study began in 1994, 20 permanent sample plots (PSPs) of 9 ha each have been established. About 90 000 trees with dbh > 10 cm have been identified, measured, numbered and mapped. The PSPs provide information on species composition, structure, and architecture of the stand. For the silvicultural interventions, three types of forest have been identified: virgin forest on good soils (type 1), in 84% of the area; virgin forest on periodically inundated land (type 2, 4%); and virgin forest on rocks (type 3, 12%). Natural regeneration dynamics of 70 timber species has been analysed, and the behaviour of each species has been estimated from their diameter class distribution. Furthermore, phenological observations on 86 timber species have been carried out during 38 months.

All scientific information collected is used for the design of silvicultural treatments. These treatments will be simulated in the PSPs to appreciate their impact on growth, natural regeneration and mortality. The two most promising treatments will then be tested in the PSPs.

Keywords: tropical rain forest, silviculture, phenology, Cameroon

1. INTRODUCTION

Silvicultural systems for tropical rain forests based on natural regeneration are mainly concerned with the condition of the remaining stand and aim at an increase in wood production of commercial species (de Graaf, 1986; Jonkers, 1987). A major problem in this respect is the lack of scientific knowledge. This study in southern Cameroon explores opportunities and limitations of forest utilisation in order to increase stand production by applying silvicultural treatments, which favour desired species. Results presented in this paper are mainly based on the analysis of patterns in the Ebom rain forest, which were required to formulate and simulate silvicultural treatment. The two most promising treatments will be tested in the field.

2. OBJECTIVES

2.1. General objective

The purpose of the present study is to develop a silvicultural system for natural forest management directed at sustainable production of timber and other services. The silvicultural methods and techniques to be developed have to be adapted to the prevailing conditions in the

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rain forest of southern Cameroon. The study will also provide data for a growth and yield model, aimed at predicting long-term stand development.

2.2. Specific objectives

The study has three specific objectives:

To design silvicultural treatments directed at:

- Stimulating the growth of timber species, which are likely to be on the timber market at the end of the first cutting cycle;
- Stimulating natural regeneration of these tree species;
- Keeping their mortality at a low level;
- Preserving and/or stimulating the production of non-timber forest products and other tree species important for the local population;

Such treatments should also preserve the biodiversity and the stability of the forest ecosystem and be inexpensive and easy to carry out.

To assess the impact of these silvicultural treatments on:

- The costs of sustainable forest management;
- Tree growth, regeneration and mortality; and
- The composition and development of these stands as a whole.

To provide basic data and information for other studies:

- For adjusting the yield predicting model developed for the rain forests of south Cameroon (Eba'a, 2000);
- For the development of a Reduced Impact Logging method (Jonkers and van Leersum, 2000); and
- For the development of a forest management plan.

These other studies will not be discussed further in this paper.

3. RESEARCH ITEMS AND DATA REQUIREMENTS

For the **design of the silvicultural treatments**, about eight treatments will be formulated first. The effects of these treatments on the stand will then be simulated, and the two most promising treatments will then be tested on the ground. For this purpose, information on a wide range of topics is needed, of which is some is obtained from other TCP studies or external sources:

- Basic information on vegetation types, landforms and soils, derived from van Gemerden and Hazeu (1999);
- Basic information on the importance of the forest for the local people, derived from the social science component of TCP (see e.g. Tiayon *et al*., 2001; van Dijk, 1999; van den Berg and Biesbrouck, 2000);
- Information on distribution patterns within the tree stand: spatial variation in species composition, diameter class distributions and spatial arrangements of trees. This information was gathered as part of the present study;
- Information on natural regeneration and spatial distributions of seedlings and saplings and lianas. This was derived partially from other TCP studies (see Bongjoh and Nsangou, 2001; Parren and Bongers, 2001) and partially from the present study;
- Growth and mortality estimates. Apart from logging damage estimates, such data are not available from Cameroon, and therefore data from West Africa will be used instead to estimate the development of the stand after various silvicultural treatments;
- Tree dimensions, in particular the relations between stem diameter, stem length, crown height and crown width.

For testing the effects of silvicultural treatments on costs, growth, regeneration, mortality and forest composition, information has to become available on:

- Diameter growth and mortality of per tree species and per size class after each silvicultural treatment, and when no treatment is applied;
- Flushing, flowering and fruiting of timber species and the impact of silvicultural treatments on these phenological phenomena;
- Recruitment per tree species after each silvicultural treatment, and when no treatment is applied;
- Changes in biodiversity, phytomass and the nutrient status of the forest;
- The manpower and capital input required for each treatment.

Apart from part of the information on phytomass and nutrients generated by other TCP studies, all data required will be generated by the present study.

4. METHODS AND ANALYSES

4.1. Defining silvicultural treatments

In the main experiment, three silvicultural treatments will be applied:

- A control treatment (treatment A), which leaves the logged stand untouched and therefore does not require further analysis to define the treatment;
- A relatively light liberation of commercial timber trees, which are likely to be harvestable after 20-30 years (treatment B);
- A relatively heavy liberation treatment (treatment C).

In treatments B and C, part of the trees, which do not produce timber or non-timber forest products, will be eliminated. Liberation will be restricted to areas within a specified distance from the nearest tree to be liberated. Treatments B and C may differ in respect to this distance, in the list of species to be liberated, which may be longer in treatment C than in treatment B, or in other treatment prescriptions. The minimum diameter of trees to be killed should be similar or larger than the stem to be liberated.

Treatments B and C will be selected out of approximately eight treatments. The differences between these treatments are again the number of species to be liberated and the distance criterion, which will be determined on the basis of present and future competition between trees, among other by using the relations between crown diameter and stem diameter. These eight liberation intensities will be simulated in permanent sample plots and transects (see below). Their effects on the development of the commercial stand, treatment costs and their ecological and social impacts will be estimated and finally the treatments to be implemented in the field will be defined. Four categories of species are distinguished in defining the treatments:

- Group 1: timber species actually on the market, i.e. all timber species exploited within Cameroon and/or in other African countries;
- Group 2: timber species of high future potential (species which are likely to be commercial after 20-30 years);
- Group 3: non-timber forest products (NTFP), species, which are used by the local population;
- Group 4: all other species encountered in the PSPs.

Trees to be liberated belong to group 1 or groups 1 and 2 and trees to be eliminated always belong to group 4.

4.2. Experimental lay-out main experiment

4.2.1. Treatment schedule

The experiment is a factorial one with two pre-felling and three post-felling silvicultural treatments and three replications. Hence, it is a 2x3x3 factorial experiment with a complete randomised block design. Logging was applied in a uniform fashion throughout the replications. Four additional plots have been established which have not been logged and which will not receive a silvicultural treatment.
Thus, the experiment has two treatment levels:

- Two pre-felling treatments: D0 (control without climber cutting) and D9 (climber cutting 9 months prior to felling), see also Parren and Bongers (2001);
- Three post-felling treatments: A (control, no post-felling treatment), B (low intensity liberation) and C (high intensity liberation).

4.2.2. Plot design

The experimental plots consists of a 100x100 m assessment plot, subdivided in 10x10 m quadrats, and surrounded by an 8 ha buffer zone. In each assessment plot, one tree has been felled. Two boundaries of the assessment plot are parallel to the expected felling direction, at 50 m distance from the trunk. The third and fourth boundary are perpendicular to the expected direction of fall, at 15 m (- 20 m) and 85 m (- 80 m) from the foot of tree, in such a way that the entire tree falls within the assessment plot. The 1-ha permanent sample plot can be located eccentrically, but the whole experimental plot, including the buffer zone, remains 9 ha. In case of eccentricity of the 1-ha plot, the buffer zone extends to at least 50 m from the boundary of the 1-ha plot. The buffer zone is also used to collect data, particularly growth data.
In each 1-ha plot, 17 sub-plots of 1x5 m have been established, in which tree regeneration is assessed.

4.3. Transects

Three permanent transects have been established inside the main experiment to allow simulation and assessment of changes in forest architecture. The longest transect (500x20 m) is on well-drained soil, and a second one (100x20 m) on a steep slope. Silvicultural treatments will also be applied in these transects. The third transect on swampy soil measures 100x20 m. Swamp forest is excluded from silvicultural treatment.
In addition, a 20.6 km transect was established outside the main experiment. This transect is used only for phenological observations on selected timber trees.

4.4. Enumerations and observations

4.4.1. Main experiment

Data collection is done through repeated enumeration of trees, seedlings and saplings, and mapping of trees and terrain characteristics. Each human intervention (including the logging operation) has been and will be preceded and followed by a tree enumeration. Thereafter, enumerations will be repeated on a biennial basis for several decades.

In the central 1-ha plot, all trees > 10 cm dhb are enumerated per 10x10 m quadrat. The following data are assessed for each living stem:

- Vernacular and scientific name;
- The location of stem in the quadrat;
- Diameter at breast height or 30 cm above buttresses (dbh);
- Trunk quality (stem class);
- Crown form and crown position;
- Physical damage to the crown and to the trunk;
- Treatment received (e.g. felled; girdled completely; girdled partially).

Characteristics, which are not supposed to change (species name, geographic position), are assessed once for each tree (or twice if checking is needed), other data will be recorded during each enumeration.

In addition, the following parameters are assessed every four or five year: stem length, stem diameter at crown point, total tree height and crown dimensions.

For trees which died since the previous enumeration or which were not found, one of the following stem classes will be recorded: uprooted tree; broken trunk, felled tree; complete dead tree (standing, with crown); tree not found.

Living trees which are broken below the level of measurement are treated as dead trees, even if they coppice (coppice shoots reaching 10 cm dbh are recorded as ingrowth). The same applies to living felled trees.

The same method is used for tree enumerations in the buffer zone, except that the enumeration is not per quadrat and that small trees are not enumerated everywhere. The minimum diameter applied varies, depending on the distance to the 1-ha plot. The enumeration in the regeneration sub-plots is by tallying individuals per species and per size class.

4.4.2. Phenological observations

Leaf-fall, flushing, flowering and fruiting are recorded monthly on 1320 trees > 10 cm dbh in the 20.6 km transect and in a few 25x25 m quadrats established inside 1-ha plots of the main experiment where silvicultural treatments will be applied. The study involves 86 timber species. The aim of this exercise is to determine phenological patterns of timber species, and the impact of silvicultural treatments on these patterns.

4.5. Vegetation analyses

Vegetation analyses deal with variation in species composition, diameter class distributions, spatial arrangements of trees and spatial distributions of seedlings and saplings. Preliminary, rather simple analyses on species composition in the permanent sample plots and on diameter class distributions of timber species have be conducted. The post-felling treatments will be based, among others, on these analyses. It is intended to use an ordination technique to investigate vegetation variation in itself, and the spatial patterns of categories of trees (e.g. species, size classes). Spatial distribution of seedlings, saplings and lianas, carried out by other sub-projects within the Tropenbos-Cameroon Programme has been analysed, and will also be used in the simulation of silvicultural treatments.

4.6. Analysis of silvicultural treatments

After treatments B and C have been applied in the field, the actual treatments will be compared with the results of the simulation. Furthermore, initial growth response will be analysed, using standard statistical methods (ANOVA, t-test and regression analysis), and the impact on biodiversity will be assessed. In a later phase of the project, more growth, mortality and regeneration data will become available to be used for the prediction of long-term stand development.

5. PRELIMINARY RESULTS

5.1. Types of forest

In the main experiment, three types of forest have been identified:

- Virgin forest on well-drained soil (type 1), which covers 84.2% of the area (197 ha). This type is rich in tree species. The architectural profile diagram shows four level of vertical stratification: emergent trees, 65-50 m height; upper storey, 50-35 m height; medium storey, 25-35 m height; and lower storey, 20-10 m height. These storeys are not discontinuous and tree crown can be found between two storeys. The most common species in the upper canopy are *Lophira alata* (Azobé) and *Sacoglottis gabonensis* (Bidou). The average density of trees > 10 cm dbh is 323.5 trees per hectare and the mean basal area is 27.2 m^2 per hectare.

- Virgin forest on periodically inundated land (type 2, 4.0% of the area). The most common species are *Uapaca guineensis* (Rikio), *Coelocaryon preussii* (Ekouné), *Plagiostyles africana* (Essoula), *Trichilia welwitschii* (Ebegbemva) and *Berlinia bracteosa* (Ebira). Lianas are particularly abundant in this forest type.
- Virgin forest on rock outcrops (type 3, 12.0% of the area), with the same common species as in forest type 1, and also a similar vertical stratification of the canopy.

5.2. Species composition

The vegetation of south Cameroon evergreen rain forest has been studied by various authors (Letouzey, 1968; 1985; van Gemerden and Hazeu, 1999; Satabié, 1991). The species composition among trees > 10 cm dbh was analysed for twenty 9-ha plots of the main experiment. A total of 252 tree species were present, belonging to 197 genera and 51 families. The most common families are Caesalpiniaceae with 21 genera and 25 species (which corresponds with findings of Letouzey, 1985), Euphorbiaceae with 21 genera and 23 species, Annonaceae with 13 genera and 16 species, Meliaceae, with 10 genera and 14 species, Mimosaceae, with 9 genera and 10 species, Rubiaceae, with 9 genera and10 species and Sterculiaceae with 7 genera and 10 species.

The species encountered have been grouped according to their use (see Section 4.1):

- Group 1, tree species actually commercialised (41 species);
- Group 2, timber species to be promoted and lesser known timber species (37 species);
- Group 3, species used by the local populations (41 species); and
- Group 4, other tree species (133 species).

The number of species per hectare ranges from 67 to 102, and per 9-ha plot from 175 to 223 (Table 1). These values are in accordance with findings in other African rain forests (Lamprecht, 1989). According to the vegetation map of Letouzey (1985), the forest belongs to his '*Forêts atlantiques biafriennes à Césalpiniacées'* (vegetation type 228).

5.3. Forest structure

The forest structure in each sample plot was studied using class diameter distribution diagrams. Three types of diagrams were drawn. The diameter class distribution diagrams of all species (for an example, see fig. 1) are similar to Rollet's (1978) exponential model. This model reflects a geometrical decrease of numbers of individuals per dbh class with increasing tree size. The diameter class distributions of species groups (e.g. fig. 1) and diameter class basal area distributions (e.g. fig. 2) show asymmetric curves with peaks between 20 and 50 cm dbh and long tails for large diameters.

5.4. Stand density and basal area

Table 1 and Figure 1 show some results of a partial inventory of the main experiment executed before logging, in 1996. The parameters density and basal area are important for a silviculturist. In Ebom forest, the density varied from 538.5 trees/ha to 408.1 trees/ha, with an average density of 479.2 trees/ha. The distribution of trees among the four species groups is:

- Group 1 (timber species actually on the market) 13.6%;
- Group 2 (lesser known timbers) 15.4%;
- Group 3 (NTFP species) 16.8%; and
- Group 4 (other species) 54.2%.

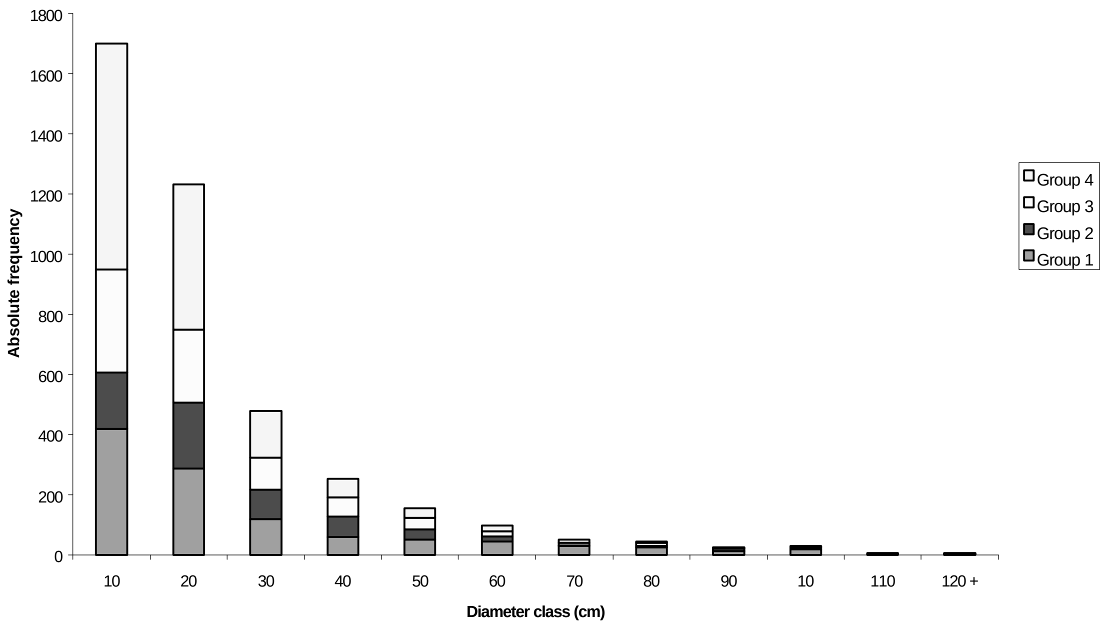


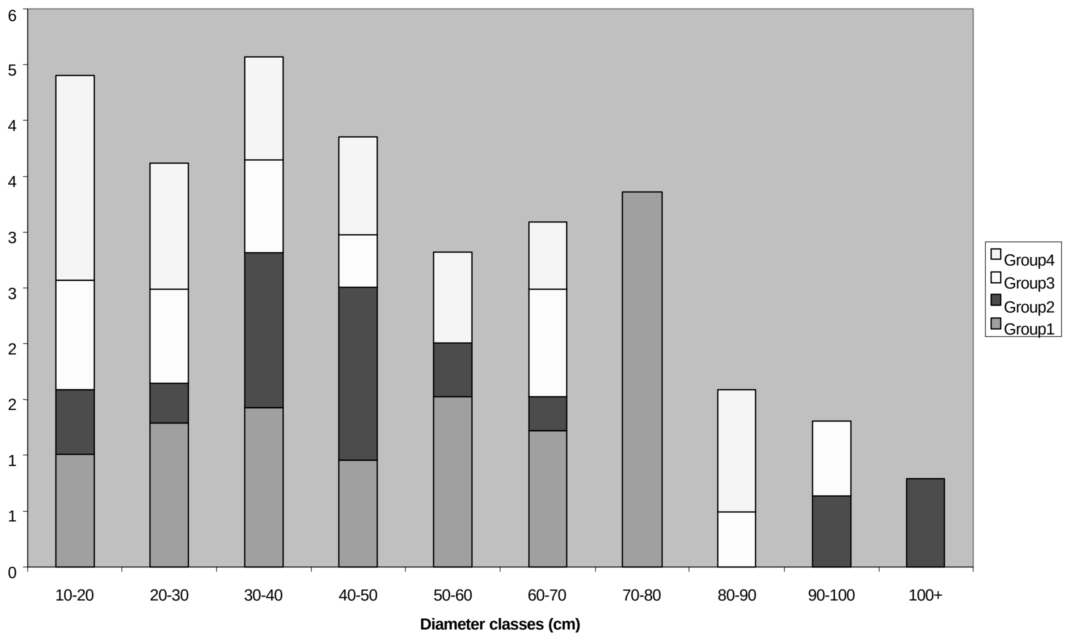
Figure 1. Diameter class distribution of tree species groups 1 - 4 in PSP Abel 89, Nov. 1996 enumeration

Table 1. Number of species, basal area and stand density in twenty 9-ha plots in Ebom forest.

Permanent Sample Plot	**Total number of species**	**Total basal area (m^2/ha)**	**Density (number of trees/ha)**
Abel 89	177	28.5	445.6
Amouk 80	203	39.1	500.3
AZ 4	223	34.6	495.3
AZ 9	192	32.9	466.3
AZ 10	194	34.8	505.0
AZ 18	183	33.0	450.5
AZ 19	211	37.5	519.8
AZ 31	198	43.4	510.6
AZ 36	216	39.5	464.4
AZ 48	200	35.4	500.7
AZ 65	178	42.1	538.5
AZ 70	175	38.0	408.1
AZ 77	215	50.5	487.4
BIB 25	193	38.4	426.4
DS 46	185	35.9	458.1
PA 72	200	44.7	527.8
Sipo 17	199	35.1	449.1
Tali 4	201	36.4	472.0
MEAN	197	37.8	479.2

Basal area varies from 50.5 m^2/ha to 28.49 m^2/ha, with an average of 37.9 m^2/ha (see Table 1 and Figure 2). The basal area is high and well above the pan-African average (Rollet, 1974; 1978). Duiker and van Gemerden (1989) found 31 m^2/ha in another part of the TCP area. The distribution of the basal area among the species groups is 37.5% for Group 1, 19.1% for Group 2, 19.6% for Group 3 and 23.8% for Group 4, meaning that a major part of the basal area belongs to timber species actually commercialised.

The silvicultural significance is that there are many timber trees to liberate, and the number of Group 4 trees is so high, that a substantial part of the Group 4 trees can be eliminated in a liberation treatment without affecting the number of tree species present. Group 4 trees are numerous but mostly rather small and contribute comparatively little to basal area and therefore to the phytomass. Liberation will therefore result in a moderate reduction in phytomass and losses of nutrients will probably be negligible. Furthermore, the high basal area of timber trees suggests that an attractive volume increment can be expected.



where *Lophira alata* and *Sacoglottis gabonensis* are predominant species.

The tree density in the experiment is high, with an average of 479 trees per hectare; and basal area is very high, with the average of 38 m^2/ha. The situation seems favourable for liberation or thinning. The number of trees in the category ‘other species’ is 54% of the total and these trees are generally rather small, meaning that a well designed liberation treatment probably has a low impact on plant biodiversity and on the nutrient capital of the ecosystem. Furthermore, the high basal area of timber species indicates a high potential volume increment. The forest structure is similar to Rollet’s (1978) exponential model, meaning that one can expect a steady increase in number of trees of harvestable sizes after silvicultural treatment.

Phenological observations show that leaf-fall, flushing, flowering and fruiting, although occurring throughout the year, are periodic and seasonal and vary among species. Most species flower and fruit twice a year, meaning that prolonged periods without recruitment of timber trees are not to be expected.

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GAP DISTURBANCE REGIMES AND REGENERATION DYNAMICS OF COMMERCIAL TIMBER TREE SPECIES IN A SOUTHERN CAMEROON FOREST

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ABSTRACT

A study investigating within-gap species differentiation among juvenile commercial timber trees in a Cameroonian moist tropical forest and comparing regeneration dynamics of these species is described. The study deals with 1, 6 and 9 year-old felling gaps and shifting cultivation fields abandoned 1, 5 and 10 years before. Only 3 out of 17 species showed any preference for one gap region demarcated along the light-border gradient. Along tree-fall axes, tree bases were found to be the foci of seedling (<1 m high) or sapling (>1 m high or >2 cm dbh) abundance and species richness. Expected differences in species composition between felling gaps and abandoned shifting cultivation fields in relation to light demanding species did not occur. This was probably due to inherent limitations imposed by inefficient seed dispersal from distant seed sources and poor morphological adaptation to fallow fields of most species. Seedling distribution in gaps of varying ages, in response to changing light levels accompanying gap closure, were used to group species into three broad regeneration guilds (light-demanding, shade-tolerant and indifferent). Although large fields were significantly ($p<0.001$) more suitable for seedling establishment at community level than smaller fields, gap and field sizes are poor indicators of regeneration potential of most species. From tree-fall gaps to fallow fields, there was a community-wide but statistically insignificant decrease in juvenile densities corresponding to an increase in species richness. Species richness significantly declined between 1 and 5 (6) years and then rose again during the years thereafter. There appears to be a reduction in scope for species diversification in fields relative to the surrounding understorey due to gregariousness.

Keywords: moist tropical forest, logging, shifting cultivation, gaps, species differentiation, tree species, regeneration dynamics, Cameroon.

1. INTRODUCTION

The tropical moist forest is a complex, heterogeneous and stratified ecosystem with a mix of plant species each requiring specific condition for establishment, survival, and growth to maturity. In its climax or homeostatic state, some species exploit tree-fall gaps for seedling recruitment (pioneers) while similar renewed resources stimulate growth resumption for seedlings of other species (shade tolerant species). Hallé *et al.* (1978) used the term silvigenesis to describe this forest-making process in openings in existing forest. Depending on the developmental stage of vegetation in a patch, three phases (gap, building and mature) can be described constituting the forest growth cycle (Watt, 1947). Brown (1992, 1993) claimed that disturbance in tropical rain forest is intrinsic and essential to the forest growth cycle. The silvigenesis concept was developed from Aubréville’s (1938) hypothesis referred to as the mosaic or cyclic theory of regeneration (Richards, 1952). According to this theory, the particular combination of species forming the dominants of a given small area of mixed tropical forest is constant neither in space nor in time. Hence, the forest could be assimilated to spatially

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and temporally dynamic mosaic patches. Overall, the floristic composition of the landscape remains stable (Whitmore, 1989) although patches change in species composition over time and space. This dynamics in species composition is called the mosaic steady state (Bormann and Likens, 1979).

In the tropical moist forests two forms of human disturbance, viz. intensive logging and shifting cultivation, generally create more drastic openings, than natural tree-falls or light selective logging, on which the regeneration of many commercial tree species may depend (Parren and de Graaf, 1995). These may result in a shift in floristic composition and abundance of established juveniles in comparison with the undisturbed forest. From a management standpoint, such canopy modifications may favour the establishment of light-demanding commercial timber tree species, which are poorly capable of responding functionally to slight light increase due to the natural disturbance regime.

With the abandonment of several silvicultural systems in various tropical countries (e.g. Tropical Shelterwood System in Nigeria), practice has swung from monocyclic to polycyclic felling systems (Dawkins and Philip, 1998). Hence, the importance of gap studies has increased. It has been postulated that different species are successful in gaps of different sizes (Whitmore, 1975; 1978; Hartshorn, 1978). This is generally referred to as the gap-size partitioning hypothesis. Yet, very little or no experimental consideration has been given to the effects of felling gap size and age on the recovery of forest vegetation. The interest of such studies to silviculture is to be able to manipulate the forest canopy in order to create gaps of a size that favours growth of chosen species (Whitmore, 1978). Such attempts to manage tropical forests based on the concept of gap dynamics are only being made in recent years (e.g. Hartshorn, 1989).

The study presented here aims at the following objectives:

- To determine within-gaps niche differentiation among juveniles of commercial timber tree species.
- To describe gap dynamics due to logging and agricultural activities.

2. STUDY AREA

The study was carried out on the Tropenbos-Cameroon Programme (TCP) site between August 1997 and December 1998. The study area lies approximately 80 km east of Kribi in the southern region of Cameroon between latitudes 2° 4' and longitudes 10° 51' E. It covers about 170 000 ha and much of this area has been under commercial logging and/or shifting cultivation. The climate is humid tropical with an average annual temperature of around 25° C. Mean annual rainfall is estimated at 1900 mm. The rocks of the site are part of the pre-Cambrian complex while soils resulting from the weathered parent material are predominantly poor, acid ferralitic sandy clay. The low nutritive status of the soil has favoured shifting cultivation practice leading to degradation of much of the vegetation

3. MATERIALS AND METHODS

3.1. Experimental sample sites

The felling sites where gaps were sampled were near the villages Nkoutou (250 m asl), Nyangong (700-900 m asl), Minkan (500 m asl), Assok II (200 m asl) and Ebimimbang (110 m asl). Sample plots selected in post-shifting cultivation patches were spatially distributed among three villages Ebimimbang, Mvié (420 m asl) and Nyangong.

3.2. Felling gaps and field age determination
Felling dates were still visible on tree stumps for up to six years after timber exploitation. The other felling dates were obtained through interviews with former employees of the concerned logging company.

The age of an abandoned shifting cultivation field is more difficult to establish than that of a felling gap. The year of cultivation could often be linked to a contemporary event, thus enabling an estimation of the date of forest clearing. For convenience of the study, field ages were regrouped into classes: 1-2 (1.5), 3-7 (5), 8-12 (10), 13-17 (15) and 18-22 (20) years. The figures in brackets refer to corresponding median ages.

3.3. Area measurements
Runkle's definition (van der Meer, 1995) was used to determine sizes of randomly selected gaps in five logged-over sites. A broad spectrum of gap sizes common to these sites as well as global size mean served in regrouping gaps under the following classes: small (700–1000
(1000-1300 m²) and large (1300-1700 m²).

A quicker surface area evaluation technique (circumference method), than that employed for gaps, was applied to fields. It entails recording distances between successive points marked along the edge of field and the bearing of the line joining each pair of points. Collected data serve in sketching field boundaries on graph paper from which field sizes are calculated. The mean area (3927 m²) found for sampled fields and the range of field sizes (1500-7000
shared among the three sites were used to arrive at the following field size classification: 1500-3000 m² (small), 3000-5000 m² (medium) and 5000-7000 m² (large).

3.4. Experimental design
A split-plot design was used consisting of age since felling (1, 3, 6, 9, 12 years) at various sites as major plots, and gap size (small, medium, large) as minor ones. In all, five age groups times three gap size classes times five replications = 75 gaps served in systematic random sampling of timber species.

Field age (1, 5, 10, 15, 20 years) and size classes (small, medium and large) were replicated in a randomised block design. Each block or replicate has a distinct topographical feature (plain, plateau, or hill) and soil characteristics, which are potential sources of unwanted variation. A total of 45 fields (three blocks times five field age groups times three field size classes) were systematically surveyed for timber tree species.

3.5. Experimental procedure
Five equidistant belt transects, each measuring 5 m in width, were laid out at right angles to the main gap axis and extended into both sides of the closed forest by 10 m. Species identification, stem size assessment for seedlings (< 1 m high) and saplings (dbh > 1 m high and/or > 2 cm dbh) and recording of sampled individuals took place in every other 5 x 1 m plots in each transect.

For fields, the bearing of the longest axis, taken as the main axis, was determined on a field sketch before the experiment was set-up. Transect disposition was the same as in gaps. Pieces of older abandoned farmlands or stretches of old secondary forest adjoining fields served as substitutes for undisturbed closed forest where the latter was absent. Juvenile count was systematically repeated in every fourth plot to take account of disproportionate field sizes in comparison with gaps.

3.6. Data analysis
Analysis was conducted in SYSTAT and computed means were Fischer's least square means. Response variables used, including seedling and sapling densities (number of stems per m²) and species richness (number of species per m²), were initially transformed to log (1+x), where

required, where x was the dependent variable The following Analyses of Variance tests were performed:

- Dependent variables were used in Multi-way ANalysis Of VAriance (MANOVA) with grouping variables age, size and light conditions.
- Similar analyses involving only seedling and sapling densities as dependent variables for individual species was performed only for gaps with the following grouping variables: gap age, gap size, and transects disposed from crown to base of the fallen tree (AB, CD, EF, GH, IJ).
- A one-way ANOVA was carried out on seedling/sapling density means corresponding to the centre and gap border regions and involving 17 selected tree species in 75 gaps. The aim was to determine species composition gradient from gap centre to border as a function of gap size.
- In order to remove or reduce the possible influence (correlation) exerted by surface area on stem densities and increase precision, an ANalysis of COVAriance (ANCOVA) was incorporated into the ANOVA resulting in adjusted mean values between gap centre and border.

4. RESULTS

4.1. Within-gap niche differentiation

Significantly ($p \leq 0.001$) higher numbers of seedlings and of species were found per unit area in the transect closest to the base of the fallen tree than elsewhere. Most of the significant species differentiation was shown for this part of the gap (Table 1).

Table 1. Preference of seedlings or saplings of a number of tree species for specific places in transects, and for gap size, gap centre and gap border. Results based on a seedling/sapling census in 75 felling gaps.

<table>
<tr><td colspan="5">Species Composition[1]</td></tr>
<tr><td colspan="5">Transects</td></tr>
<tr><td>AB (crown end)</td><td>CD</td><td>EF</td><td>GH</td><td>IJ (base of tree)</td></tr>
<tr><td>Z. heitzii
(saplings*)</td><td>-</td><td>S. kamerunensis
(saplings***)
M. africana
(saplings*)</td><td>E. ivorense
(seedlings***)
Z. heitzii
(saplings*)
C. schweinfurthii
(seedlings***)
M. excelsa
(seedlings*)
M. africana
(saplings**)
P. oleosa
(saplings*)</td><td>S. kamerunensis
(seedlings*, saplings*)
P. angolensis
(seedlings*)
C. schweinfurthii
(seedlings***, saplings*)
Z. heitzii
(saplings*)
M. excelsa
(seedlings*)</td></tr>
<tr><td colspan="5">From gap centre to gap edge[2]</td></tr>
<tr><td colspan="2">Centre</td><td colspan="2">Border</td><td>Indifferent</td></tr>
<tr><td colspan="2">D. crassiflora
(seedlings*, large gaps)
C. schweinfurthii
Saplings*, small gaps)</td><td colspan="2">P. angolensis
(seedlings*, large gaps)
G. cedrata
(saplings*, medium gaps)
A. pachyloba
(saplings*, medium gaps)
L. alata
(saplings*, small gaps)
D. crassiflora
(seedlings*, small gaps)</td><td>L. trichilioides
Z. heitzii
G. tessmannii
A. congensis
S. oblonga
M. excelsa
D. benthamianus
P. soyauxii
E. ivorensis
Z. heitzii
S. kamerunensis
P. africanum
T. bifoliolata
N. diderrichii</td></tr>
</table>

[1] Probability values: *=p<0.05, **=p<0.01, ***=p<0.001
[2] Species composition is expressed as a function of gap size in addition to regeneration stage.

4.2. Gap dynamics due to logging and shifting cultivation compared

Time elapsed since disturbance (1, 6, 9 and 1, 5, 10 years) was used as basis for comparisons on gap dynamics due to logging and due to shifting cultivation which are hereafter referred to as gaps and fields respectively.

Potential seed sources

In logged-over sites, recovery of timber species proceeds from seedling recruitment from seed or from growth of the residual seedling bank. Some of the logged areas, where mature individuals of *Pycnanthus. angolensis*, *Ceiba pentandra*, *Antrocaryon klaineanum* and *Terminalia superba* are abound, are popular locations for the establishment of shifting cultivation fields. These species are thought to be indicators of fertility if they are found in great numbers. Pre-cultivation clearing is extensive and followed by burning. In the process, perching or roost sites for potentially seed-dispersing birds (e.g. hornbills for *Staudtia kamerunensis*, *Pycnanthus angolensis* and *Canarium schweinfurthii* seeds; pers. comm. H. Mbelli) are lost. As an illustration to the importance of birds in seed dispersal, in La Selva (Costa Rica), 49% of the dispersal of seeds into gaps is accomplished by this means (Hartshorn, 1978). Fortunately, not all trees present in the field are felled prior to cultivation for various reasons ranging from the work involved in cutting big trees (e.g. *C. pentandra, T. superba, Piptadeniastrum africanum*), through stem hardness (*Desbordesia glaucescens)* to allowing trees to serve as shade. In addition to this potential seed source, many Leguminosae (shade bearers) have innate dormancy and germinate over a period of time thus surviving as a 'seed bank' (Whitmore, 1984).

Seedling establishment preferences

Community-wide seedling density dropped significantly from 0.453 at one year to 0.182 at six years in the wake of felling and the value almost doubled at 9 years (Table 2). During the same interval no significant density variations took place among similar field age groupings. Thus, expectedly, seedling abundance in gaps for most species was affected by canopy closure. In some cases, this implied a significant decrease in densities as gaps filled up with new recruitment or vegetation growth. This decline in density may be predominantly the result of large reductions in stem densities due to natural thinning as gaps mature (Hubbell *et al*., 1999). Examples were *Lophira alata*, *Erythrophleum ivorense*, *Distemonanthus benthamianus*, *C. schweinfurthii*, *Zanthoxylum heitzii*, *M. excelsa* and *Lovoa trichilioides.* The trend was less obvious in fields and shown only by *Afzelia pachyloba* and *D. benthamianus* (Table 5). In contrast, other species attained peak densities at later stages following disturbance. For instance, in six or nine year-old gaps as the case may be, some species achieving highest densities were *Staudtia kamerunensis*, *Diospyros crassiflora*, *Tetraberlinia bifoliolata*, *Funtumia africana* and *Guarea cedrata,* whereas in fields the highest value for *Pterocarpus soyauxii* was found five years after disturbance (Table 5).

Table 2. Multi-way analysis of variance: parameter means with respect to gap or field age.

Parameter	**Gap age**				**field age**			
	1	**6**	**9**	**p-value**[1]	**1**	**5**	**10**	**p-value**[1]
Seedling density	0.453a	0.182c	0.342b	0.000	0.246a	0.258a	0.206a	0.621
Sapling density	0.095a	0.074b	0.107a	0.002	0.087a	0.090a	0.107a	0.287
Species richness	0.059a	0.047b	0.055a	0.000	0.066a	0.074a	0.065a	0.217

[1] The p-value indicates the probability that parameter means are similar. Letters also indicates similarity: the same letter in the same row for gap or field indicates similarity.

Seedling density did not vary significantly with gap size but such a significant relation could be shown in fields. In comparison with other field sizes, large fields had a highly significant and much larger density, which even exceeded the figure for large felling gaps (Table 3). Pertaining to both disturbance regimes, seedlings of a few species showed gap or field-size specialisation in their distribution patterns. These were *E. ivorense* and *G. cedrata* (large and medium gaps), *T. bifoliolata* (medium gaps), *P. angolensis* (large fields) and *A. pachyloba* (small fields) (Table 5).

Table 3. Multi-way analysis of variance: parameter means with respect to gap (field) size.

Parameter	Gap Age				Field Age			
	Large	Medium	**Small**	**p-value**[1]	**Large**	**Medium**	**Small**	**p-value**[1]
Seedling density	0.311a	0.350a	0.316a	0.495	0.362	0.173	0.175	0.002
Sapling density	0.088a	0.101a	0.087a	0.246	0.125	0.067	0.092	0.000
Species richness	0.049b	0.057a	0.054ab	0.037	0.070a	0.064a	0.071a	0.420

[1] The p-value indicates the probability that parameter means are similar. Letters also indicates similarity: the same letter in the same row for gap or field indicates similarity.

Both gaps and fields showed densities, which were statistically similar to those associated with the respective nearby understorey (Table 4). But at the level of individual populations, seedling recruitment affinities into gaps in relation to the immediate understorey were typical of *Z. heitzii* and *M. excelsa*. In fields, such species differentiation could not be shown.

Table 4. Multi-way analysis of variance: parameter means with respect to light condition.

Parameter	Gap Age			Field Age		
	Gap	**Understorey**	**p-value**[1]	**Field**	**Understorey**	**p-value**[1]
Seedling density	0.299a	0.353a	0.065	0.238a	0.235a	0.950
Sapling density	0.096a	0.088a	0.257	0.073	0.117	0.000
Species richness	0.052a	0.054a	0.418	0.044	0.093	0.000

[1] The p-value indicates the probability that parameter means are similar. Letters also indicates similarity: the same letter in the same row for gap or field indicates similarity.

Table 5. Seedling establishment preferences in felling gaps and abandoned agricultural fields.

Species	Establishment preferences[1]					
	Gap			**Field**		
	Age	**Size**	**Understorey**	**Age**	**Size**	**Understorey**
Afzelia pachyloba	Indif.[1]	Indif.	Indif.	1 year*	Small	Indif.
Alstonia congensis	1 year	Indif.	Indif.	Indif.	Indif.	Indif.
Antrocaryon klaineanum	Indif.	Indif.	Indif.	Indif.	Indif.	Indif.
Berlinia bracteosa	1 & 6 years	Indif.	Indif.	Indif.	Indif.	Indif.
Canarium schweinfurthii	1 year***	Indif.	Indif.	Indif.	Indif.	Indif.
Ceiba pentandra	Indif.	Indif.	Indif.	Indif.	Indif.	Indif.
Desbordesia glaucescens	Indif.	Indif.	Indif.	Indif.	Indif.	Indif.
Diospyros crassiflora	6 & 9 year***	Indif.	Indif.	Indif.	Indif.	Indif.
Distemonanthus benthamianus	1 year**	Indif.	Indif.	1 year**	Indif.	Indif.
Erythrophleum ivorensis	1 year***	Large/medium*	Indif.	Indif.	Indif.	Indif.
Funtumia africana	6 year	Indif.	Indif.	Indif.	Indif.	Indif.
Guarea cedrata	9 year*	Large/medium*	Indif.	Indif.	Indif.	Indif.
Guibourtia tessmannii	Indif.	Indif.	Indif.	Indif.	Indif.	Indif.
Khaya ivorensis	Indif.	Indif.	Gap*	Indif.	Indif.	Indif.
Lophira alata	1 year***	Indif.	Indif.	Indif.	Indif.	Indif.
Lovoa trichilioides	Indif.	Indif.	Indif.	Indif.	Indif.	Indif.
Mammea africana	9 year***	Large/medium**	Indif.	Indif.	Indif.	Indif.
Milicia excelsa	1 year***	Indif.	Indif.	Indif.	Indif.	Indif.
Nauclea diderrichii	1 year**	Indif.	Indif.	Indif.	Indif.	Indif.
Piptadeniastrum africanum	Indif.	Indif.	Indif.	Indif.	Indif.	Indif.
Paraberlinia bifoliolata	6 year*	Indif.	Indif.	Indif.	Indif.	Indif.
Pterocarpus soyauxii	Indif.	Indif.	Indif.	5 year*	Indif.	Indif.
Pycnanthus angolensis	Indif.	Indif.	Indif.	Indif.	Large**	Indif.
Staudtia kamerunensis	9 year***	Indif.	Indif.	Indif.	Indif.	Indif.
Sterculia oblonga	1 year***	Indif.	Indif.	Indif.	medium	Indif.
Tetraberlinia bifoliolata	9 year***	Medium*	Indif.	Indif.	Indif.	Indif.
Zanthoxylum heitzii	1 year***	Indif.	Indif.	Indif.	Indif.	Indif.

[1] Probability values *=p<0.05, **=p<0.01, ***=p<0.001 indicate that the preference for a given factor (gap/field age, size or light condition) is similar to other levels of that factor. Indif. = indifferent.

Sapling distributions

Number of sapling stems per unit area decreased significantly from 0.095 at one year to 0.074 at six years before achieving a significant rise to 0.107, ten years after logging (Table 2). In fields, sapling density was statistically similar, rising during the same period from a value of 0.087 through 0.09 to 0.107 (Table 2). Some species such as *A. pachyloba, S. oblonga, C. schweinfurthii, L. trichilioides* and *M. excelsa* produced their highest sapling densities in one-year old gaps (Table 6). Others, abruptly (*T. bifoliolata)*, or gradually (*D. benthamianus, F. africana, L. trichilioides, M. excelsa)* built up stocks to peaks at six or nine years after disturbance. Five years after abandoning cultivation in fields, *Nauclea diderrichii* achieved its highest density while *P. africanum* and *P. angolensis* were at their peak densities when that interval doubled.

Table 6. Sapling distribution preferences in felling gaps and abandoned agricultural fields.

Species	**Sapling distribution preferences**[1]					
	Gap			**Field**		
	Age	**Size**	**Understorey**	**Age**	**Size**	**Understorey**
Afzelia pachyloba	1 year *	Small**	Indif[1].	Indif.	Indif.	Indif.
Alstonia congensis	Indif.	Indif.	Indif.	Indif.	Indif.	Indif.
Antrocaryon klaineanum	Values close to zero	Indif.	Values close to zero	Indif.	Indif.	Indif.
Berlinia bracteosa	6 year***	Indif.	Indif.	Indif.	Indif.	Indif.
Canarium schweinfurthii	1 year**	Indif.	Gap***	Indif.	Indif.	Indif.
Ceiba pentandra	Indif.	Indif.	Indif.	Indif.	Indif.	Indif.
Desbordesia glaucescens	1 & 9 year***	Indif.	Indif.	Indif.	Indif.	Indif.
Diospyros crassiflora	Indif.	Indif.	Indif.	Indif.	Indif.	Indif.
Distemonanthus benthamianus	6 year*	Indif.	Indif.	Indif.	Indif.	Indif.
Erythrophleum ivorensis	Indif.	Indif.	Indif.	Indif.	Indif.	Indif.
Funtumia africana	6 year*	Indif.	Indif.	Indif.	Indif.	Understorey*
Guarea cedrata	Indif.	Indif.	Indif.	Indif.	Indif.	Indif.
Guibourtia tessmannii	Indif.	Indif.	Indif.	Indif.	Indif.	Indif.
Khaya ivorensis	Indif.	Indif.	Indif.	Indif.	Indif.	Indif.
Lophira alata	Indif.	Indif.	Indif.	Indif.	Indif.	Indif.
Lovoa trichilioides	1 & 9 year*	Indif.	Indif.	Indif.	Indif.	Indif.
Mammea africana	9 year***	Indif.	Indif.	Indif.	Indif.	Indif.
Milicia excelsa	1 & 9 year	Indif.	Indif.	Indif.	Indif.	Indif.
Nauclea diderrichii	Indif.	Indif.	Indif.	5 year*	Medium*	Indif.
Piptadeniastrum africanum	Indif.	Indif.	Indif.	10 year*	Indif.	Indif.
Paraberlinia bifoliolata	Indif.	Indif.	Indif.	Indif.	Indif.	Indif.
Pterocarpus soyauxii	Indif.	Indif.	Indif.	Indif.	Indif.	Indif.
Pycnanthus angolensis	Indif.	Indif.	Indif.	10 year*	Large/small***	Indif.
Staudtia kamerunensis	Indif.	Indif.	Indif.	Indif.	Large*	Understorey*
Sterculia oblonga	1 year***	Indif.	Indif.	Indif.	Medium	Understorey*
Tetraberlinia bifoliolata	9 year***	Indif.	Indif.	Indif.	Indif.	Indif.

[1] Probability values *=p<0.05, **=p<0.01, ***=p<0.001 indicate that the preference for a given factor (gap/field age, size or light condition) is similar to other levels of that factor. Indif. = indifferent.

Sapling density did not vary significantly relative to gap size, but on shifting cultivation fields it was significantly more abundant in large fields (Table 3). For individual species, saplings of *A. pachyloba* were statistically abundant in small gaps while medium and large-sized fields recorded significantly large quantities of *N. diderrichii* and *S. kamerunensis* respectively. Responding somewhat differently, *P. angolensis* showed up in significantly larger quantities in both small and large fields than in medium-sized fields (Table 6).

While the figure did not vary significantly between gaps and adjoining understorey, it was higher in relatively undisturbed forest than the fields they surrounded. As to individual species, saplings of *C. schweinfurthii* and *Z. heitzii* were significantly more concentrated in gaps than in the adjacent undisturbed forest whereas the reverse was observed for *F. africana, S.*

kamerunensis and *S. oblonga* in fields (Table 6). Thus, saplings of *S. kamerunensis* have a bias for large fields as well as for the field-surrounding understorey.

Species richness
Species richness followed a similar trend observed in gap and field-age-related seedling and sapling variations. After a significant decrease in richness from 0.059 at one year to 0.047 at six years, there was a significant increase to 0.055, nine years after exploitation (Table 2). Unlike in gaps, the parameter did not vary significantly in fields during the same period whereas for similar age groups a higher juvenile stem number per unit area were achieved by the latter (Table 2).

While species richness in statistical terms was highest in medium-sized gaps of the three size groupings, it was independent of field size. Species richness in field was only half that of the surrounding understorey, whereas there was no significant difference in species richness between gaps and the surrounding forest.

5. DISCUSSION

5.1. Within gap species differentiation
Hubbell and Foster (1986) have identified the base of the fallen tree as a zone of maximal light in a new opening in the canopy created by tree-fall. Perhaps this explains why this zone is a focus for seedling recruitment of a disproportionate number of species (Table 1). A mix of species belonging to different broad regeneration guilds shows predilection for the fallen tree base. This might suggest an overlap in ecological amplitudes (Zagt and Werger, 1998) among these species in terms of their functional response or tolerance to relatively high light levels available for germination and seedling establishment. Perhaps, seedling concentration towards tree base is also a consequence of relatively low mortality due to less severe competition for light in comparison to species located away from the tree base. Further, significant high seedling densities could be associated with relative minimal damage inflicted by logging in this zone.

However, species distribution among gap transects may also be influenced by factors other than the light gradient across these transects. For example, Brandani *et al.* (1988) found species differentiation within tree-fall gaps on different micro-site types and attributed these patterns to differences in soil conditions and distribution of tree-fall debris. Therefore, an absence of a significant concentration of seedlings in transect CD for any given species (Table 1), coinciding with an important cover of debris strewn in this gap zone, may not surprise anyone.

In a survey of seedling/sapling allocations between centres and borders of 75 gaps of varying age (1, 3, 6, 9, 12 years since disturbance) as a function of gap size, only 6 out of 17 species studied showed any affinity to one of these micro-sites (Table 1). Except for the distribution of saplings of *C. schweinfurthii* in favour of centres of small gaps, pioneer or light-demanding species either preferred gap borders (e.g. sapling of *L. alata* in small gaps) or were indifferently distributed to both micro-environments. The relationship between species composition and gap size is not clear-cut. This unexpected trend in juvenile stem allocations among light-demanding species, to an extent, mimicked pioneer distributions in a study conducted by Popma *et al.* (1988). In that study, four species preferred gap centre while 11 showed a relative predominance in gap borders. Such seedling allocation patterns underline the complex nature of the gap environment. According to the same authors, some interactions between gap size and other factors can cause gap size or microenvironments to appear similar. These include surface inclinations, slope aspect, height of the surrounding vegetation, daily and seasonal variation in the position of the sun and gap origin. No doubt, therefore, that only a small amount of intraspecific variation due to seedling density, ranging from 0.1% to 27.7%, was explained by seedling/sapling positions across the gap-border light gradient in 75 gaps. It can be inferred from these findings that gap location, which is a random variable, is largely responsible for variability in seedling densities among gaps.

5.2. Relative seed dispersal efficiency and seedling abundance

Primary forests tend to have heavy seeds or fruits ill-adapted to long-distance dispersal by birds, bats or wind (Richards, 1996). It is not surprisingly, therefore, that some species represented abundantly in gaps, were virtually absent in fields (Table 7), where seed sources are relatively scarce as a result of pre-cultivation clearing. Similarly, although more species per unit area (albeit insignificant) were being established in fields than in gaps (t-test), this corresponds to less juveniles per unit area. *T. bifoliolata* is a classic example of a species with seeds, which mainly fall within the area of the canopy where they germinate almost immediately (Newbery *et al*., 1998). Perhaps, it is more important that this species is very unlikely to regenerate in the absence of an ectomycorrhizal inoculum that may rarely or not be found at all in fields (pers. comm., N. Onguene). *L. alata*, a wind-dispersed species (Hladik and Miquel, 1990), was also much more abundant in gaps than in fields (Table 7).

Table 7. Average number of juveniles /1000m² in felling gaps and abandoned fields and their modes of dispersal.

Parameters	**Seedlings**		**Saplings**		**Mode of dispersal**[1]
	Gaps	*Fields*	**Gaps**	**Fields**	
Lophira alata	175	12	5	2	Wind
Tetraberlinia bifoliolata	125	-	38	-	Na
Staudtia kamerunensis	80	89	28	26	Animal, Bird
Pycnanthus angolensis	54	122	12	30	Animal, bird
Diospyros crassiflora	52	7	26	2	Na
Mammea africana	32	-	5	-	Animal
Zanthoxylum heitzii	26	7	23	7	Animal
Funtumia africana	23	47	7	16	Wind
Erythrophleum ivorensis	23	2	0	2	Na
Canarium schweinfurthii	21	16	28	16	Animal
Sterculia oblonga	19	16	2	5	Na
Distemonanthus benthamianus	16	38	5	12	Auto
Alstonia congensis	16	-	2	-	Wind
Piptadeniastrum africanum	14	183	2	7	Wind
Milicia excelsa	14	5	2	9	Na
Pterygota macrocarpa	12	5	9	2	Na
Desbordesia glaucescens	12	16	5	0	Na
Guarea cedrata	9	5	2	2	Animal
Afzelia pachyloba	5	5	5	2	Na
Pterocarpus soyauxii	5	2	2	2	Wind
Lovoa trichilioides	2	16	2	0	Wind, Birds
Paraberlinia bifoliolata	2	-	0	-	Na
Antrocaryon klaineanum	2	7	0	2	Animal
Guibourtia tessmannii	2		0	0	Animal
Nauclea diderrichii	0	2	0	0	Animal
Berlinia bracteosa	0		2		Auto
Khaya ivorensis	0	0	0	2	Na

[1] Sources: Gautier-Hion *et al.* (1985) and Hladik and Miquel (1990). Na = not analysed

Hence, disturbance due to shifting cultivation may not be of such an overriding importance to the regeneration of this species, as has been suggested by Letouzey (1968). Besides, folacious photosynthetic cotyledons, an attribute associated with successful natural regeneration after shifting cultivation in the Makokou field research station in Gabon (Hladik and Miquel, 1990), are absent in seedlings of *L. alata*. This morphological set back may largely account for the low regeneration capacity recorded for this species in fields. However, seedling density may not be the most important index of seedling performance and performance may not depend on seedling morphology alone. This is because seedlings of the most abundant species occurring in fields do not possess folacious cotyledons and their densities are actually increased two or thirteen-fold as high as in gaps. *P. angolensis* on the one hand occurs characteristically in disturbed forest and farmers' field and has been associated with wetter parts of the topography (Veenendaal and

Swaine, 1998). *P. africanum* on the other hand seems seldom to attain the sapling stage in spite of its high seedling density (Table 7).

5.3. Seedling establishment preferences and regeneration guilds

A good number of species established preferentially in one year old gaps (Table 5). In addition, seedling abundance for some of these species was significantly associated with gap sites in relation to the adjoining understorey. Consequently, species showing high degrees of affinity to recruitment in open conditions are qualified as light-demanding species. This classification corresponds to a large extent with that produced by Hall and Swaine (1980), who employed a different evaluation method. It can be speculated that coincidence of statistically high densities of seedlings and saplings in one year old gaps in relation to other age groups, exhibited by a few species (Tables 5 and 6), are predominantly due to higher survival levels in open conditions for these juveniles. As gaps get older, competition for progressively reduced light sets in, leading to increased mortality and hence reduced juvenile populations. For other species, established seedlings were concentrated in six or nine years old gaps and are said to be shade-tolerant (Table 5). A third group of species recruit into gaps independently of changing levels of light accompanying canopy closure, and are referred to as intermediate species (indifferent, Table 5). In fields, neither seedling establishment aptitudes nor sapling distribution preferences for the whole juvenile community significantly depend on time elapsed since allowing fields to fallow. But it is noteworthy that sapling densities for both disturbance regimes converge at 0.107, ten years after disturbance (Table 2).

It can be concluded from this study that gap size appears to be an unsuitable predictor for regeneration niche for a wide range of species studied (indifferent). Few species show any establishment preferences with respect to the size of gaps which, besides, are not clear-cut. Two of the three significant seedling distributions are in favour of both large and medium gap sizes (Table 5). If simultaneous specialisations to two different gap-sizes by a species are synonymous with seedling responses to comparable environmental conditions present in these gaps, then similar microclimates may prevail in gaps of different sizes as demonstrated elsewhere by Brown (1992). However in a more extensive analysis of felling gap studies involving 1, 3, 6, 9 and 12 year-intervals following logging, medium-sized gaps have been shown to be most favourable to seedling establishment ($P<0.003$). Still, very few species are specialised for particular gap size classes as far as seedling recruitment is concerned. Further, distribution patterns among species based on gap-size differences are basically the same as seedlings grow into saplings. These findings are not upheld by the gap-partitioning hypothesis underlying the equilibrium theory (Brown and Jennings, 1998). Indeed, most of these species appear to be generalists (Hubbell and Foster, 1986) in the absence of gap-size specialisation with respect to recruitment affinities.

The very idea of using gap-size gradient to test niche differentiation among climax species may be methodologically inappropriate. Brown and Jennings (1998) have cited poor correlation between gap size and microclimate, practical difficulties involved in conceiving experiments of this nature, and the limited practical value of the distribution of individuals in the natural forest as problems posed in detecting niche differentiation. Further, absence of large-scale studies on seedling dynamics, difficulties in quantifying light and growth for large populations of plants under field conditions, as well as the contribution of chance factors to regeneration (Zagt and Werger, 1998) may blur species differentiation in gaps of different sizes.

5.4. Seedling recruitment mechanism

As predicted by Whitmore (1989) concerning forests recovering after a felling operation, simultaneous colonisation is common on the TCP site. The community of juveniles is a mix of pioneer and non-pioneer species. This observation is also applicable to natural regeneration in shifting cultivation fields.

Studies conducted by Hubbell *et al*. (1999) on Barro Colorado Island, Panama, demonstrated that local species richness is established very early in gap-phase regeneration. A similar initial pattern was observed in the present study. Further, seedling recruitment of species as a community into gaps of varying size is also directional and in favour of medium-sized gaps while in fields, it is an essentially random process governed only by the chance arrival of species. This suggestion falls in line with the recruitment limitation hypothesis proposed by Hubbell *et al*. (1999) for felling gaps under which many sites are won by “default” by species, which are not absolutely the best competitors for the site. The same reasoning may be extended to the absence of significant difference in species richness between gaps and the forests, which surround them. In fields, the doubling effect of the understorey on species richness with respect to the bounded field may be linked to the gregarious nature of juvenile distribution characteristic of *P. angolensis, P. africanum, C. schweinfurthii* and *S. kamerunensis.* Such occurrence of seedlings in clumps is likely to be a consequence of seed dispersal by terrestrial birds or mammals according to predictions by Howe (1990). Table 7 indicates that except for *P. africanum,* these species are dispersed by animals. The tendency for single species to dominate in very large disturbed areas had earlier been observed by Hartshorn (1978) working in La Selva (Costa Rica). Thus, clearing fields for cultivation may drastically reduce the scope for species diversification.

6. CONCLUSIONS AND RECOMMENDATIONS

- The basal area of the gap should also be given priority in silvicultural manipulations. Here, there may be a concentration of valuable species due to minimum competition.
- Silvicultural operations should be carried out in the second or third year after logging so as to rescue regeneration of light demanding species.
- Gap size should not exceed 1300 m². This approximately corresponds to a maximum of two or three trees to be felled per gap.
- In fallows, silvicultural action can be taken from 3-7 years after cultivation to safeguard valuable species that may serve in restoration of soil fertility. It is at this stage that a maximum in species richness is attained.
- Because of comparatively low seedling recruitment potentials posed by seed dispersal limitations, a broader spectrum of species than is presently the case, should be retained during pre-cultivation tree-felling. Such trees should include leguminous ones with the capability to fix nitrogen and delay depreciation in soil fertility. This would allow a shifting cultivation farmer to stay on longer on a given piece of land before migrating to another. In the long-term, biodiversity will benefit immensely from such measures.

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DEMOGRAPHIC STUDY ON NON-TIMBER SPECIES FOR SUSTAINABLE USE AND MANAGEMENT OF FOREST RESOURCES: THE CASE OF *GARCINIA LUCIDA* VESQUE

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SUMMARY

Garcinia lucida Vesque. (Guttiferae) is a highly valued Non-Timber Forest Product for domestic consumption and commercial purposes in the South-Cameroon region. The bark is used as an additive in palm wine, while bark and nuts are also exploited for medicinal purposes. To assess the sustainability of harvesting the fruits and the bark of this gregarious and small sub-canopy tree of undisturbed forests, a detailed demographic study was carried out in permanent plots established in low and high exploited areas in two locations. Preliminary data concerning size-class distribution, phenology, germination and reproduction rates, from an ongoing monitoring of a sample of marked trees are examined in the present paper. Analysing this information on growth, mortality and reproduction may provide elements of transition matrices that will serve as a tool to simulate population dynamics and to evaluate the impact of the actual local extraction practices. These models will also serve to investigate or to predict changes in population age/size structure when subjected to different harvesting or management regimes, and to define the sustainable level of resource extraction. The plant demographic survey was combined with an experimental approach to test different local harvesting techniques and intensities, and a participatory monitoring and evaluation system. This combination is expected to provide tools and applicable guidelines to develop an efficient, socially appropriate and sustainable exploitation and management system of this resource, as well as recommendations for the incorporation in forest management planning.

Keywords: non-timber forest products, Garcinia lucida, autecology, tropical rain forest, Cameroon.

1. INTRODUCTION

Pressure on forest resources is increasingly notable in most Central African countries, as a result of the economic crisis combined with the devaluation of the regional currency FCFA. Processing of Non-Timber Forest Products (NTFPs) to generate sources of income or food for subsistence has become more attractive for several unemployed people in these countries. In Cameroonian humid forest area, Ndoye *et al.* (1997) recorded for *Irvingia spp*. kernel, *Cola acumita* nuts, *Garcinia kola* and *G. lucida* nuts and bark, a total of 138 tons and 85 tons sold in 1995 and in 1996 for a total value of 84 072 000 and 76 424 700 FCFA. In the Southwest Province of Cameroon, the market value of the *Prunus africana* bark is estimated at USD 150 000 000 per year and represents an average of 1923 metric tons of bark processed between 1986 and 1991 (Cunningham and Mbenkum, 1993). The kernel of *Irvingia gabonensis* is exported from Cameroon to Nigeria and Gabon while the bark of *Garcinia lucida* and *G. kola* is exported to Gabon and Guinea Equatorial. According to AEERD (1993), cited by Ndoye *et al*. (1998), 428 tons of *Gnetum africanum* leaves were exported from Cameroon to Nigeria in 1992. Unfortunately, in most cases, increased processing of these NTFPs has been directly linked to resource depletion in natural forests. An average of 35 000 trees of *Prunus africana* is debarked per year (Cunningham and Mbenkum, 1993) and this extraction threatens to eliminate the

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species. In the same area, *Gnetum africanum* is depleted by an intensive commercial extraction of leaves. There are many other examples of resource depletion as a result of overexploitation: Recent data show decreases in rattan yield in Cameroon (Bene, 1994). In the Bipindi-Akom II region more than 50% of tree mortality has been recorded in some natural extractive areas *of G. lucida* bark as a result of intensive extraction (Guedje, 1996).

This species is highly valued in the region for domestic consumption and commercial purposes. It is a gregarious species of the family of Guttiferae and a small sub-canopy tree of undisturbed or mature forest at more than 500 m altitude. It grows in restricted areas. The bark is used as an additive in palm wine production, while bark and nuts are also exploited for medicinal purposes as anti-poison and to cure stomach pains. The extraction of the bark is often done by stripping the stem all around, resulting in the death of the tree.

Wise utilisation and management of this non-timber resource is needed to ensure its long-term availability. To achieve this, it is essential to identify the conditions for sustainable exploitation, which can help to assess the potential of forests. In general, quantitative analysis of the impact of extraction on population structure and dynamics are lacking. Furthermore, there are few available data on the establishment, growth, and reproductive ecology for most of these non-timber forest resources in Central Africa.

As the nature and the importance of NTFPs are closely related to the ecological, economic and socio-cultural conditions of local population, the emphasis of the study presented here is to combine demographic survey, experimental and participatory approaches. This study is part of the Tropenbos-Cameroon Programme, which aims to develop methods and strategies for natural forest management, directed at sustainable production of timber, non-timber forest products and other services. As it is an ongoing study, most observations are incomplete. However, some sets of data, particularly concerning size-class distribution; phenology, germination rates, and effects of the traditional harvesting practices at plant level, lend themselves to a preliminary analysis and are presented in this paper. The demographic survey, the test of harvesting practices and the participatory monitoring and evaluation together may provide tools for developing efficient, socially appropriate and sustainable exploitation and management system of *Garcinia lucida* and its integration in forest management planning.

2. METHODOLOGY

2.1. Study site

The Tropenbos-Cameroon study site covers an area of approximately 170 000 ha in the South Province (Bipindi, Akimbo II and Ebolowa districts), some 50 km east of the coast. The area is flat in the west (40-280 m) and mountainous in the east (over 1000 m). According to Letouzey (1985), the vegetation changes gradually from low altitude evergreen forest of *Lophira alata* to mid altitude evergreen forest rich in Caesalpiniaceae. Biodiversity in this part of Cameroon ranks among the highest in Africa. The climate is tropical with a yearly rainfall between 2000 and 2500 mm, with two rainy and two drier seasons. The forest cover is still largely present, but due to human influence, is alternated with a mosaic of fields, fallow lands, secondary forests and logged-over forests. Population density is low with Bantu and Bagyeli as the main population groups. People live from hunting, fishing, gathering and practising shifting cultivation. In addition to food crops, they grow cocoa and palm wine trees as cash crops. Off-farm employment is restricted to logging.

2.2. Data collection and analysis

The methodology was based on plant inventory and demographic surveys on NTFP species described by Peters (1996), Hall and Bawa (1993) and Dallmeier *et al.* (1992). The sampling design was determined on the basis of observations and data from previous surveys (Guedje, 1996). Based on an inventory of the entire *G. lucida* populations at two locations, demographic data were collected in a series of eight plots of 100 x 40 m on growth, reproduction and population dynamics. At each location, four plots were chosen, of which two in barely exploited and two in heavily exploited sites (high and low rate of tree mortality after decorticating). In each plot, all *G. lucida* individuals from the largest diameter classes (> 15 cm) were tagged, mapped and diameter measured. Individuals from the lower size-classes were inventoried in each plot on a random sample of five 4 x 5 m quadrates for seedlings, five 10 x10 m sub-subplot for saplings and juveniles and five 20 x 20 m sub-plots for small adults (between 5 and 15 cm dbh).

Phenology (presence of flowers, fruits and new shoots) of a sample of 135 adult trees (dhb ≥ 5 cm) were monitored once a month during 16 months.

After two periods with seed fall, the rate of germination as well as predation of dropped seeds was monitored twice a week, during 12 months in a series of ten 5 x 4 m quadrates.

An experimental test of the traditional harvesting techniques and levels was carried out and several treatments applied:

- Knocking the bark with a stick and harvesting the bark over 1/3 and 2/3 of the diameter;
- Peeling the bark with a machete and harvesting over 1/3 of the diameter;
- Knocking or peeling the bark with a stick or a machete and harvesting all around;
- Felling the tree at 1 m height.

For each treatment, 20 trees were selected, equally distributed in two size-classes (> 17 and < 17 cm dbh). Health parameters are measured by monitoring two branches of each tree on a monthly basis. Production parameters such as re-growth of bark and development of (stilt)roots were monitored on a three-monthly basis. Especially the regeneration of the bark was monitored using transparent paper on which the surface covered with regenerated bark was marked.

The data collected will be analysed with the help of matrix models in which the population dynamics of the actual harvesting regime as well as the impact of the different harvesting or management regimes will be simulated to estimate the sustainable level of resource extraction.

3. RESULTS

3.1. Population structure

Figure 1 gives the size distribution of healthy trees in two locations of *Garcinia lucida* in the Bipindi – Akom II area. The curve displayed by these populations does not show a constant reduction in numbers from the smallest to the largest classes. These *G. lucida* populations lack individuals in the intermediate (large saplings) and the biggest (large adults) size classes. However, the percentage of individuals in the smallest classes (seedlings and small saplings) suggests a good recruitment.

In spite of the good recruitment in the smallest classes, it could be expected that the elimination of large trees by decorticating has serious consequences for the continual regeneration of the species. This structure shows the selective exploitation of the largest trees.

3.2 Phenology

Phenology is the timing of recurring biological processes within populations, such as flowering, fruiting and leaf set. Observations in the field permit to notice that this small diocious species has flowers and fruits during each month of the year. Although two flowering peaks can be distinguished between March and June for the first peak and between September and December for the second one, only one fruiting peak occurs between July and December, during the main rainy season.

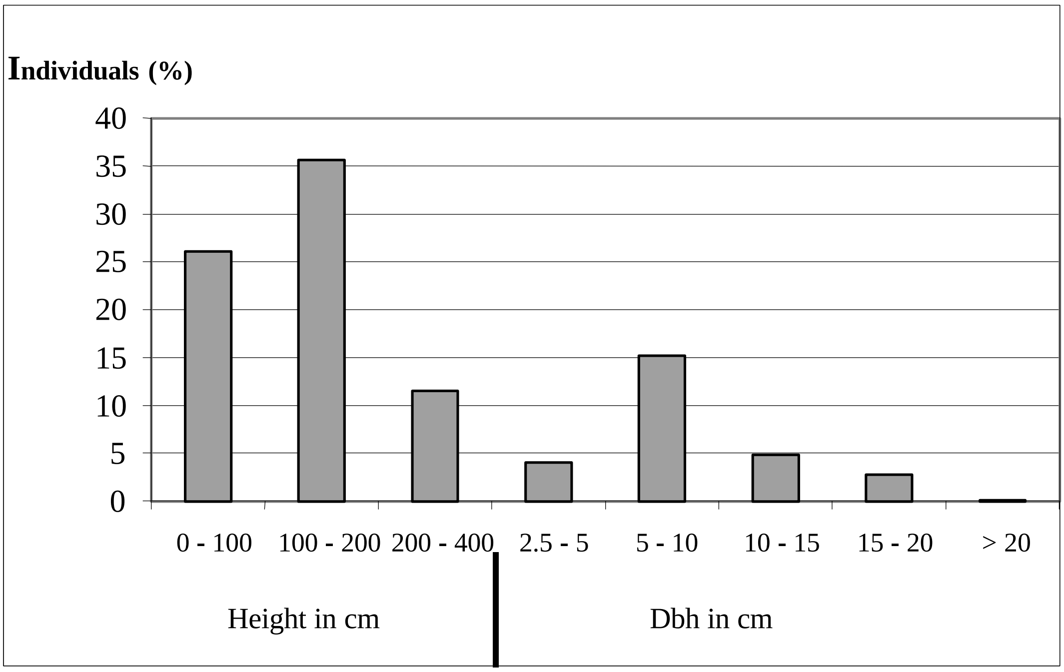

Figure 1. Size class distribution of *Garcinia lucida* in some sites in the Bipindi - Akom II region (n = 1726).

3.2. Seed predation and germination

After maturation, the medium-size seeds drop on the ground beneath the parent tree. The percentage germination is high, around 70% (Figure 2) and the dormancy period of the seeds is very short. The rate of predation of seedlings by rodents is high, around 30%. These rodents may be also the dispersal agents of *Garcinia* seeds. However, the role of these animals seems to be more that-of predators than of dispersers. Field observations indicate that other seed destroyers are the larvae of insects.

The results indicate that predation by rodents and insects is the most common fate of *G. lucida* seeds in the absence of human interference. Taking into account this high predation rate and the extraction of seeds by the local population, one could expect a very low recruitment rate.

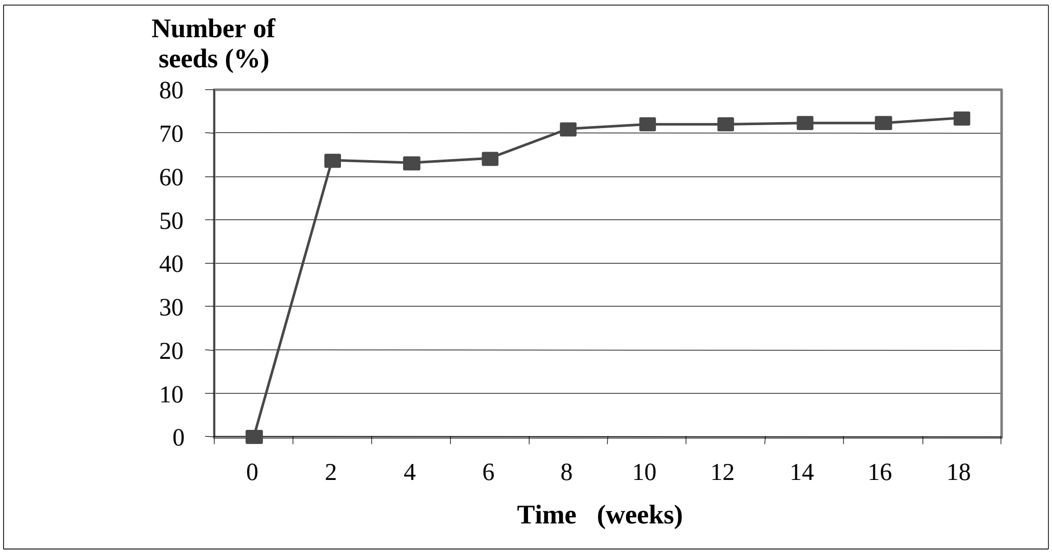

Figure 2. Germination curve of *Garcinia lucida* seeds (n = 106)

3.3. Impact of the traditional harvesting practices

The natural stands of *G. lucida* are under the regime of open-access for the exploitation of the bark and seeds. The traditional harvesting techniques of *G. lucida* bark are peeling with a machete or stripping with a stick (Guedje, 1996). In case of commercial use, the peeling or the stripping involves an almost complete harvesting of the tree. Trees that are stripped all around the stem die after few weeks or months. Mostly adult trees are exploited. Another technique, although less frequently used, consists of felling the tree at approximately 1 m height before decorticating (Guedje, 1996). The criteria used to select a tree for harvesting are mostly the thickness of the bark, the facility of the bark to detach easily from the wood and the diameter of the tree. These traditional harvesting techniques and levels of bark extraction have been tested and the effects on plant health and vitality monitored. Preliminary results clearly established that the practise of stripping the tree all around the stem is the most destructive (T4), with more than 60% tree mortality (Figure 3). The least damaging levels and techniques are stripping only 1/3 of the total bark surface with a stick or a machete (T2 and T1).

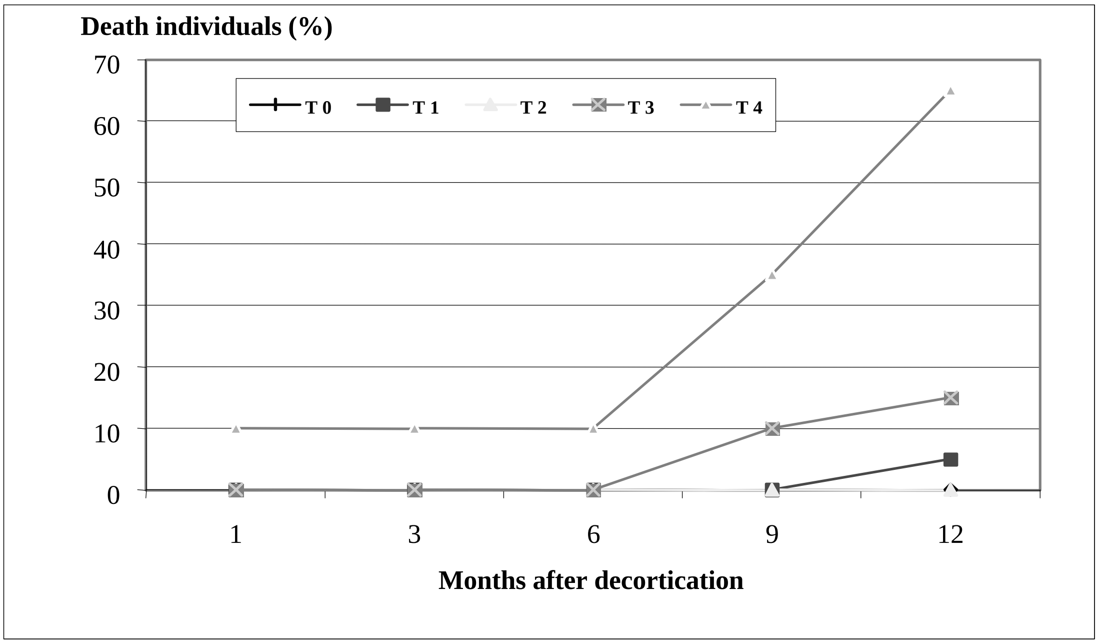

Figure 3: Mortality curves of different bark harvesting treatments for *Garcinia lucida* species
Notes: T0: control; T1: peeled with machete 1/3 of diameter; T2: knocked with stick 1/3 of diameter; T3: knocked with stick 2/3 of diameter; T4: harvested all around; n = 120

4. DISCUSSION AND CONCLUSION

The goal of a detailed study of population dynamics is to understand its basic ecological requirements. The size-class distribution of a healthy population, almost comparable to those obtained by LaFrankie (1994) and Murali *et al*. (1995), shows good recruitment in smallest classes and severe lack of individuals in medium and largest classes. The timing of flowering and fruiting in terms of duration tends to be staggered over the year. However, two maxima in flowering and one in fruiting have been recorded. The first maximum in flowering occurs between the dry and the wet season, the second one during the dry season; the production of *Garcinia* fruits occurs during the main rainy season as for many tropical trees (Mori and Prance, 1987). *Garcinia lucida* seeds produced by female trees exhibit a good and rapid germination with a rate of approximately 70% two weeks after seedfall.

These data, in addition to growth and mortality rates will be used to construct transition matrices. Matrix models record the number of individuals in age or size classes through repeated cycles of growth, mortality and reproduction. These models, using average values of growth, survival and fecundity for all individuals in the population, allow a detailed analysis of life history properties. They will reveal, among others, potential rates of population increase, predicted stable size-class structures, and sensitivity of the population to change in rates of growth, survival and fecundity (Enright and Watson, 1991). The effects of changes in the rates of fecundity, growth and survival can be simulated easily with these models, by changing one or more coefficients of the initial matrix and calculating the dominant latent root for the new matrix. There are many examples of the use of matrices to model the demography of tropical trees, see Hartshorn, 1975; Enright and Ogden, 1979; Peters, 1991; Debroux, 1998.

With these models, the sustainability of the current bark extraction practices will be tested, as well as the long-term consequence of different harvesting or management regimes. The model constructed for *Grias peruviana* by Peters (1990) suggests that a natural population could withstand harvesting of up to 80% of its seed crops without showing a decline in the population. The use of matrix models for prediction purposes in the case of *Garcinia lucida* will be difficult and is hindered by the fact that both the bark and seeds are harvested, from which the latter are also eaten by rodents and almost the largest individuals are selected for exploitation.

The assessment of the traditional harvesting practices permits to determine their various effects on plant health and viability. The effective use, by forest gatherers, of the least damaging techniques and levels of bark removal resulting from the test could permit to reduce tree mortality in natural stands. In consequence, the number of adults, especially individuals with thickly bark, as well as the fruit production, the regeneration of the species will increase and the "genetic quality" of trees will be preserved in natural populations. The unique way to achieve this is through participatory approach, based on indigenous knowledge and practices, in which forest gatherers will be actively involved in the process of evaluating the harvesting practices, determining and selecting the least damaging, the most efficient and socially appropriate techniques and levels of bark extraction.

The establishment of such appropriate systems could permit to improve the sustainable use and management of this important NTFP resource in order to ensure the long-term availability of the species and to increase incomes to local population.

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THE SOCIAL AND LEGAL ASPECTS OF FOREST MANAGEMENT[1]

P.N. Nkwi[2], F. von Benda-Beckmann[3], J. van den Berg[4], P. Geschiere[5], F. Nkoumbele[6] and F.F. Tiayon[6]

SUMMARY

The Tropenbos-Cameroon Programme (TCP), launched in 1992, adopted a multi-disciplinary approach with a strong social science component. After five critical years of scientific osmosis, social sciences have definitely contributed in its own way to the achievements of TCP's objectives. Indeed, social scientists have generated data useful to biological sciences. This paper attempts to critically analyse the social and legal issues linked to the development of (forest) land-use plans or Forest Management Plans. It discusses the problems and possibilities of enhancing interdisciplinary exchange within TCP and the benefits that can be drawn by each discipline from such an exchange. The paper will also address the existing gaps that required further research and how the social science component can contribute significantly in the development of management plans of rainforest projects.

Keywords: rain forest management, community participation, empowerment, leadership, legal aspects, traditional rights, power negotiation, Cameroon.

1. INTRODUCTION

The integration of social sciences into the multi-disciplinary team of researchers of the Tropenbos-Cameroon Programme (TCP) was designed to permit social scientists to focus on the local populations - their conceptions, practices, and strategies in relation to the forest. This focus remains valid since the participation of the local populations has been acknowledged as crucial for any sustainable management of forest resources. The studies carried out by social scientists within the TCP must be placed in a broader political-economic context, despite the limitations imposed by this focus.

What have emerged from the social studies are the contradictions between what exist in policy statements and what actually happens on the ground. In recent years, there has been indeed, a rapid acceleration of the exploitation of forest resources in Cameroon in general. New logging companies, especially from South-East Asia- have acquired large-scale concessions from the State, despite the formally expressed intention to limit forest exploitation. The State's urgent need for cash and the high levels of official corruption has made timber export a lucrative domain. The rush for the 'green gold' has wetted the appetite of local communities who see the new provisions of the law on community forests as an opportunity for them to become a new category of logging companies. The South-East Asian companies are said to control their own sectors of the ports of Douala, Tiko and Limbé through which they spirit out some of

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Cameroon's rainforest resources unabated. Recent measures may have slowed down the process but instruments to protect our forest still remain weak.

In view of this general rush on timber resources, accompanied by all sorts of more or less illicit practices, it might seem somewhat naive to focus on the role of local communities, their possibilities for participating in the management of forest resources, or the impact of their techniques in exploiting the forest. It is crucial that the findings of the TCP projects will be related to this acceleration in the exploitation of Cameroon timber resources in general. Analysis of these developments - the effects of changes on the world-market, the relation between expatriate logging companies and the Cameroonian State, and the role of Cameroonian entrepreneurs in this context - must be an integral part of TCP. Since 1992, the social sciences within TCP have not paid attention to these large-scale developments since other disciplines, especially economics, are better equipped to deal with these aspects. Therefore, it is extremely worrying that it still seems to be the case that none of the present TCP projects deals with these aspects. It is clear that this will lead to a serious lacuna, which will undermine the validity and the credibility of the final findings of TCP as a whole.

A second general remark is that the social science's focus on local populations creates the impression that they have to play the main role in efforts to conserve forest resources. A broader overview of the Ocean region, comparing the small-scale deforestation by a peasant village to the huge areas, which were cleared by large-scale plantations (such as for rubber and oil palm plantations) or affected by logging companies, shows that this impression is completely erroneous. The local populations can only play a role in the conservation of forest resources if their activities are combined with parallel efforts by other actors or stakeholders in the area.

In the contribution of social science to the overall conclusions of TCP the following issues are of critical importance:

- The issue of community: the identification of local communities, which can play a role in managing forest issues;
- Issues of leadership and negotiation power: how to empower local communities in their negotiations with outside agencies;
- Techniques of exploitation (both endogenous ones and newly introduced ones) and the pressure of local communities on forest resources;
- Local perceptions of the activities of logging companies and their relation to the State: alternative views of how to organise forest exploitation;
- Law and rights related issues, notably on the difficult articulation of local rights and the claims of the State as expressed in the new forest law.

2. THE CONCEPT OF COMMUNITY

In general, research in the TCP research area points out that the identification of communities which can play a role in the sustainable management of the environment - for instance in relation to the new forest law - is particularly difficult. One of the main conclusions of a recent ODA study in various parts of the Cameroonian forest zone has adequately shown this (Burnham and Grazia, 2000). Until the colonial conquest, the Bantu groups in this area were organised in highly segmentary and highly mobile units. Villages were constituted out of small patrilineal segments. Regularly ambitious leaders split off with their own followers to constitute a new village elsewhere in the forest. There was no clearly instituted central authority above the village level. Leadership was rather of the 'big man'-type; that is, it was based on personal achievements and qualities of leadership. A man could emerge as a real leader especially by accumulating a large number of followers - wives, children, but also other relatives or even clients coming from families- around his compound. However, there were no clearly instituted ‘offices’. Therefore, it is a debatable point whether one can speak of ‘chiefs’ - as a clearly institutionalised position - for these societies.

The Colonial State forcefully tried to fix these highly mobile societies. Kin-groups, often of different backgrounds, were brought together in larger villages along the roads, where control (for levying taxes and labour) was easier. However, such a reorganisation often led to the constitution of heterogeneous villages. Nowadays, villages consist of a variable number of patrilineal groups (lineages) who are often not related by common descent. They often claim to have different origins, from which they deduce, moreover, rights to different parts of the forest. Lineages who claim a common (but often mythical) descent feel that they belong to a larger group, which might be called ‘clan’. However, the concepts of ‘village’ and ‘clan’ do not coincide. In most villages, one finds lineages from various clans and all clans are dispersed over various villages. To give an idea of the variations involved, most villages have people from three to four different clans, while such a clan segment in one village may contain up to 20 lineages constituting more or less independent segments.

The Colonial State imposed also a new form of chieftaincy on the newly constituted villages, somewhat misleadingly termed *chefs traditionnels* or *chefs coutumiers*. However, due to the heterogeneous character of these villages, and especially due to the administrative character of these new chieftaincies - chiefs were mainly used to execute the administrative orders from above, often highly unpopular among their subjects – these chiefs had great difficulty in acquiring a more general acceptance of their authority within their villages and in developing a broader form of leadership.

For the Bagyeli[7], the situation is even more elusive. The core of most camps is formed by a small patrilineal unit (for instance, two or three brothers) with whom a varying number of other relatives (in-laws, maternal kin, possibly also ‘friends’) have associated themselves. However, the composition of these groups is constantly changing due to great individual mobility. Persons may temporarily (or more or less definitively) go and live with other groups. Moreover, people are constantly moving between more definitive settlements (*kwaato*) and more irregularly inhabited camps *(ngya’a*, or ‘hunting camp’) even though the periods that people sojourn outside the *kwaato* seem to get shorter and the mobility of the Bagyeli somewhat reduced (Biesbrouck, 1999). The core of each group recognises a special relationship with a villager, expressed in common clanship (*ka’a*). These clans unite therefore both Bantu and Bagyeli groups[8]. The villager concerned acts as some sort of ‘ for the Bagyeli groups. In principle he plays a mediating role in exchanges between Bantu and Bagyeli, and he is credited with some authority over ‘his’ Bagyeli. Such rights are inherited following patrilineal descent.

Especially during the first decade after independence there was a clear movement or sedentarisation under heavy pressure of the State: Bagyeli groups settled along the road, often near the village of their ‘*patron*’. However, in more recent times, this sedentarisation movement came to a stop or was even reversed. Co-habitation led to growing problems between Bagyeli and Bantu villagers, and many Bagyeli groups withdrew again to settlements deeper in the forest. At present, it seems that Bagyeli groups are experimenting with different mixtures of sedentarisation and mobility, trying to combine the advantages of both. More permanent forms of settlement can have the advantages of both, for instance more regular forms of access to the

[7] We prefer to use this term since it seems to be the one that is most generally used to indicate the ‘Pygmies’ in this area. It should be emphasised, however, that this is the plural form (Ba- is only the prefix for the plural). Ngyeli is the singular form.

[8] Most Bagyeli claim to belong to a Ngumba clan. Indeed, it seems that relations of Bagyeli with Ngumba have a much longer history than the ones with other groups. According to most informants, it was only later that Bagyeli groups attached themselves to Bassa, Bulu or Fang groups. But even these Bagyeli groups retained their affiliation to a Ngumba clan. In these areas, the situation is all the more complex since some of these Bagyeli groups claim at the same time a special relation with the clan of their new ‘patrons’.

market (sale of bushmeat, honey, etc.) and to new facilities (for instance, those provided by Catholic nuns in the Bipindi area). But it is clear that most Bagyeli groups prefer to combine this with continuing mobility and long-term stays in the 'hunting camps', so as to be able to exploit additional resources for hunting and gathering[9]. A special case is a number of Bagyeli settlements along the roads, which were formed around Bagyeli healers of great renown. But even people in these settlements regularly live for longer periods of time in the forest.

The vicissitudes of this 'sedentarisation' process and a parallel process of increasing commercialisation (see below) seem to go together with a general loosening of the special tie between Bagyeli groups and their '*patron*' in the village. Many villagers are complaining that Bagyeli now sell their products to any buyer (including '*buyesellams*' from elsewhere) and no longer respect their special obligations to 'their' villagers. This has led to new interpretations of the relationships. Thus, while formerly taking food from the farms or palm wine from the trees of their *patrons* was not considered to be a serious thing, it is now denounced by villagers as downright stealing. Bagyeli, on their part, say that 'their' villagers are no longer willing to play their role as protector and only intent on exploiting their labour and appropriating their bushmeat. It is clear that there are increasing tensions between villagers and Bagyeli which in several cases have led to physical attacks on the Bagyeli (and even manslaughter).

In view of the complexity and the diffuse nature of local forms of organisation, it is of particular interest that recent studies of problems and possibilities of local participation in forest management have warned against the equation - which seems to be self-evident for many law-makers and development experts - of 'community' with the 'village' (Biesbrouck, 1997; see also Biesbrouck, 2001). For instance, in efforts to involve local communities in the Sahel in agro-forestry projects, it turned out that this equation of village and community led to all sorts of problems. It became clear that village authorities did not have sufficient power to make commitments in the name of the villagers. Neither could they act in a satisfactory way as intermediaries in the distribution of benefits of the project among the villagers concerned. The consequence was that a large part of the village population did not feel any commitment to the project. The solution found in the agro-forestry projects concerned was to include units at different levels of organisation in decision-making processes regarding the project and the distribution of the benefits.

The brief description above of local forms of organisation in the Cameroonian forest area suggests that unproblematic equation of community and village implied by the new forest law is highly problematic. For this area as well, it might preferable to develop a more complex model of 'co-management' by different units and levels. The following units, which could play a role in such a more complex model, have been identified:

- The Bagyeli camp, which claims on its part of the forest are formulated on the basis of its special relation with its 'patron' in the village;
- The village, which claims a general right of control over a more or less clearly delimited part of the forest (over only a part of which definite user rights have been established by lineages and households through clearing and cultivation);
- The lineage, which claims rights to specific parts of the village's forest domain (in practice, such a lineage domain may be dispersed over different parts of the village domain)[10] ;
- The household, which holds the user rights over those parts of the forest which are cleared and brought under cultivation by one of its members (or ancestors); such user rights have become greatly enhanced due to the spread of cocoa cultivation leading to more permanent farms.

[9] Another current reason to withdraw to a forest camp is to escape from conflicts with the villagers.
[10] As said before, lineages claiming a common mythical origin form larger clans. However, such clans are not holders of rights over specific parts of the territory.

This enumeration clearly shows that it would be erroneous to look for one community, which holds 'the' rights over a specific part of the forest - in the sense of exclusive property. Instead the situation could be characterised- like in many parts of Africa- as one of a 'bundle of rights': the claims of different forms of community overlap and do not exclude each other. One can distinguish in this context zones '*de droit fort'* and zones '*de droit faible'* (Tiayon, pers. comm., 1999). Zones '*de droit faible'* are parts of the forest, generally farther away from the village, which villages/lineages claim as part of 'their' forest without, however, forbidding access to it by people from other communities.

A consequence of this complex overlapping of rights is that the solution will not be to try and identify one of these units as **the** community which has to be allotted a central role in the efforts towards ensuring local participation for sustainable management. Rather, a more complex model should be developed which involves the various units mentioned above, at different levels of decision-making, in relation to their specific rights, as it will be demonstrated below (see paragraph on law and rights).

In this context, it is of interest that, especially in the Ngumba area, lineages/clans unite both Bantu and Bagyeli, which are - since most Bagyeli groups claim to belong to Ngumba lineages/clans - mostly the units of their patrons. These groups might therefore play a role in realising collective forms of management of the forest by both Bantu and Bagyeli. However, there is a real danger that involving these units in forest management will reinforce existing relations of exploitation of Bagyeli by Bantu. It might, therefore, be advisable to reserve at least some part of the forest to the Bagyeli exclusively and have it managed by their communities as developed below (see paragraphs on leadership and negotiation power and on the need for separate Bagyeli representation).

More in general, it is preferable not to put to heavy a stress on the role of 'the community' in this context. The strong emphasis on 'community development' in the sixties and the seventies led to increasing disappointment in nearly all branches of the development industry. It is therefore somewhat surprising that this ideology of community development is now so easily taken over as a point of departure in more recent projects for ensuring local participation in forest management. For the Cameroonian forest area, and certainly not only there, it is highly questionable whether existing forms of community have sufficient coherence to allow for a communal management of the benefits of forest projects. It might be advisable to create a leeway for individual (e.g. house) initiatives and individual use of benefits.

3. ISSUE OF LEADERSHIP AND NEGOTIATION POWER

Formally, public consultation of the local population is of critical importance for the enhancement of people's participation. However, local people are in a weak position
the authoritarian State and foreign logging companies with their much stronger capital position and/or direct access to means of coercion (notably the threat of the gendarmes). Therefore it is important to look for ways in which the people can be empowered in their negotiations with powerful actors from outside.

In this context, local leadership is of critical importance. However, ethnographic studies carried out in the region show the diffuse nature of local communities in the forest zone and conclude that there is a corresponding problem in identifying stable and well-institutionalised forms of leadership at the local level. In the preceding paragraphs, we emphasised the segmentary and highly mobile character of local societies during pre-colonial times, and the colonial background of present-day 'traditional' chiefs in this area. In some respects, forest societies seem to be marked by fairly democratic forms of governance. Although within the family elders have a great deal of authority, discussions in the larger village meetings have a fairly open character where all adult villagers, women included, can publicly vent their opinions during such meetings[11]. The reverse side seems to be that it is hard to identify leaders who can take decisions on behalf of the villagers and who have enough authority to impose the execution of such decisions,

Ready-made solutions for this problem of leadership are hard to find. But it is useful to try and identify different positions of leadership at the local level and discuss their assets and handicaps. On the basis of such an exploration we can try to evaluate which role these leaders and institutions can play in attempts to reinforce the negotiation powers of the local population.

For the Bantu villages, we pointed out already the limitations of the so-called 'traditional' chiefs that seem to be characteristic for the whole forest area. Formally, these chiefs were empowered by the State to act as spokesmen and representatives of the village. However, due to the prominent administrative character of their position, many chiefs have difficulties in developing more general forms of leadership, outside their strictly administrative capacities. Moreover, in many areas, democratisation and the introduction of multiparty politics have further undermined the powers of these chiefs. The type of mobilising leadership, needed to stimulate local participation in the administration of the forest, can hardly be expected from these chiefs.

Around the chiefs, lineage heads, elderly notables and village councils have a more or less formalised role. As stated already, elders have considerable authoritative voice within their own families. But their authority is much less self-evident in a broader context. Moreover, many elders have difficulty in dealing with modern problems related to the intervention of outside agencies (such as the State and the logging companies). However, village councils can certainly play a role as more or less institutionalised fora for public consultation and decision-making.

Another category of leaders is the urban elites, which are *originaires* (or *ressortissant*) of the area concerned. In many parts of Africa, such urban elites, even though they are physically absent from the village, are among the true leaders of the village. They emphasise their continuing involvement with the village. For the villagers, they are the obvious brokers in the relation with the world outside and this gives them a considerable power over the villagers. From this they do derive a real leadership: there are many examples from other African regions where such elites play a crucial role in organising development projects for 'their' village and in mobilising the villagers for such projects[12] (see Nkwi, 1997). In Cameroon, the role of such elites has recently been further reinforced due to official support for the formation of elite associations from a specific area. Earlier, under the then one-party State such associations were rather discouraged because they were supposed to encourage division and question or put doubts on national unity.

However, it is clear that interventions by the elite can have also problematic aspects. Their involvement with local affairs can be directly affected by their private interests. There are several examples in the area of urban elites who used their kinship relations with 'their' village to appropriate larger tracts of the forest for the creation of plantations or obtain forest concessions through the adjudication process. The general feeling among the villagers is that such elites might help them as brokers in the world outside is often balanced by a feeling that they are exploited by these same elites, who demand services and presents (food) without doing anything or offering other services in return.

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[11] For the TCP area, it seems useful to distinguish between a more or less formal *'conseil de village'* - constituted by the village chief and his notables- and larger meetings of all villagers which are regularly convened when issues regarding the village as a whole have to be discussed.

[12] In the TCP area, as elsewhere in Africa, it is an important question whether these urban elites will or will not return to their area after retirement. Elites often profess that they will do so and there are cases where this has indeed happened: in such cases, these returnees may come to occupy important formal positions in the village (for instance, as chef de village or in one of the party organisation). But there are also many cases of retired elites who hesitate to return since they fear the strong levelling impact of daily life in the village.

Despite this ambivalence, it is clear that urban elites can and will play a role in efforts to stimulate local participation in forest management. It is certainly to be expected that these elites will take a keen interest in what is happening with the forest resources of 'their' area and they do have assets at their disposal to give weight to their interventions. Moreover, recently, new elite associations have emerged in the TCP area. It may be useful to involve these associations and the urban elites in general - with due respect to problematic aspects mentioned above - in efforts to stimulate local participation.

Special interest should be paid to the existence of NGOs formed by what could be termed 'local' elites in this area. For instance, ARBI (*Association des Retraites de Bipindi*) regroups elites who have retired and are living in the area but who, due to their experience in the outside world, can play their role in reinforcing the negotiation powers of the local population. Similarly, religious NGOs can serve as alternative fora to mobilise the local population and co-ordinate the expression of their interests and rights

Problems of leadership are even more prominent among the Bagyeli. And here, these are even more urgent since the Bagyeli depend even more on the forest. Although sometimes one of the brothers of the core group of a camp may, nowadays, claims to be 'the chief' of the camp, it is clear that here a formally institutionalised chieftaincy is completely lacking. Earlier in this paper, we stated already that the role of authority attributed to the Bantu 'patron' of a camp is weakening due to a general weakening of the special links of Bagyeli groups with a specific Bantu villages. However, more recently a new NGO, CODEBABIK (*Comité du Développement des Bagyeli de Bipindi*), was established by the Bagyeli in the Bipindi area, thanks to the strong support from SAILD (*Service d'Appui aux Initiatives locales de développement*) and the catholic nuns. Although it is expected that this NGO will meet with considerable difficulties, there are obvious entry points for trying to stimulate Bagyeli participation in managing the forest.

An alternative approach might be in view of the apparent lack of clearly institutionalised forms of leadership, to create new '*comités de développement*'. Such an approach seems to be inspired by other projects in the area (for instance, the Canadians and the SNV in the Campo area). However, in the forest area (just as elsewhere) experiences with this approach have been extremely disappointing. ZAPI (*Zone d'Action Prioritaire Intégrée de l'Est*) seems to be a good and characteristic example. It created an impressive pyramid of committees in various parts of its forest zone of operations, of which hardly a trace is left today after the ZAPI's demise twenty years later. This explains why development organisations now strongly emphasise the need to build upon existing forms of organisation (although in practice, they seem, time and again, to succumb to the temptation of building up their own structure).

The balance of this rapid overview is that even though there is not a clear solution for the leadership problems in this area, there are possibilities to build on existing traditional forms of organisation. In view of the delicate character of leadership in the area, it is even more crucial than in other areas that all forms of consultation and decision-making are public. The large village meetings do offer fora for such public consultation. The various forms of authority mentioned above should be involved in such consultations. In addition to this, village workshops need to be organised in order to educate the people not only on the dangers of environmental degradation but also on their rights and privileges.

On the whole, it must be emphasised that an important way to strengthen the negotiating power of local people is the validation and recognition of the rights that define the legitimate administrative and economic position from which they negotiate. Here, differences will have to be made with respect to the issues negotiated. The involvement of local people in the more administrative aspects of forest resource management, such as zoning, monitoring and enforcement of environmental protection is different and may involve other negotiating partners than issues concerning the direct appropriation of the economic benefits from forest resources. In the latter case, the property holders whose rights are directly affected, are the ones who must be approached for negotiation.

Rights by themselves are of course, of little value unless coupled with the economic and political resources required to mobilise them successfully. Yet, they are a necessary precondition for such mobilisation and constitute an independent ‘bargaining chip’ in negotiations. But it is also clear that the economic and political bargaining power must be strengthened.

As said earlier, it is important to organise meetings and workshops in which local people are informed about their rights- especially in relation to the new forest law. But what is equally important is the education of various external agents (from different State departments, commercial companies, etc.) so that they are also fully aware of the rights and privileges of local people and the legal limitations of State power and authority. They should also be educated about the many unintended, though not necessary unpredictable, social and ecological consequences of the State’s and the companies’ interventions that disregard local people’s legitimate concerns and rights

Finally, it must be emphasised that special attention should be given to the position of Bagyeli groups. It can not be expected that their interests will be represented adequately by Bantu administrators and/or property holders in negotiations with external agencies. Bagyeli, or spokesmen trusted by the Bagyeli, should be independently represented in negotiations with external agents. Moreover, they should have a voice equal to the one of Bantu groups.

4. TECHNIQUES OF EXPLOITATION, ENDOGENOUS AND NEWLY INTRODUCED PRESSURE OF LOCAL COMMUNITIES ON FOREST RESOURCES

The introduction of new technologies is usually based on the assumption that cultures seek better ways to solve perennial problems. The adoption of new technologies usually depends on their high degree of performance Data gathered in the TCP area seem to indicate that new technologies accepted by the people have produced both negative and positive impact on the life of the people. Some examples will illustrate the point:

- New logging roads have provided access to once inaccessible forest land. Thus, these roads have facilitated both the transport of harvests from existing farms and the creation of new farmlands. Both aspects have stimulated agricultural production.
- Although traditional medicine is still an important alternative health system, there is increased consumption of modern pharmaceutical products by the Bagyeli. Because of the immediate effect of these modern pharmaceutical products a window of opportunity has been provided to a possible improvement of the health status of the Bagyeli.
- The introduction of new hunting techniques seems to have led to an intensified exploitation of wildlife or game resources. But it also seems that this intensification comes much more from Bantu hunters than from Bagyeli. The Bagyeli now regularly use iron wire for making snares. But this is much more common among the Bantu, from whom the Bagyeli seemed to have learnt the very practice of snaring as such. And it is especially the Bantu (Bulu, Ngumba) people who have acquired guns for hunting, while few or no Bagyeli can afford this expensive hunting tool. The expensive operation of the gun has made it out of the reach of most Bagyeli. Guns are much more common among Bantu villagers. Their attempts to use experienced Bagyeli hunters or to use Bagyeli as guides and carriers have been a source of mistrust and conflict.
- Agriculture seems to be a domain where people tend to accept new and improved technologies more readily and faster, for instance in cocoa production. Social science research suggests that the recent fall of cocoa prices in the world market and abandonment

of cocoa plantations has led to an increasing pressure on forest resources, for instance, due to the creation of new farms of food-crops by men. This happened in the TCP area as well as elsewhere. In order to encourage the spread of new agricultural technology and a further intensification of the exploitation of existing clearings, the presence and activities of the International Institute of Tropical Agriculture (IITA) in Mbalmayo should be encouraged to spread to the TCP area.

5. LOCAL PERCEPTIONS OF LOGGING COMPANIES, THEIR LINKS WITH THE STATE AND IDEAS OF CONSERVATION

Among the local people, the general perception of the forest might be characterised as utilitarian or even materialistic. The forest is to be exploited by hunting, or transformed into farmland. To a certain extent the same perception holds true for the Bagyeli. However, the difference is that there is emphasis on the role of the forest as a provider of food, medicines and other products and services. Another major difference lies in their stronger emotional attachment to the activities by logging companies and hunting villagers. The Bagyeli informants used terms as 'we feel it in our hearts' and 'we are hurt'.

Local forms of resource management occur, in the form of regulations restricting the access to particular valued resources to certain categories of people (kin). Membership of a kin group of which a predecessor was the first to clear a part of the forest, or to plant trees, legitimises the right to get access to forest products, strangers are supposed to create '*une entente'* with those people holding the rights, for example by providing them with gifts or by sharing the profits. More data on rights and claims will be treated later in this paper.

From this point of view, logging companies are categorised as 'strangers', as no-kin, and are therefore expected to proceed accordingly in order to obtain right to legitimate access. Many of the complaints about logging activities in the region stem from the disappointment with regard to the *'souvenir'* that logging companies leave behind when exploiting 'their' territory[13]. For instance, expectations were that they would employ more workers from the area itself. Furthering negotiations with a logging company over the '*contrepartie*' for exploiting the forest, in which local people (not Bagyeli) took part, primarily short-term benefits (food and liquor) were asked for. It is immoral and unjust that such transient compensation has to compare with the huge profits logging companies made. In some cases, however, broader ideas about enhancing socio-economic development did play a role, especially under outside influence for instance from urban elites. Furthermore, ideas about compensation have changed due to a changing appreciation of the economic value of timber. Nowadays, the presents offered by the company- whether or not in relation to a formal '*cahier de charge'*- are generally seen as just a '*pourboire'*. And there is a feeling of resentment about the informal character of these gifts. Many villagers believe that more substantial gifts are offered secretly to chiefs or administrative authorities. Some informants, however, also mentioned advantages of these logging activities. Local people mentioned that logging roads facilitate access to the forest. Bagyeli said the thick undergrowth in areas where logging has taken place favour a concentration of certain animals.

The disappearance of valued resources - tree species as well as fauna - is easily noticed both by local Bantus and Bagyeli. However, the conservationist's view that the whole rainforest ecosystem is seriously threatened hardly finds a resonance at the local level. Local Bantu people as well as Bagyeli have difficulties in perceiving the forest as a resource that could possibly be

[13] However, in certain respects, local populations seem to accept that apparently the forest belongs to the government. This does not exclude, however that these informants will at the some time emphasise that the forest is 'theirs' (that is belongs to their village, lineage or camp). Apparently, people do not see this as a contradiction but rather reason in terms of bundles of rights and rather reason in terms of rights that do not exclude each other.

exhausted. Whereas among the Bagyeli certain techniques have clear conservationist implications (cf. Nkoumbele, 1997) their management is directed at specific resources, not at ‘higher’ environmental goals (Biesbrouck, 1997).

On the whole it is difficult to trace a clear and consistent alternative perception of how the forest should be exploited, as an alternative to the present forms of exploitation by logging companies. Even the more educated local leaders (teachers, civil servants, councillors, and others, who are quite numerous, especially in the Ngumba area due to the relatively early introduction of schools in this region) do not formulate clearly different visions.

It seems clear, in view of the utilitarian attitude *vis-à-vis* the forest, that mere conservationist notions can only be reinforced among the local population if the alternative value of the forest resources as such - implied by the very idea that the forest should be conserved - is translated into concrete benefits for villagers and Bagyeli. This could be done, for instance, by the creation of employment opportunities in conservation projects, premiums for the conservation of special parts of the forest, etc. Until now conservationist interest-groups involved in drawing up the forest law and encouraging projects for sustainable exploitation have not succeeded in concretising such benefits for the local population. On the contrary, one of the main effects of WWF involvement in the new law seems to be the insistence that in some parts of the forest hunting should only be allowed with ‘traditional weapons’. This formulation by itself may lead to serious misunderstanding of what exactly is meant by ‘traditional’. Is it any use of iron or non-iron tools? Should hunters return to the Stone Age? But, more seriously, it may lead to a drastic deterioration of the quality of life of the local groups involved. Efforts to persuade the villagers that forest resources should be valued as such - the idea of ‘teaching’ them - will be hardly effective unless such additional value is translated into concrete benefits.

This obsession of ecologists and conservationists with the emptying the forest of its resources is dangerous since it leaves the area wide open for poachers and forest bandits. Instead of resettling the sparse populations, development projects should be happy with the fact that there are at least some local people present that can assist in protecting the area.

6. LAW AND RIGHTS IN THE MANAGEMENT OF FOREST RESOURCES

6.1. Legal pluralism in the TCP zone

The issues of communities, rights, and leadership in the management and exploitation of forest resources have to be seen within a wider legal and administrative context. All researches have shown that the management and exploitation of forest resources in the TCP zone are subject to a complex body of legal instruments. These laws pertain to the political control and administration of resources, rights to access resource environments for different purposes, rights to withdraw or otherwise exploit resources, the sharing of economic and other benefits. These may also pertain to the style and technology of resource exploitation.

This body of rules, principles, concepts, and procedures is particularly complex. There is a plurality of different and largely contradictory bodies of legal rules that have different sources of legitimisation. Roughly speaking, there are legal rules originating from three different sources:

- The State law making authorities;
- Rules of different Bantu groups;
- Rules of Bagyeli population groups.

In the conceptualisation of management and exploitation rights on forest resources, the different rule systems differ, and contradict each other in a variety of aspects: Here are some specific examples:

- In designating the social entity that can be a holder of rights: individuals, kinship (inheritance) based social groups, territorial units such as administrative villages, State agencies;
- In the demarcation of different elements of the resource environment as distinct resources that can be the object of property relationships: land, sub-soil resources, trees, vegetation, various parts/products of trees, roots, etc., water, live organisms in the water (fish, shrimps, etc.), various animals;
- In the conceptualisation of different legitimate activities with respect to these resource elements administrating and managing, hunting, collecting, cultivating, harvesting, etc.

Each of the legal systems on which rights and obligations are based, are rather complex by themselves in their constructions and differentiation of their ‘bundle of rights’. Different rights, held by different entities, are held with respect to different resource elements. They can converge in the same physical object and/or larger space. Objects and spaces (land, trees, plantations, animals, hunting spaces, etc.) therefore often are subject to multiple, overlapping rights, held by different social entities. As has been mentioned earlier, there exist a complex mixture between individual, family, or clan rights with respect to the same resources in the local Bantu laws. But the situation becomes especially complicated when these different constructions of administrative use and exploitation rights come into contact with each other, for instance, when the State law imposes its own mix of rights and property objects on the already existing ones.

This not only concerns the different State conceptions of rights holders, property objects and types of property rights. An extra complication is that different notions of space and boundaries underlie Bantu, Bagyeli and State legal laws or regulations. Research has shown that in the TCP zone there are hardly any forest areas (neither primary nor secondary forest) over which no rights are claimed. However, in the more distant areas in the primary forest such rights seem to be ‘weaker’. And especially with respect to resources in primary forest regions not exploited systematically in a sedentary manner, the property spaces of reserves and recognised zones of influence of lineage units are not clearly demarcated. The social science research in the TCP zone has also shown that there is no congruence between village residence and membership and rights to resources adjacent to the village settlements. Rights acquired during earlier phases of migration in other settlements are not lost when a group moved to their present day villages along the roads.

6.2. Law, rights and practice[14]

All these legal systems are dynamic. They have changed and are in the process of changing, adapting to new economic, political and technological developments. In Bantu and Bagyeli legal thought and rules, new notions of space and territoriality have emerged, as a consequence of gradual closure of some frontiers in the forest, and/or of long-term to permanent cultivation of some cash crops (cocoa).

While rules and principles, and the rights and obligations defined through them, do not determine social interaction and resource use, and in the case of the management and the exploitation of forest resources, they are usually significant. They do provide positive or negative motivations, objectives for people’s activities, provide legitimate constraints, and can be used as ‘resource’ itself. To what extent rights can be mobilised successfully, however, largely depends on the economic and political power of the actors concerned. The extent to which the proponents assert the validity of ‘their’ legal systems, attempts to enforce their rights, or to which they are forced to make compromises about the superiority of the respective systems is context dependent.

[14] See also von Benda-Beckmann (1995) and von Benda-Beckmann and von Benda-Beckmann (1999).

The legal systems are also interdependent and influence each other. Bantu and Bagyeli incorporate ideas from State law. For instance, the idea of *mise en valeur* has been incorporated into Bantu laws. The extent to which the proponents of the different legal systems have knowledge about the other systems, of how the proponents of other systems conceptualise and recognise their own law and rights, differs considerably. Such knowledge is largely superficial, selective, and strategically employed. Depending on the situation, Bantu villagers and Bagyeli may also refer to the law of the State, while State officials may also use Bantu customary legal notions.

The co-existence, ambiguity, and contextual specificity of actual local law underlie the considerable legal and economic insecurity in the TCP area. It also harbours a great potential for social and economic conflicts, which often are expressed as conflicts over the valid legal basis. Conflicts involving the use of violence have already erupted. This may, however, be only the tip of the volcano. One important task for further planning will be to avoid the expansion of such conflicts in the future.

Research has shown that the structure of conflicts is complex. A dominant line, that defines opposing interests, runs along a combination of ethnic and socio-political differences. Bantu farmers versus Bagyeli 'forest people'; both categories also in conflict with the State, and/or economic actors such as logging companies or plantation owners who have received their rights from, and are supported by State agencies. Conflicting interests, however, also crosscut these lines of division. There are internal differences within these different categories, and alliances are forged between members of local communities and external actors.

6.3. Plan making and intervention under conditions of legal complexity

Any new intervention into the current management and exploitation regime, for instance by the attempts to implement resource management plans (or land-use plans) will add new rules to the already existing ones. It can be expected that any attempt to implement such new plans will be significantly affected by the existing conditions of legal pluralism as well as by the economic and political relationships. The planning and implementation will therefore have to take these conditions into account. 'Taking rights into account' has to be seen in a double way.

First, the existence of these conflicting body of rights and obligations is an empirical evidence which cannot be overlooked in the analysis of the current situation, and attempts to develop scenarios for future development. Neglect of their existence and significance, however relative, will only lead to the construction of 'forest management dream castles'.

Second, taking these into account becomes also relevant in the normative sense: that is, that the validity of certain rights and obligations has to be re-asserted and recognised, while others may have to change or to be invalidated, or new compromises between conflicting validity claims have to be made.

These considerations have implications for a number of crucial themes which any land-use plan or management plan must address: the question of zoning and other constraints on resource exploitation, the rights to economic benefits from the exploitation of natural resources, and the identification of possible partners in negotiation about such plans and their implementation. They have also implications for the current State legislation on natural resources. Four major corollaries need to be looked into carefully:

- *Rethinking the boundary between public and private rights in the administration and exploitation of natural resources is important*. The Cameroonian State law regarding natural resources is still largely based upon 19th century notions of private law ownership coupled to an exaggerated notion of State sovereignty. The latter is, notwithstanding de-colonisation and the advent of democratic ideologies and institutions, basically colonial in nature and treats its subjects as persons with inferior economic and political rights. These notions continue to shape the ways in which the State recognises the rights of local human groups over natural resources that have their basis of legitimacy in tradition and self-regulation. It also underlies the way and extent:

- To which the State has appropriated rights, legitimating the economic exploitation of resources, either directly or indirectly via the granting of exploitation rights (licenses, etc.) to others.
- In which it apportions so-called user rights to people that are different from, and are more restricted than the rights that the same people have under their own customary law.

However, this may have changed. The continuation of these legal forms not only perpetuates colonial injustice; it also is a constant source of economic and political insecurity, which is detrimental to attempts to improve the economic and ecological conditions for resource management.

The limitations of internal State sovereignty, the difference between public and private domains, between rights to public regulation of resource use including environmental protection, and the recognition of local people's rights should be rethought and clarified. Particular attention should be given to the difference between management (public regulation and control) and exploited rights/appropriation of economic benefit. Also when thinking about the reorganisation of resources, one has to take into account that public management functions can be attached to local administrative organisations such as the administrative villages and their functionaries. But as we have described earlier, the property holding units holding use and exploitation rights, are usually shared by smaller social entities such as (sub)lineages.

- *Local property rights should be validated as having their own basis of legitimacy independent from State recognition*: The rights to appropriate the economic benefits from resource exploitation are based upon property rights, and the labour arrangements through which the resources are exploited - whether this is for subsistence or for market production. This means, that, in principle, holders of local exploitation rights have the rights to the economic benefits. The State, as sovereign, has superior public regulation rights. The State may also via taxation extract parts of the benefits in the name of, and for the common good. But the rights in the public domain derived from State sovereignty do not include the right in the private domain to acquire exploitation rights via a legitimate transfer (sale, legitimate expropriation). In principle, however, the State cannot be considered to be the owner in the sense of private law.

  In the TCP zone, there are no reasons for deviating from these general principles. The improved livelihood of the population, which is economically dependent of the exploitation of forest resources and land/vegetation adjacent to forests, is essential. These, in general, are poor people for whom alternative sources of income are closed off. Their chances of improving their livelihoods should be increased or at least not additionally weakened by new interventions. Recognising their property rights implies:

  - That they receive a fairer share in the economic profits from the exploitation of 'their' resources;
  - That their resource reserve for their future generations and future economic needs is not overexploited.

  Restoring security over their rights and giving them the opportunity to guard resource reserves for their descendants, the pre-condition for 'social' sustainability, can work as an important means for 'sustainable' exploitation of the physical environment.

- *Conflicting rights and claims of Pygmy and Bantu groups*: One of the major problems in the area are the relationships between the various Bagyeli groups and Bantu 'patrons'. Their mutual recognition of rights to cultivable land and forest resources is ambiguous and contradictory. Many Bagyeli concede that they derive some rights from the 'membership' in Fang, Bulu or Ngumba clans which they have on the basis of fictive kinship relations: and so far they recognise superior rights of their Bantu ‘patrons’. Yet, they also maintain the idea that actually the forest is ‘theirs’, that their user-rights are older and stronger; and that it is only the more powerful position of the Bantu, enhanced during colonisation and maintained after independence by the State, which forces them to submit to Bantu superiority. Bantu villagers, on the other hand, tend to emphasise that the forest land belongs to them, though they would sometimes concede that Bagyeli have their own rights in forest areas, which are not claimed by the Bantu themselves.

In practice, the spatial demarcation of Bantu and Bagyeli property rights is highly negotiable, with the Bagyeli generally in the weaker position. In case of conflict, out-migration by Bagyeli families used to be a frequent occurrence. As we have described earlier, the stronger involvement in agriculture and commercial exchanges has led to a situation in which conflicts are less likely to be resolved through such ‘exit’ option. The sedentarisation policy of the Cameroonian government contributes to a situation in which forest or agricultural land at the forest edge comes under increasing pressure of Bantu and Bagyeli cultivators. It is here that conflicts are most frequent and intense. Finding a just solution to the conflicting claims of Bantu and Bagyeli groups, delimiting and protecting resource areas which allow for the economic livelihood of both groups in the future, constitutes one of the most important problems in the area.

- *Implications relating to State legislation*: Looking at the difference between these implications and the current Cameroonian legislation on land and forests and the associated administrative practices, we can point towards the following desirable changes:
  - The recognition of local people’s rights in the Forest and Land legislation should be extended to those primary forest areas under local rights. In the TCP zone, more or less all primary forest is subject to such rights. Under the present legislation, limited rights are only recognised for secondary forest areas;
  - The recognition of rights therefore should include naturally grown trees and vegetation. Presently, people’s rights to trees are only recognised to self-planted trees;
  - Such rights have to be recognised also if they differ in their intensity, spatial and temporal dimension from State law concepts of ownership. Not permanently exploited forest areas, reserve areas and zones of influence recognised in Bantu laws as legitimate, also must be recognised as type of property right;
  - The dynamics of legal change at local level must be recognised as well.

One consequence of these explanations of the legal situation is that the provisional and temporary exploitation rights which the State allocates to third parties in the form of concessions - as what is called ’government largesse’ in the literature on the new property rights - does not seem to have a legitimate legal basis. One should rather envisage a change ‘from government largesse to property holder largesse’. Those who have the exploitation rights, should grant concessions, and be the prime beneficiaries of the counter-performance. State involvement should be restricted to designating the areas, or kinds of resource environments in which concessions can be given. The decision of whether a concession is actually granted, however, should be with the property right holders. Rather than having local people ‘participate’ in the economic profits, it is the State who, like as in other economic activities of its citizens, would participate in the form of taxation.

Another consequence should be drawn with respect to environmental protection and zoning plans. While ‘social sustainability’ should not be sacrificed to eco-cratic imperatives, some constraints on resource exploitation will be necessary. Zoning efforts should be adapted to local people’s notions of space and boundaries, their different kinds of property rights, and their mobility in the exploitation of forestland and other forest resources. It is highly questionable whether zoning based upon mutually exclusive functions (environmental protection, conservation, commercial production, and self-provisioning) is an adequate and feasible option.

More thought should be given to the 'interweaving of some of these functions (for instance hunting and gathering together with conservation) in differently demarcated spaces.

In order to develop more constructive ideas with respect to this problem, there is need to stress the desirability of coming to a *'cartography of rights'* as proposed by the research carried out by Tiayon. Such a cartography shows overlapping spaces or maps, based upon the following criteria:

- The different spatial localisation of property rights and economic activities;
- Ecological zones based upon different ecological criteria (vegetation, soil fertility);
- Administrative boundaries;
- Zones that form an ecological perspective ideally suited for commercial production or conservation.

Such overlapping maps will give a good indication where the greatest potential for conflict or compromise exists between the objectives and functions which resources have in these socio-economic spatial scenarios. Current ideas of zoning and the planning of large contiguous spaces as production zones may then have to be reconsidered. The construction of such a map will be an ideal form of co-operation within TCP, especially between the land use and soil use research teams.

7. FURTHER RESEARCH STEPS

One of the questions that must be further discussed is how our conclusions regarding the issues outlined above and the general contribution of the S1 project can be integrated in the formulation of a master management plan (land-use plan) for the TCP area. This master management plan will only one of the result of TCP; the ultimate findings of TCP must have a broader relevance (and not be relevant for the TCP zone only) (Foahom, pers. comm., 1997). We, the sociology researcher in TCP emphasise that such a master management plan can never take a form of a detailed '*plan d'aménagement*' (forest management plan). This will be only possible when institutional channels have been created through which representatives of local communities themselves can co-decide which choices can be made for such a *plan d'aménagement.* TCP researchers can certainly not act as spokesmen for 'their' community when definite choices have to be made (confer also what was said above in the paragraph on leadership and negotiation). The issues outline above suggest, nonetheless, clear points of departure for the formulation of such a master management plan.

The discussions with other researchers it became clear that in addition to this, there is a clear demand from other projects - whether or not in direct relation to the formulation of a master management plan - for survey data of socio-economic aspect of local communities. Some of the data mentioned during these discussions do indeed relate to the research undertaken by the social scientists within TCP. Others seem to relate rather to other land-use projects. As far as these are relevant to the social research more survey-like data will certainly be presented in the final reports (Ph.D. theses) of the junior researchers. Some of these data were, moreover, already gathered during the preparation of the TCP program in 1992.

However, if - and this seems to be the case - there is a need for this data in an earlier phase of PTC it might be useful to insert a brief survey project. The collection of baseline data could take place through an extrapolation of existing official quantitative data, complimented by a brief survey in a representative sample of a limited number of villages and camps, for instance, in other to update the data of the 1987 census. The scientific direction of PTC could best decide at which moment such a survey could be executed (depending, for instance, on the time schedule for the master management plan and on the needs of other projects).

Such a survey will also serve to reinforce the representative character of the social research. Social research activities until now are already representative to a certain. But in view of the highly heterogeneous character of the zone, it is desirable to further increase this representativiness. It is important to emphasise in this aspect that it is not evident but that the various ethnic groups form homogenous and clearly distinct blocks (there is a tendency to relate representation to supposed differences between 'the' Bulu, 'the' Ngumba, 'the' Bassa, etc.) Regional variations (for instance between the Bipindi and the Akom II areas) might be at least as important.

The survey outlined above might also further interdisciplinary exchange within TCP. In relation to other debates with other disciplines/projects we want to emphasise that interdisciplinary must be a two-way process, in which all projects have their input in the formulation of the point of departure for the master management plan. It does not seem superfluous to underline this, since there is - in TCP as in other projects - an apparently self-evident tendency among the more technologically oriented disciplines to see the role of the social sciences as mainly one of furnishing data or 'tools' for facilitating the execution of plans for which the points of departure are already 'fixed' politically and/or technologically. It must be clear that the issues outlined above have important consequences for the formulation of points of departure for models for sustainable exploitation of forest resources and that the input of social sciences is of special importance also at this level.

By way of conclusion, we want to emphasise that this preliminary synthesis of the social research can offer no more than a summary of certain issues that have emerged as crucial problems from our research. More detailed analysis of these issues will follow in the final reports of the PhD-researchers who work within the project (see also van den Berg, 2001; van den Berg and Biesbrouck, 2000; Biesbrouck, 2001; Parren *et al*., 2001; Tiayon, 2001; Tiayon *et al*., 2001). Indeed, as said above, priority should be given now to the finishing of these dissertations both in the interest of the TCP and the researchers personally. However, we trust that the issues and considerations outlined above- which can, of course always be further elaborated, if necessary- offer relevant starting point for further discussion and collaboration with the other TCP-projects.

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MODELLING SUSTAINABLE TIMBER PRODUCTION IN SOUTH CAMEROON

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SUMMARY

Modelling timber production is to support decision-making in rainforest management in Cameroon. A model called TROPFOMS (TROPical Forest Management support System) has been designed to guide decisions on the cutting cycle and timber yields during the steady state and the conversion period, taking ecological, social, economic and technical aspects into account. TROPFOMS includes a mathematical programming module, a growth and yield module, an economic module and a constraint definition module. It uses quantitative methods (transition matrices, cluster analysis, logistic regression analysis, mathematical programming, stumpage prices derivation). The model results in an optimal cutting cycle of about 30 years, and a harvest of 13.4 m^3/ha for species currently commercialised. It would require about 120 year to convert forest at the study site into a steady state forest.

Keywords: forest management, modelling, tropical rainforest, Cameroon.

1. THE IMPORTANCE OF TIMBER PRODUCTION IN CAMEROON

Natural forests play an important role in the economy of Cameroon, at both the national and local levels. At the national level, logging, which takes place exclusively in natural forests, contributes about 7% to the Gross Domestic Product and 20% to the export of Cameroon. At the local level, the forests constitute a life support system for the populations who collect non-timber forest products in it (see van Dijk, 1999).

Industrial logging has been conducted in Cameroon for more than 50 years at an increasing rate. Nevertheless, Cameroon still possesses important forest resources. Closed forests cover a total area estimated at 22.5 million hectares including productive forests on drained land (17.5 million hectares), degraded forest (4.5 million hectares) and swampy forests (0.5 million hectares). Cameroon produces about three million m^3 of roundwood logs per year, which makes it a major producer of tropical logs in Africa. Most of the production is exported to foreign markets either as roundwood or as processed products (first processing only).

2. PRACTICES AND PROBLEMS OF FOREST MANAGEMENT IN CAMEROON

The Government of Cameroon has made a number of efforts in recent years to create adequate settings for the sustainable management of the Cameroon's forests. Among these efforts are the design of a national forest policy and the adoption of new forestry legislation (Government of Cameroon, 1994; 1995a). An objective of the Cameroon forest policy is to maintain 30% of the National territory as a permanent forest estate. An indicative zoning plan has been developed for 14 million hectares of closed forests (Côté, 1993; Government of Cameroon, 1995b). Of these 14 million, about 9 million are proposed to be part of the permanent forest estate within which there are about 6 million ha of production forests divided in 90 Forest Management Units (FMUs). The main objective of the production forest is timber production.

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Despite those efforts, there is still a general sense that in Cameroon, like in most tropical countries, forests are not managed in a sustainable way. There are concerns about both the degradation of forests resources and the failure of the forestry sector to contribute as much as it potentially can to the improvement of the well being of Cameroon nationals.

The poor forest management practices, which still prevail in Cameroon, result from both an inadequate institutional context and insufficient scientific and technical knowledge. To gradually decrease the problem of insufficient knowledge in tropical forestry many research projects have been undertaken. However, the research efforts concentrate on developing silvicultural systems and more and more on predicting growth and yield of forest stands. Research on supporting decision-making for forest management has been negligible in tropical forestry. This is true despite the fact that forest management planning, in which decision-making plays an important role, is recognised to be vital for the quest of sustainable forest management. Decisions related to management parameters of production forests, such as the cutting cycle, stocking level and structure and the need to incorporate silvicultural treatments have by and large been based on subjective experience of decision-makers, or at best on fragmented scientific knowledge in different sub-disciplines of forestry. The research discussed in this paper provides a scientific tool to support such decisions. It is described in more detail in Tropenbos-Cameroon Series 2 (Eba'a, 2000).

3. GENERAL CONTEXT OF THE RESEARCH

This research project was conducted within the general context of the Tropenbos Cameroon Programme (TCP), which consists of 14 research projects in five research areas, which are: Agronomy, Ecology, Forest Management and Economics, Social Sciences and Forestry. The global objective of the TCP is to develop an appropriate technology for sustainable management of the tropical forest of southern Cameroon.

The TCP research site is situated in Cameroon, approximately 80 km from Kribi, a coastal town where the head offices of the TCP are located. The site stretches out from $2^{o}47'$ to $3^{o}14'$ E longitude and from $10^{o}24'$ to $10^{o}51$ N latitude (van Gemerden and Hazeu, 1999) and it covers a total land area of about 200,000 hectares. The zoning plan of Cameroon (Côté, 1993) distinguished different forest types within the TCP research site as shown in Table 1, while the orientations given by the Zoning Plan for the Tropenbos Cameroon research site are summarised in Table 2. It can be noted that production forests are the least important in area compared to other types of forest. Nevertheless, it is thought that they should be managed as carefully as possible because of their status as permanent forests. In contrast to protection forests (the other type of permanent forest on the TCP research site), production forests are more subjected to utilisation by different stakeholders among which are loggers and the local populations.

Table 1. Vegetation types of the Tropenbos Cameroon research site

Vegetation types	Area (ha)
Dense humid forests	61,820
Dense humid forests (inaccessible)	22,300
Old secondary forests	71,980
Young secondary forests	22,550
Agriculture (young fallow)	1,420
Agriculture (farms)	15,920
Housing	170
Total	196,160

Source: Côté (1993)

The climate is typically equatorial and characterised by rainfalls that occur all the year long although there are two rainy seasons and two dry seasons. The mean annual temperature is about 25 ^{0}C. The altitude ranges from 40 m above sea level to about 1000 m.

Table 2. Extract of the Zoning Plan of the Tropenbos Cameroon research site

Proposed land utilisation type	Forest category	Land area (ha)
Production forests	permanent	15,470
Protection Forests	permanent	41,190
Community forests	Non permanent	17,170
Agroforestry and habitat	Non permanent	122,310
Total		196,140

Source: compiled from Côté (1993)

4. RESEARCH OBJECTIVES AND CONCEPTUAL FRAMEWORK

The research presented here was initiated from the thought that forest management planning involves making decisions to affect the forest now and in the future. Therefore, it should use the best available methods, which combine knowledge collected in different scientific fields to support decision-making and generate practical management strategies for field implementation. From this line of thinking, a general objective of the research was conceived as "to design a system, which can support decision-making for the management of natural tropical forests". This general objective was further differentiated in five specific objectives listed as:

- To design a system for supporting decision-making with respect to the management of tropical forests.
- To assess the effects of different management options on the economic returns of the logging enterprise as well as on the structure of the forest at steady state.
- To provide insights into the trade off between income generation through sustainable timber harvesting and the use of the forest by the local population on the one hand, and between income generation through sustainable timber production and nature conservation on the other hand.
- To derive recommendations for conversion of the current forest at the Tropenbos-Cameroon Programme (TCP) research site into a steady state forest.
- To suggest and evaluate adaptations of existing strategies aimed at sustainable management of the tropical moist forest of south Cameroon.

The conceptual framework (Figure 1) of the research was based on two main assumptions, which are:

- The goal of sustainability in forest management can be attained only if ecological, economic and sociological constraints are taken into account within any management strategy developed and implemented.
- There are ways to reconcile forest conservation (maintenance of forest cover and a high biological diversity) with some levels of both industrial timber harvesting and forest utilisation by the local population.

These assumptions mean that a tool to support decision-making for the management of natural tropical production forests should be able to incorporate different aspects related to the biological characteristics of forests stands, the market of timber products, the needs of the local populations and the needs for forest conservation.

5. MODEL DEVELOPMENT

A methodological tool was developed to support decision-making with respect to tropical forest management. The system was given the acronym TROPFOMS, which means TROPical FOrest Management support System. The management items to which TROPFOMS provides support for decision-making include:

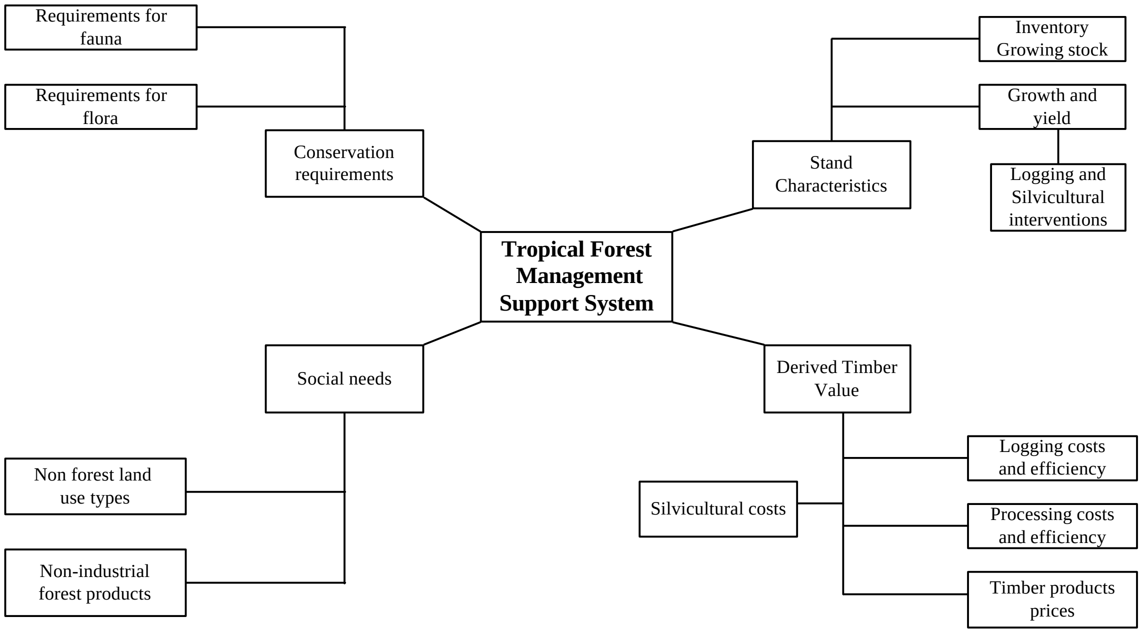

Figure 1. Conceptual framework for integrated decision-making in tropical forest management

- The target steady state growing stock characteristics, mainly the structure in terms of number of trees per size class to be found both before and after harvest and the species composition of the stand,
- The appropriate cutting cycle for timber harvest,
- The amount of wood to be harvested at the end of each cutting cycle,
- The expected length of the conversion period and the expected levels of harvest during that period,
- The multiple use of the forest through an analysis of the trade off between alternative land use types and especially between timber production, nature conservation and forest utilisation by the local population, and
- Consequences in changes of management parameters.

The focus of TROPFOMS is on the level of the stand instead of on that of the Forest Management Unit.

TROPFOMS uses tree species groups instead of individual tree species and consists of four main components (Figure 2), which are:

- A growth and yield module based on transition matrices,
- An economic module consisting of stumpage prices derived from market prices of timber products and harvesting costs,
- A constraint formulation module included into the model concerns diversity of species groups and tree sizes,
- A mathematical programming module which uses linear programming techniques to search for optimal stand characteristics at steady state and performs simulations to achieve projections of forest stand characteristics during the conversion period.

5.1. Coefficients and parameters in TROPFOMS
The information needed by TROPFOMS in order to provide support for decision-making include:

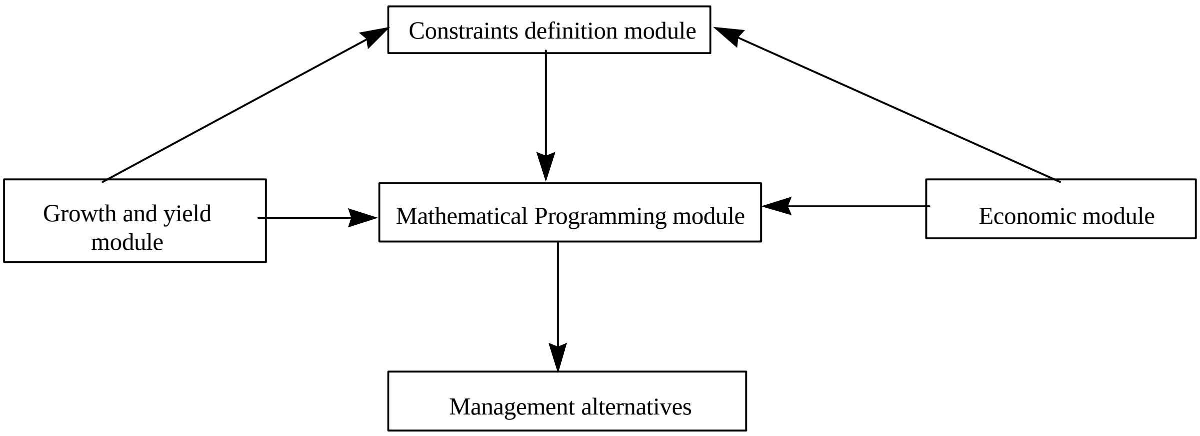

Figure 2. Main components of TROPFOMS

- *A definition of tree species groups*. An important characteristic of tropical forests is its heterogeneity, which results from the large number of tree species. The great number of species makes growth and yield modelling difficult. Thus, tree species should be aggregated in groups. In this research, tree species were aggregated in four groups by cluster analysis. The grouping was based on commercial value, diameter increment, minimum diameter for felling and diameter at the beginning of the growth period. The data used to group species were collected in permanent sample plots in Liberia, as there is no such information from Cameroon. Re-measurement was done every five years (growth period).
- *Transition probabilities*. These are probabilities that a tree of a certain species group and in a given diameter class grows up one diameter class or stays in the initial diameter class after a certain time interval. The transition probabilities were estimated by logistic regression analysis. However, mortality was estimated from results of prior studies. Ingrowth was included as average number of trees that entered the smallest diameter class after each growth period.
- *Stumpage prices*. They were expressed in CFA francs[2] (FCFA) per tree for each species group and each diameter class. The stumpage prices were estimated following a residual approach. The basis of the approach was the FOB price of logs from which the cost of availability were deducted also taking into account the efficiency of the logging process.
- *Discount rate*. A discount rate of 5% was chosen based on the literature. A sensitivity analysis was also conducted which showed that the effects of the discount rate were not very important for the studied forest management parameters up to 10%.
- *List of non-timber forest products (NTFP) tree species*. To be able to incorporating the use of the forest by the local population in the system, a list of trees species that are used by both the local population and the logging industry was needed. A study was conducted in south Cameroon to obtain such a list (van Dijk, 1999).
- *Forest inventory results*. These results are necessary for the estimation of characteristics of the conversion period. The inventory results provided information about the current structure and stocking of the average forest stand in terms of number of trees per hectare per species group and per diameter class.
- *Technical information on logging*. The information needed concerns logging intensity, logging damage and logging costs, and the relationships among these items and with the structure of the forest stands.
- *Ecological limits in basal area removal.* When conducting logging or silvicultural treatments or a combination of both, the basal area is reduced. However, it is feared that, if the basal area is excessively reduced, the forest may be irreversibly damaged and loose its

[2] 1 Euro = 656 FCFA

capacity to regenerate without artificial intervention. Therefore, in most cases, it has been avoided to reduce the basal area of forest stands by more than 50%.
- *Definition of management objectives*. It is important to know which forest management objectives are of interest and which levels of satisfaction of these objectives can be accepted. This research examined the objective of income generation through sustained timber production in relationship with the objectives of nature conservation through species group diversity and tree size diversity and the objective of improved living conditions for the local population through continued supply of NTFPs.

6. THE OUTCOMES OF THE MODEL

6.1. The outcomes of TROPFOMS for the optimal steady state

The optimal cutting cycle obtained for sustainable timber production was estimated to be 30 years. The steady state harvest for species, which are currently commercialised, was estimated at 13.4 m^3/ha but could be as high as 117 m^3/ha if all the species are harvested. The harvesting rule only allows cutting of trees of 100 cm of diameter or more. The structure of the stand before harvest is constituted by all species groups with a negative exponential distribution of trees among diameter classes. Such a distribution is characteristic for uneven-aged forest stands. The outcomes have shown a great deal of sensitivity to assumptions on stumpage prices especially as related to logging costs and waste.

6.2. Conversion of the current forest to the steady state forest

The average forest stand at the TCP research site shows important differences with the desired steady state structure. The total number of trees per hectare is currently higher. However, for the most commercialised species group, this number is smaller. It would require more than 120 years to convert the current forest stand at the TCP research site to the desired steady state structure, but during the conversion timber harvest with positive financial returns is possible.

6.3. Trade off between management objectives

The forest can be used by the local population without important consequences of this use for the income generation objective. Similarly, it is possible to have at least one tree of every species group in every diameter class within an area of 50 ha without important reduction of financial returns from logging.

7. RECOMMENDATIONS

7.1. Recommendations for forest policy and management.

The research had limitations, which in general relate to the quality of information available. The most important limitations came from the lack of data from Permanent Sample Plots (PSPs) in Cameroon, which forced to used data from another African country for the growth and yield module. The other important limitations are related to logging costs, which affect the stumpage prices. The available information on these costs did not allow to investigate thoroughly the different relationships between logging practices and optimal stand characteristics. Many other points deserve to be studied in order to improve the outcomes of TROPFOMS. The following recommendations were made for policy and management:

- *Increase minimum permitted diameters for felling to 100 cm*
- *Apply silvicultural operations*.
- *Adopt a cutting cycle of about 30 years*.
- *Acquire adequate computation equipment and trained human resources*. It is important for the management to acquire the necessary equipment for the needed computations by the model. In addition, trained manpower capable of using the software adequately as well as for planning and implementing silvicultural prescriptions should be present.

- *Create an information base*. Management should carefully archive all information related to management activities to improve the quality of future analyses. All information about the quality and the quantities of forest products harvested as well as various costs and benefits should be well gathered and stored.
- *Create a network of permanent sample plots*. In order to improve forest management gradually, a good monitoring system of the forest is needed. It is necessary that for each forest type a number of PSPs be maintained.

7.2. Recommendations for further research

- *Costs and returns of silvicultural operations*. More knowledge is needed to assess the impact of silvicultural treatments on stand dynamics in general and on tree growth in particular. In addition, the costs of treatments should be studied in comparison with the gains in growth.
- *Relationship between growth and yield and density of forest stands*. It is generally known, that stand density has a strong effect on growth of individual trees (see Vanclay, 1991). Stand density can be expressed in many ways, basal area, overtopping basal area, standing volume per ha. Because of low variability in basal area, in the data set used, this study failed to quantify the impact of stand density on growth. It would be interesting in the future to investigate more on this relationship.
- *Reproductive maturity of different tree species*. A study is needed to determine at which sizes different species groups start to produce enough viable seeds.
- *Logging efficiency, costs and damage*. There is a need to characterise relationships between logging costs on one hand and logging intensity and tree size on the other hand.
- *The utilisation of the forest by local population*. The way the local population chooses NTFP supplier trees should be better understood in order to better conceive the type of restrictions to be imposed on timber harvesting and to guarantee proper supply of the local populations with desired products. Similarly, it is important to improve the understanding of the effects of logging and silvicultural treatments on NTFP supplier trees and other plant and animal products utilised by the local population.
- *Royalties*. Sensitivity of forest management to royalties should be investigated. Such an investigation will allow obtaining more insight in the way tropical forest management can best contribute to generating government revenues, and in the way a forest revenue system can contribute to sustainable forest management.

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CONCLUSIONS AND RECOMMENDATIONS

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Managing tropical rain forests in a sustainable way is a challenge and that improving this management is even more challenging. The Tropenbos-Cameroon Programme makes efforts to do the last and has tried to develop new concepts that can be implemented in forestry and forest management in Cameroon, and possibly also elsewhere. The scientific results forming the foundation for these new concepts are presented in this proceedings, with a special emphasis on their applicability.

The first part of this proceedings is devoted to the (procedure to develop a) Master Management Plan (MMP), the second part to the procedure for a Forest Management Plan (FMP). The MMP focuses on land-use planning for a large area (2000 km^2); the FMP - on a more detailed scale – has a medium size production forest as subject. The same sequence will be followed in this contribution. However, some important issues related to stakeholders are mentioned separately, because they are often neglected in current forest management. It should be stressed that this contribution is not meant to repeat the recommendations made in the preceding articles and that some projects are not yet so advanced that recommendations can be formulated.

Recommendations with regard to the Master Management Plan

The aim of a MMP development procedure is to come to a consensus between all stakeholders on the land uses allotted to different parts of a certain area. Management and development options, which are expected to reflect the wishes and needs of local populations and other stakeholders, and which are in accordance with the biophysical and social environment, are presented to these stakeholders as a basis for discussion, negotiation and decision. Only after the stakeholders have agreed upon a land use allocation, a final version of the Master Management Plan can be written and subsequently implemented, with the involvement of all stakeholders. Aspects to be taken into account here are:

- All stakeholders should be included in the whole decision making process of the MMP, from the first development of options till the final decision and its implementation.
- The negotiation procedure of the MMP should be done according to the following four steps, using appropriate mediation tools:
  - presentation of the land-use options (draft maps, environmental impact assessment tables) to each group of stakeholders separately;
  - discussion at local level, gathering all relevant stakeholders, aiming at consensus at that level, using land use maps and impact matrices;
  - discussion at subdivision level, gathering all relevant stakeholders, aiming at consensus at that level, using land use maps and impact matrices;
  - overall meeting, gathering all stakeholders to establish a final proposal for the MMP that is acceptable to all the stakeholders (mediation tools: MMP draft maps and impact matrix).
- All stakeholders should be flexible and should have an open mind for the point of view of the other stakeholders;
- The traditional rights of the local populations and their other particularities (e.g. mobility) should have at least the same value and weight as the governmental rights.
- All participants in the negotiation should have the same information and understand this information. It may be necessary to launch an education programme before the start of the negotiations.

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Recommendations with regard to the Forest Management Plan
The aim of a procedure to develop a Forest Management Plan is to obtain an agreement of all stakeholders on the objectives, borders and modalities of forest management for a certain forest tentatively delineated in the master management plan. In principle, logging operation should not start before the FMP, inclusive an operational plan for the first year and a five-year plan, is approved. Aspects to be taken into account here are, in addition to the ones mentioned for the MMP:

- The needs of the local populations should be incorporated in the FMP. On the one hand, certain NTFP producing tree species may have to be excluded from logging and so should sacred places. On the other hand, the economic value of NTFPs could change the economic viability of the forest unit in a positive way;
- Both the actual and the future timber market should be taken into account;
- In the operational plan the following aspects should be taken into account:
    - Logging, although it damages the forest, should be considered as and thus be conducted as a silvicultural intervention. So, a detailed map, based on the harvest inventory, should be elaborated, indicating the ecological and silvicultural possibilities and risks. On the same map, the interest of the local population (NTFPs, sacred places) should be indicated. Timber harvesting should be in accordance with the principles of Reduced Impact Logging. That is, trees should be felled trees in the direction of existing gaps and young forest patches to minimise felling damage to potential crop trees, roads and skid trails should be well planned and winching or logs from the stump to the skid trail should be applied whenever feasible.
    - The local population should be involved in all phases, the inventory phase, the discussion and decision phase, the planning phase and the controlling phase. In this way, their interests are safeguarded and the knowledge integrated and used in the FMP. A village forest committee in the framework of a national collaborative forest management board could be helpful here.
    - An education plan, providing formal training to forest workers to achieve high professional standards rather than on-the-job training/apprenticeships in forest management should be included in the operational plan.
    - The installation of an unequivocal system of unique tree-log-numbers used from the inventory phase until transformation at a timber processing plant (sawmill, plywood factory) and even thereafter will ensure adequate monitoring and control.
- The local people should be allowed to use (transform) the logging waste. It may be necessary to change the law in this respect.

Recommendations with regard to stakeholders
All stakeholders should be involved in all phases of the decision process of a MMP or a FMP. To guarantee a well-balanced process, with comparable power for all stakeholder groups, special attention should be given to the local population.

All stakeholders should have and understand the same information, which means that not only all information should be distributed, but also that some forestry education may be necessary. All stakeholder groups should be represented by persons, which really have obtained a mandate from the people they represent. This means that the representatives of the local populations should be selected with care. Village chiefs, authorities or elites may not always be the most appropriate, and head of families or clans (lineages) or NGOs should be considered as candidates.