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NORTHWEST DEVELOPMENT AUTHORITY
MIDENO

SOILS, LAND USE AND LAND EVALUATION OF THE NORTH-WEST PROVINCE CAMEROON

VOLUME IIIa LAND EVALUATION: GENERAL METHODOLOGY AND RESULTS FOR THE RINGROAD AREA, WITH EMPHASIS ON LOW IMPUT MAIZE, SMALLHOLDER COFFEE AND OIL PALM, AND EXTENSIVE GRAZING

J.Hof
Ph.A.Kips
A.de Vlaminck
E.E.Bisong
S.Trinh

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IRA/CNS-Ekona Station, PMB 25 Buea   IRA/CNS-Nkolbisson, BP 5578, Yaounde

SOILS, LAND USE AND LAND EVALUATION

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by

J. Hof, Ph.A. Kips, A. de Vlaminck (FAO/UNDP Soil Resources Project)
E.E. Bisong (Ekona Station of CNS/IRA: National Soils Centre of the Institute of Agronomic Research)
S. Trinh (FAO/UNDP)

Maps traced by L.D. Essama and F. Fombad (CNS/IRA)
Word Processing by Ms. E.N. Njie (CNS/IRA)

HOW TO USE THIS REPORT

This explanatory report to the Land Evaluation Studies of the Ring-road Area of the North West Province contains information that can be applied in rural development planning in the Province and is therefore directed in the first instance to the coordinating North-West Province Development Authority (MIDENO) and further to specialized provincial and national authorities concerned with different types of land use. For maximum profitability this report and the maps should be used together with the **soil and land use maps** (see page 1 for titles) prepared simultaneously.

Locating suitable areas for particular crops

In order to get an overview of the potential of all lands of the Ring-road area for particular crops, land evaluation maps, scale 1/200 000, for major crops and uses (maize, coffee, oil palm and extensive grazing) are included in a separate volume. Their mapping units contain symbols built up of codes evaluating respectively climatic conditions, soil edaphic conditions, erosion hazard and workability (only three codes for extensive grazing: climatic, soil edaphic and accessibility codes). The overall potential of each mapping unit is indicated by a shading determined by the most limiting factor, the code of which is underlined. The legends of the land evaluation maps explain these principles and the codes. Chapters 5 to 9 decribe these maps and the procedures followed.

For crops and land uses for which no land evaluation maps are included in this report, the instructions as laid down in Chapter 10 can be followed to derive land evaluation maps for overview, or to determine land use alternatives for individual tracts of land. These procedures are to be carried out with the soil maps and reports at hand.

Finding additional information

In the chapter 'Introduction', the background and objectives of this survey are explained. In Chapter 2, the reader can find a detailed account of the methodology employed in this study.

In this chapter also some basic terminology is explained, but a more complete account of terminology is given in the Glossary at the back of this report. The chapter 'Land Evaluation Criteria' gives comments on the choice of land evaluation criteria applied. The chapter 'Climatic Inventory' gives a detailed account of the agro-climatological conditions in the NWP. For further reading many titles in the Bibliography at the back of the report can be recommended.

Getting an overview of the survey area

The following pages give a summary description of the results of the land evaluation studies in the survey area and serve as a quick reference text. This text also summarizes the recommendations in this report. Conclusions on these land evaluations and recommendations for follow-up studies follow these summary descriptions.

SUMMARY

This report on the land use in the Ring-road area forms part of a comprehensive study on soils, land use and land evaluation in the North West Province of Cameroon. The study is to serve the North West Province Development Authority (MIDENO) as a reference base to tune the Provincial rural development programmes optimally to the physical environmental conditions, taking present land use into account.

The study area, with 10 750 km^2, covers about 60 percent of the whole Province, particularly its central part.

With the criteria applied the lands of the survey area can be classified as follows (in percentages) for the major crops:

	Maize	Arabica coffee	Robusta coffee	Oil Palm
good	0.5	2.5	negl.	0.5
fair	18	46	16	15
poor	13	11	8	9
very poor	56.5	11	18	31.5
no potential	12	29.5	58	44

The large proportions of land without potential for coffee and oil palm are either too warm or too cold. The large proportion of very poor land for maize is mainly due to very acid soil conditions and/or steepness of the land.

For extensive grazing two-thirds of the land have good or fair potential. A main constraint is the length of the dry season which necessitates transhumance.

The suitability of the lands for other crops and uses was studied in less detail, but land evaluation criteria and procedures are proposed to allow users of the report to evaluate where in the province which crops can be cultivated on a sustained basis.

RESUME

Présent rapport sur l'occupation des terres dans la zone du "Ring-road" fait partie d'une étude compréhensive des sols, de l'occupation des sols et d'évaluation des terres de la Province du Nord-Ouest du Cameroun. Cette étude servira la Mission de Développement du Nord-Ouest (MIDENO) comme base de référence pour accomoder les programmes provinciaux de développement rural au maximum aux conditions du milieu physique et de l'occupation actuelle des sols.

La zone étudiée couvre, avec 10 750 km^2, à peu près 60 pour cent de la superficie de toute la province, plus en particulier sa partie centrale.

Avec les critères qu'on a appliqués, les terres étudiées peuvent être classifiées comme suite (en pourcentages) pour les cultures principales:

	Maïs	Café Arabica	Café Robusta	Palmier à huile
bon	0.5	2.5	negl.	0.5
assez bon	18	46	16	15
médiocre	13	11	8	9
très médiocre	56.5	11	18	31.5
sans potentiel	12	29.5	58	44

Les grandes proportions des terres sans potentiel pour les cafés et le palmier à huile sont ou bien trop froides ou bien trop chaudes. La grande proportion de terres très médiocres pour le maïs est surtout à cause de conditions très acides des sols et/ou la raideur du terrain.

Pour l'élévage extensif deux tiers des terres ont des bons ou assez bons potentiels. Une majeure contrainte est la longueur de la saison sèche qui nécessite une système de transhumance.

L'aptitude des terres pour d'autres cultures et utilisations a été étudiée en moindre détail. Cependant des critères et procédures sont proposés qui facilitent l'utilisateur de ce rapport d'évaluer où dans la province quelles cultures sont possibles d'une façon soutenue.

CONCLUSIONS AND RECOMMENDATIONS FOR FOLLOW-UP STUDIES

The following list of conclusions and recommendations is provisional only. It is difficult to be exhaustive and probably many questions may have been left unanswered. Users of this report and map should therefore not hesitate to contact the authors for questions and further consultation.

Among the major, largely amendable limitations to crop cultivation are erosion hazard, soil acidity and low nutrient status.

In order to assess **erosion hazards** better, it is recommended:

- to analyse existing automatic rainfall records to assess rainfall erosivity and to draw up iso-erodent maps;
- to study soil erodibility on a number of typical profiles on each type of parent material. This could be done with rainfall simulators, where possible complemented with run-off plots and laboratory tests;
- to study the effects of present cultivation practices on soil erosion. Thus accumulated data should serve as a basis to formulate improved conservation practices;
- to compare actual land use, as shown on the land use maps, with the land evaluation maps. Thus areas can be detected which are not fit for present use.

Soil acidity

For many crops soil acidity and high aluminium levels are limiting factors. It was noted that at similar pH, aluminium problems are less in soils on basalt than on other parent materials. This requires further investigation. Liming to pH 5.0-5.5 in soils on basalt and to pH 5.5-6.0 on other parent materials is expected to neutralize aluminium sufficiently. Application of lime in large quantities is, however, hardly feasible seeing the absence of nearby lime sources and the land utilization types. An alternative or complement to liming is the breeding of aluminium tolerant cultivars. This should be considered, for instance, in the maize breeding programmes.

Low nutrient status

To amend low nutrient status it may be worthwhile to develop compound fertilizers adapted to the different soil types (and crops) in the North West Province. To this end fertilizer trials are recommended on representative soils on each parent material. Other practices which can help to intensify crop production and which should be further tested and introduced include improved fallow, application of organic manures, improved crop mixtures and rotations.

Agro-climatic conditions

It is noted in the report that many more climatological data and records must exist than those made available to the authors. It is therefore recommended that a team of agro-climatologists completes and systematizes this data base. Analysis of these data could lead to a better understanding of meso-climatic conditions. Analysis of rainfall records of 10-day or 7-day periods could give better insight into optimal planting dates and the risks of dry periods shortly after planting. Best planting dates for a second maize crop (in the second half of the rainy season) could be investigated.

For coffee, no or only limited shading seems a sound practice seeing the low solar radiation and the high air humidity. (It is however not optimal for soil conservation.)

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Chapter 1

INTRODUCTION

In response to a request of the North West Province Development Authority (MIDENO*), geographers and soil scientists, attached to the National Soils Centre of Cameroon (CNS/IRA**), Ekona Station, recently carried out a land evaluation study of nearly the entire North West Province of Cameroon, comprising about 17 900 km². The present report covers the Ring-road area with a surface area of about 10 750 km² (Figure 1).

This report forms part of a series concerning soil survey, land evaluation and present land use of the Ring-road area, which together give a comprehensive picture of the land resources and agricultural potential in the area. These documents are to serve MIDENO in planning and coordinating programmes concerned with the integrated rural development of the Province. Their publication is envisaged under the title "Soils, Land Use and Land Evaluation of the North-West Province", comprising the following volumes:

Volume Ia : Explanatory Report to the Detailed Reconnaissance Soil Map of the Ring-road Area, Scale 1/200 000.

Volume Ib : Explanatory Report to the Detailed Reconnaissance Soil Maps of the Njikwa, Batibo, Bamenda, Bambalang and Nwa Areas, Scale 1/200 000.

Volume IIa : Description of the Land Use in the Province and Explanatory Note to the Land Use Map of the Ring-road Area, Scale 1/100 000.

Volume IIb : Explanatory Note to the Land Use Maps of the Njikwa, Batibo, Bamenda, Bambalang and Nwa Areas, Scale 1/100 000.

Volume IIIa : Land Evaluation: General Methodology and Results for the Ring-road Area, with Emphasis on Low Input Maize, Smallholder Coffee and Oil Palm, and Extensive Grazing.

Volume IIIb : Land Evaluation: Results for the Njikwa, Batibo, Bamenda, Bambalang and Nwa Areas, with Emphasis on Low Input Maize, Smallholder Coffee and Oil Palm, and Extensive Grazing.

The particular interest of the land evaluation studies is to give insight to where in the Province which crops can be profitably grown on a sustained basis.

The information in this report can be used in two different ways. First to get an overview of the potential of the whole Province for particular uses, as a help to indicating priority areas for development of that particular use. As such it serves as a powerful tool in land use planning at provincial and national levels. This approach is used in chapters 5 to 9 to draw up land evaluation maps at scale 1/200 000 for respectively maize, Arabica coffee, Robusta coffee, oil palm and extensive grazing. A second approach is to get an overview of land use and crop alternatives for each individual tract of land. In particular, the information in chapter 10 is meant for this purpose, but also information in chapters 5 to 9 can be applied to this end. It is pointed out, however, that this type of use of the information is limited by the reconnaissance character of the studies.

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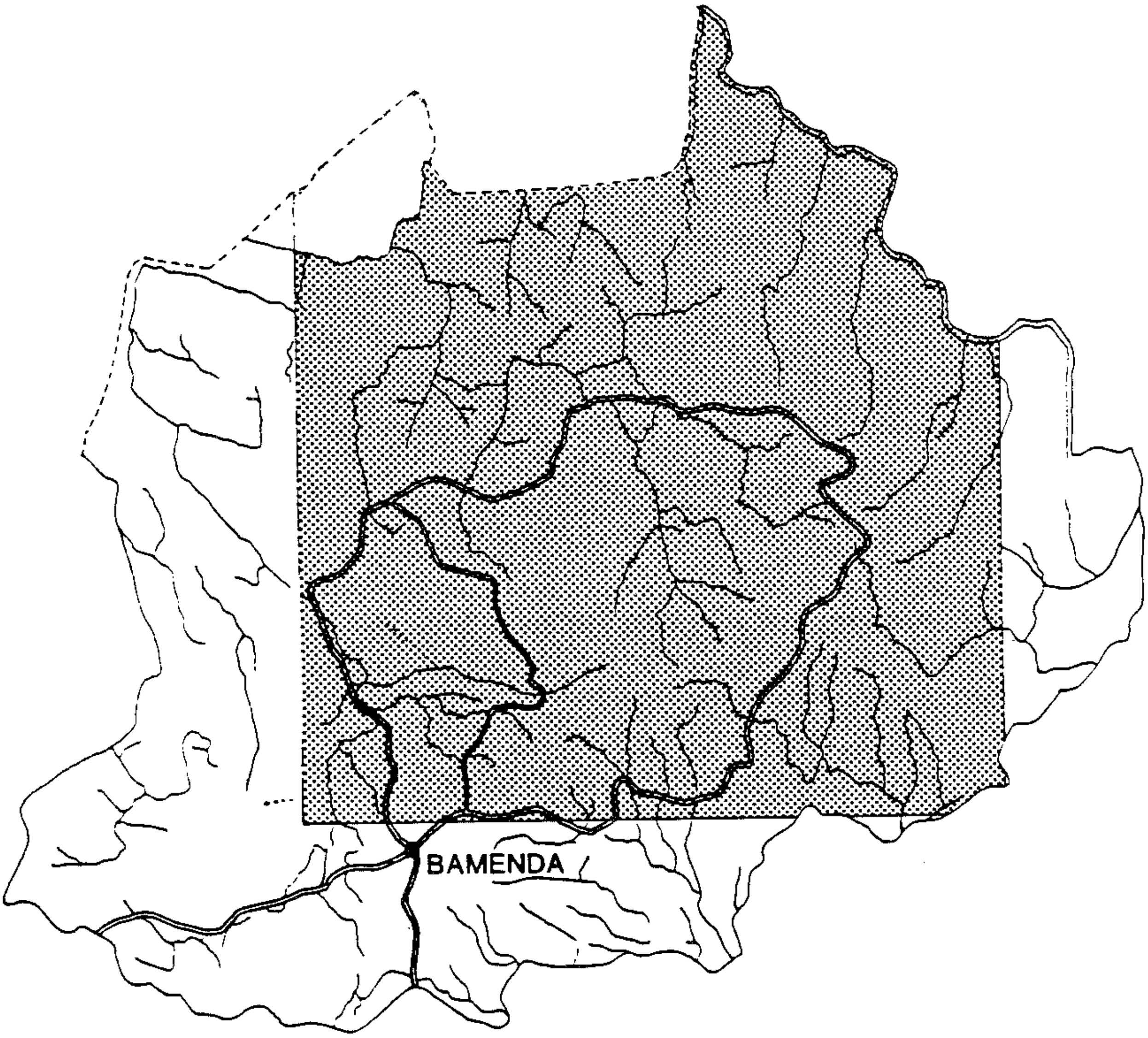
* The 'Mission de Développement de la Province du Nord-Ouest' (MIDENO) is a body supervised by the Ministry of Agriculture, which has as its principal function to administer the North West Province Rural Development Project.

** Centre National des Sols/Institut de la Recherche Agronomique du Ministère de l'Enseignement Supérieur et de la Recherche Scientifique (MESRES).



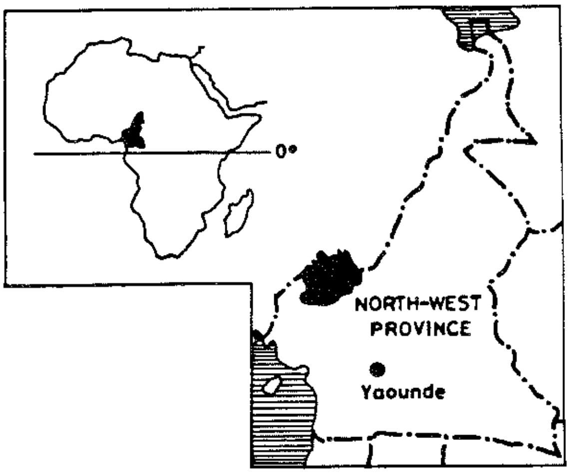


Figure 1 Location map, Ring-road area

The land evaluation studies are interpretations of the detailed reconnaissance soil maps, scale 1/200 000. Those maps and reports should therefore always be used together with the present report.

In order to compare land use potentials with actual land use, it is recommended to consult the land use reports and maps in this series. Those reports also give background information on human population, economic activities and vegetation.

Chapter 2

METHODOLOGY

2.1 SCOPE AND OBJECTIVES

The main objective of present land evaluation studies is to provide a rational basis for rural land use planning and improvements in land management in the North West Province.

The function of **land use planning** is to guide decisions on land use in such a way that the resources of the environment are put to the **most beneficial** use for man, whilst at the same time **conserving those resources for the future.** This planning must be based on an **understanding both of the natural environment and of the kinds of land use envisaged.**

It is the function of **land evaluation** to bring about such understanding and to present planners with alternatives covering the most promising kinds of land use.

Land evaluation is concerned with the assessment of land performance when used for specified purposes. It involves the execution and interpretation of basic surveys of climate, soils, vegetation and other aspects of land in terms of the requirements of alternative forms of land use. To be of value in planning, the range of land uses considered has to be limited to those which are relevant within the physical, economic and social context of the area considered, and the comparisons must incorporate economic considerations.

2.2 LAND EVALUATION CONCEPTS

This section is an abstract from 'A Framework for Land Evaluation' (FAO 1976), adapted to the procedures actually followed in this report.

The main activities in a land evaluation are as follows:

- Initial consultations, concerned with the objectives of the evaluation, and the data and assumptions on which it is to be based.
- Description of the kinds of land use to be considered, and establishment of their requirements.
- Description of land mapping units, and derivation of land qualities.
- Comparison of kinds of land use with the types of land present.
- Economic and social analysis.
- Land suitability classification.
- Presentation of the results of the evaluation.

An important and always recurring phase in a land evaluation study is the matching of the requirements of relevant, well defined **land utilization types** with relevant **land qualities** in order to determine the fitness of the land for that use. This process is called **land suitability classification.**

Land Utilization Types

A land utilization type (LUT) is a kind of land use described or defined in a degree of detail greater than that of a major kind or land use (for instance, 'rainfed agriculture', 'irrigated agriculture', 'grazing', 'forestry').

In this report the descriptions of LUTS include data and assumptions on such attributes as:

- crop(s) grown
- production method
- capital intensity
- market orientation
- labour intensity
- technical knowledge and attitudes
- power source
- size and shape of farms
- land tenure
- infrastructure
- cropping characteristics
- material inputs
- cultivation practices
- yields and production

In the present report, social and economic considerations are limited to those presented in each LUT description.

Land Qualities and Land Characteristics

A land quality is a complex attribute of land which acts in a distinct manner in its influence on the suitability of land for a specific kind of use.

Land qualities may be expressed in a positive or negative way. Examples are moisture availability, erosion resistance, flooding hazard, nutritive value of pastures, accessibility.

Land qualities can be assessed by estimating the aggregate effect of one or more **land characteristics**, i.e. attributes of land that can be measured or estimated. Examples are slope angle, rainfall, soil texture, available water capacity, biomass of the vegetation, etc. Land mapping units, as determined by resource surveys, are normally described in terms of land characteristics.

Structure of the Suitability Classification

i.	Land Suitability Orders	:	reflecting kinds of suitability
ii.	Land Suitability Classes	:	reflecting degrees of suitability within Orders
iii.	Land Suitability Subclasses	:	reflecting kinds of limitations, or main kinds of improvement measures required, within Classes.

Land Suitability Orders

Land suitability orders indicate whether land is assessed as suitable or not suitable for the use under consideration. There are two orders represented in maps, tables, etc. by the symbols S and N respectively.

Order S Suitable : Land on which sustained use of the kind under consideration is expected to yield benefits which justify the inputs, without unacceptable risk of damage to land resources.

Order N Not Suitable : Land which has qualities that appear to preclude sustained use of the kind under consideration.

Land may be classed as Not Suitable for a given use for a number of reasons. It may be that the proposed use is technically impracticable, such as the irrigation of rocky, steep land, or that it would cause severe environmental degradation, such as the cultivation of steep slopes. Frequently, however, the reason is economic: that the value of the expected benefits does not justify the expected costs of the inputs that would be required.

Land Suitability Classes

Land suitability classes reflect degrees of suitability. The classes are numbered consecutively, by Arabic numerals, in sequence of decreasing degrees of suitability within the Order. With the Order Suitable, three classes are recognized:

Class S1 Highly Suitable : Land having no significant limitations to sustained application of a given use, or only minor limitations that will not significantly reduce productivity or benefits and will not raise inputs above an acceptable level.

Class S2 Moderately Suitable : Land having limitations which in aggregate are moderately severe for sustained application of a given use; the limitations will reduce productivity or benefits and increase required inputs to the extent that the overall advantage to be gained from the use, although still attractive, will be appreciably inferior to that expected on Class S1 land.

Class S3 Marginally Suitable : Land having limitations which in aggregate are severe for sustained application of a given use and will so reduce productivity or benefits, or increase required inputs, that this expenditure will be only marginally justified.

Within the Order Not Suitable, there are normally two classes:

Class N1 Currently Not Suitable : Land having limitations which may be surmountable in time but which cannot be corrected with existing knowledge at currently acceptable cost; the limitations are so severe as to preclude successful sustained use of the land in the given manner.

Class N2 Permanently Not Suitable : Land having limitations which appear so severe as to preclude any possibilities of successful sustained use of the land in the given manner.

Land Suitability Subclasses

Land suitability subclasses reflect kinds of limitations, e.g. moisture deficiency, erosion hazard. Subclasses are indicated by lower-case letters with mnemonic significance, e.g. S2o, S2e, S3wx. There are no subclasses in Class S1.

2.3 ACTUAL PROCEDURES FOLLOWED

Figure 2 shows the different steps followed in present land evaluation studies.

Initial consultations took place as early as 1982 and were in fact reciprocal (between MIDENO and CNS). After several meetings the **Terms of Reference** were agreed upon in 1984.

The **inventory of present land use** carried out by CNS consists of land use maps 1/100 000 produced by aerial photo interpretation with limited field checking. Thus a full inventory of crops grown in individual fields and different areas was not made. However, much background information, collected by literature search and consultations, is included in the report (Hof **et al.** 1987).

The **soil resources inventory** carried out by CNS consists of a soil map 1/200 000 on which, per mapping unit, are indicated: dominant soil type, major associated soil type, surface rockiness, surface stoniness and slope class. The explanatory report contains detailed descriptions of mapping units and representative soil profiles, together with laboratory analyses data (Kips **et al.** 1987).

The **climatic inventory** consists of a description of the climate and its main agro-climatological characteristics in chapter 3 and climatic tables in Appendix I of this report. Temperatures, rainfall and length of growing season are shown on the climatic map. The locations of the weather stations listed in Appendix I are shown in Figure 4.

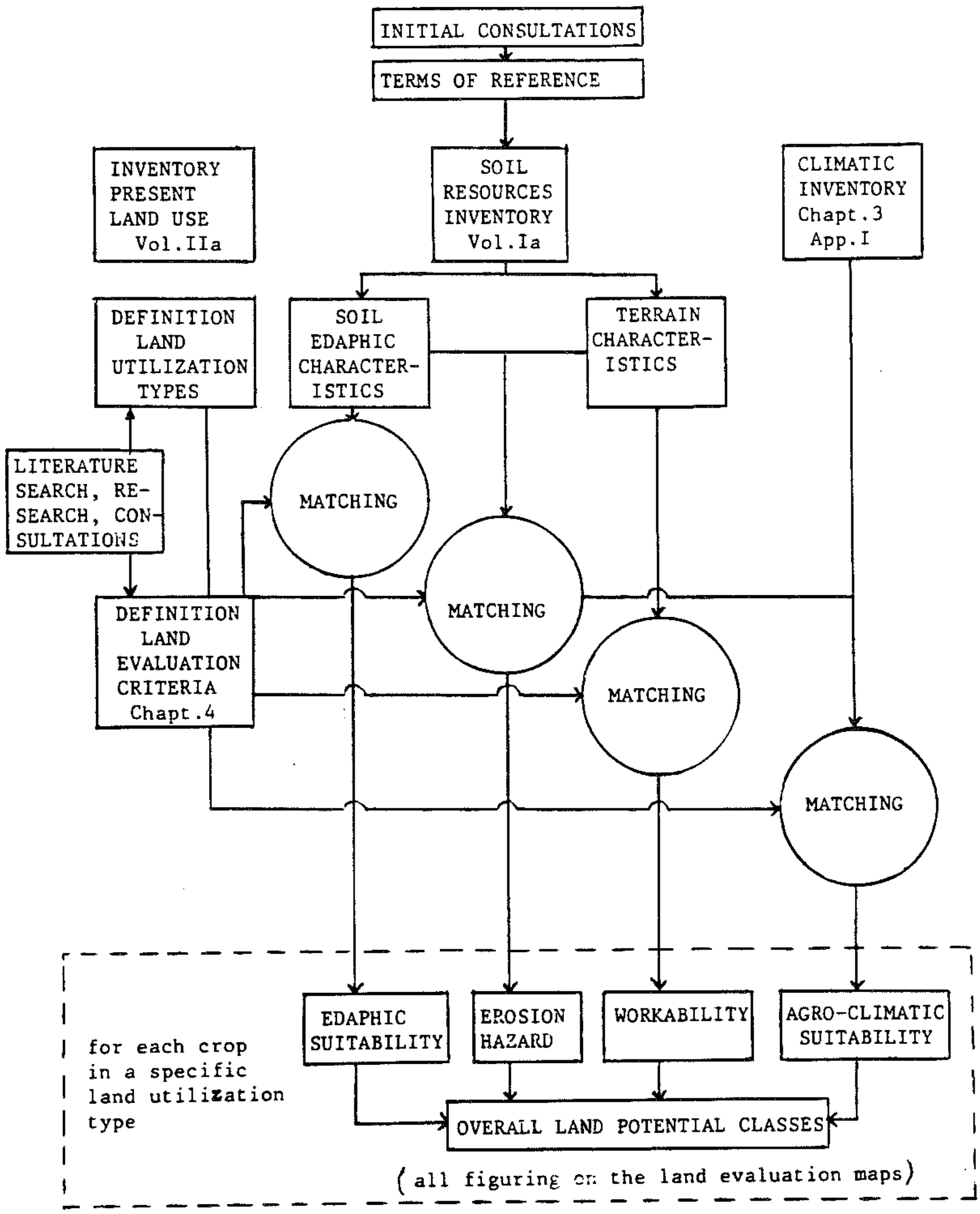


Figure 2 Structure of the land evaluation approach

The **land utilization types** are described in chapters 5 to 9 for each LUT for which the lands have been evaluated in detail. In the paragraphs on crop/land use requirements of these chapters, further specifications and assumptions are discussed, narrowing the variations which exist within LUTs further down, thus defining better for which cultivation and management practices the evaluation is done.

In chapter 4 the **land evaluation criteria** are discussed in general, indicating how they were derived, their precision, the units in which they are expressed, etc. In chapters 5 to 10 the applied requirements for specific crops and land uses in specific LUTs are presented in tables together with a brief elucidation where deemed useful.

The **matching** of land characteristics with the requirements of each crop or group of crops within each LUT is done stepwise as outlined in the diagram in Figure 3, which shows as an example the procedures followed for oil palm. For other crops and land uses somewhat different criteria may apply.

- The lowest suitability rating given to one or more land characteristics per land quality determines the overall suitability rating of each land quality (**'law of the minimum'**). For instance, ratings S1 for rooting depth, S3 for depth top stoneline, S3 for % coarse fragements and S1 for texture results in an overall rating S3 seeing the rooting conditions.

- Overall edaphic suitability, again following the 'law of the minimum', is determined by the land qualities rooting conditions, oxygen availability, nutrient retention and reserves, and toxicities.

  Appendix II summarizes in tabular form the edaphic suitabilities and main limitation of all soil types as evaluated for the main crops and land uses.

- The **symbols in the mapping units** on the land evaluation maps are built up from four individual codes, from left to right:

  - a number indicating the degree of climatic limitation,
  - a capital letter indicating the degree of soil (edaphic) limitation,
  - a small letter indicating the degree of limitation posed by erosion hazard,
  - a number indicating the degree of workability limitation.

The most severe limitation(s) is underlined and determine(s) the overall land suitability of the mapping unit. This is further demonstrated in the legends in chapters 5 to 9.

The step from individual soil types and tracts of land to combinations per mapping unit needs some further explanation. The mapping units on the soil maps are not pure units but contain combinations of dominant and subordinate soils, slope classes and surface stoniness classes. Therefore, when evaluating mapping units as a whole, these mapping units will also show combinations of edaphic suitabilities, erosion hazard and workability.

Edaphic suitability codings on the land evaluation maps were derived from the matrix (shown adjacent) presenting all theoretically possible combinations of edaphic suitabilities of dominant and subordinate soil types.

edaphic suitability dominant soil \ edaphic suitability subordinate soil	S1	S2	S3	N1	N2
S1	A	B	C	G	H
S2	D	E	F	I	J
S3	K	L	M	N	O
N1	P	Q	R	V	W
N2	S	T	U	X	Y

For ranking in overall potential classes these codes were grouped as follows:

I	A
II	B, C, C, E, F
III	G, H, I, J, K, L, M
IV	N, O, P, Q, R, S, T, U
V	V, W, X
VI	Y

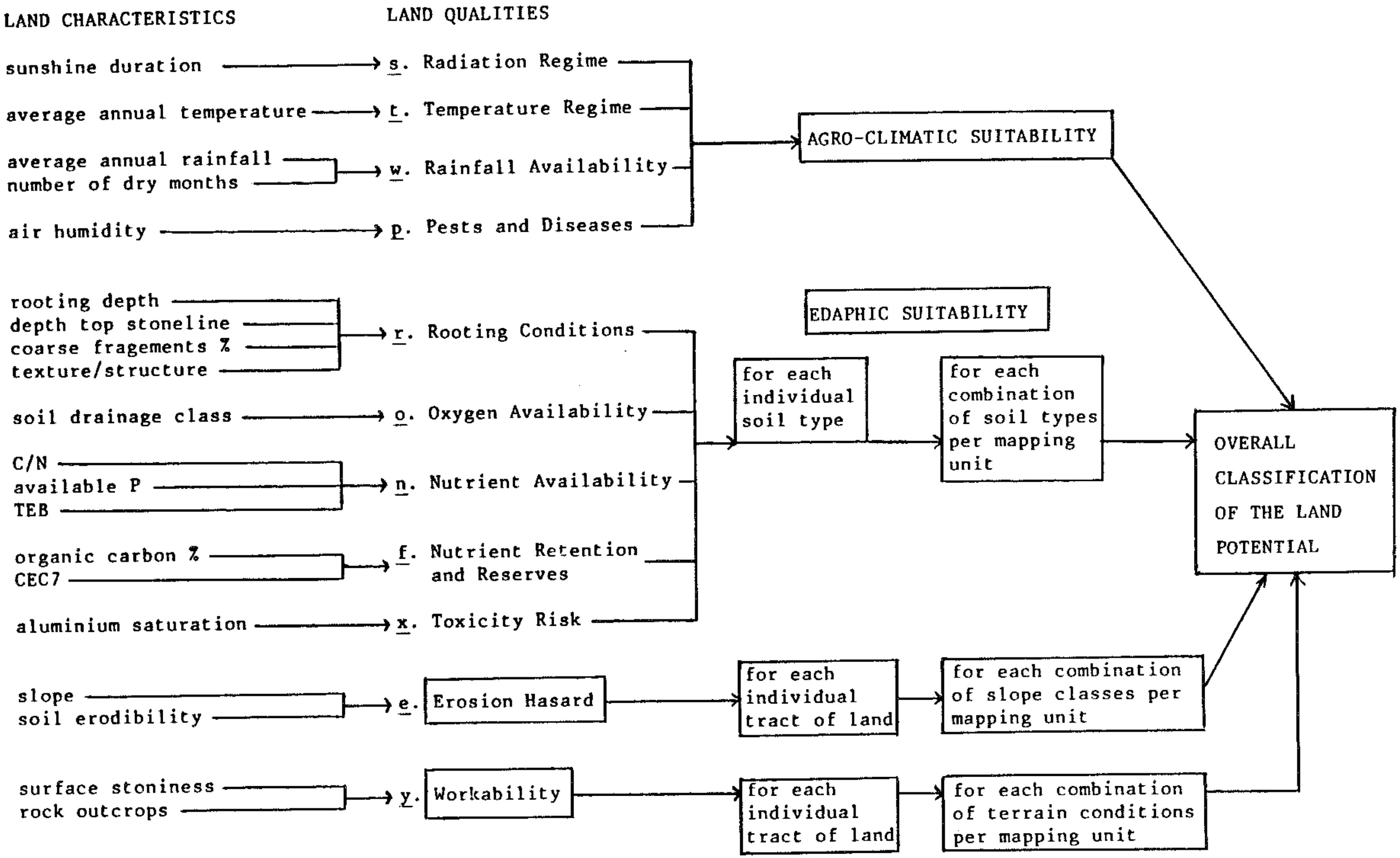
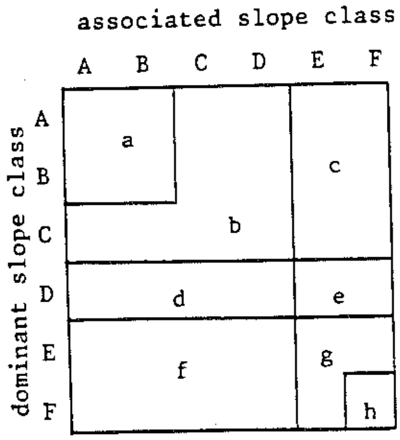


Figure 3 Steps in land evaluation

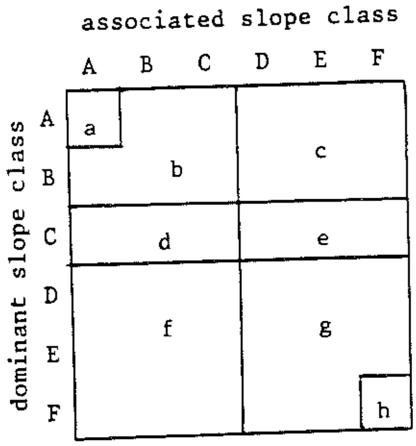
Erosion hazard codes were derived using the following matrices:

MAIZE

soils on basalt and trachyte

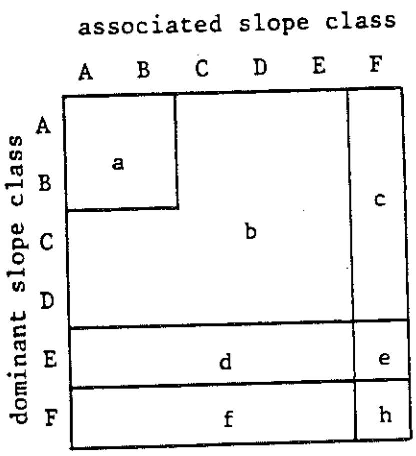


other soils

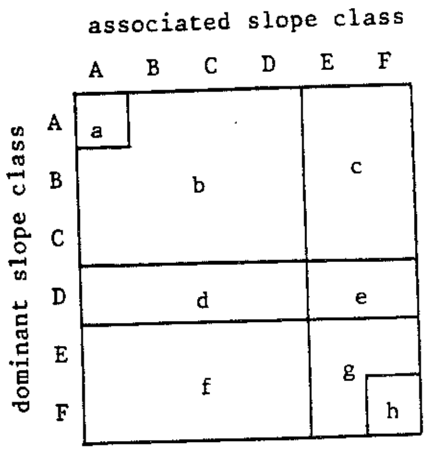


COFFEE, OIL PALM

soils on basalt and trachyte



other soils



(Slope class symbols as on the soil map.)

For ranking in overall potential classes these codes were grouped as follows: I-a; II-b; II-c,d; IV-e,f; V-g; VI-h

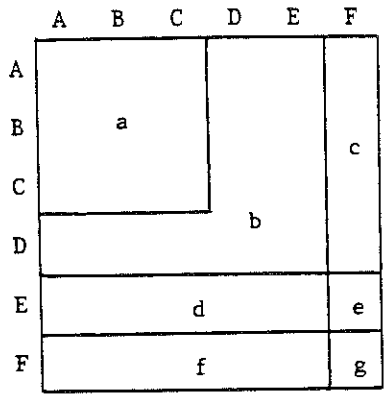
Workability codes were derived using the following table:

code	surface stoniness class	surface rockiness class
1	-	-
2	a,b,c,d	1
3	e,f,g,h	2
4	-	3,4

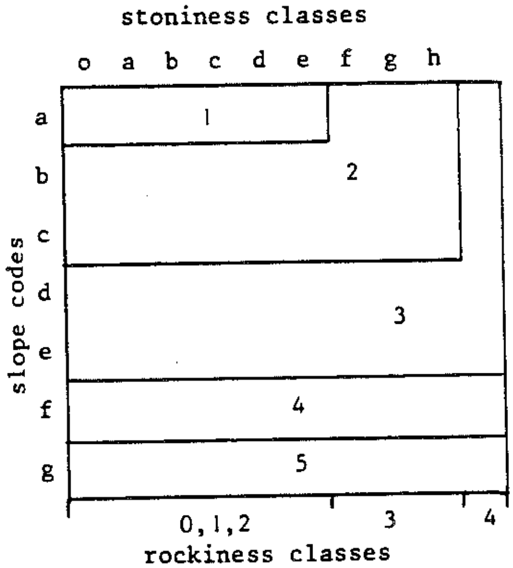
(Surface stoniness and rockiness class symbols as on the soil map.)

The workability codes were ranked as follows in overall potential classes: I-1; II-2; II-3; VI-4.

The approach for **land evaluation for extensive grazing** is somewhat different. In the first place no currently unsuitable lands were distinguished and overall potential classes could be reduced to V instead of VI classes. Secondly, **terrain accessibility** was assessed from slope class, surface stoniness and surface rockiness. First symbols are given to combinations of slope classes:



Subsequently accessibility codes are derived using the following diagram:



Ranking of the accessibility codes in overall potential classes is as follows: I-1; II-2; III-3; IV-4; V-5.

Chapter 10 gives an outline of the proposed procedures to evaluate the lands for a number of selected crops and timber/firewood species.

Chapter 3

CLIMATIC INVENTORY

Appendix I contains respectively:

- a list of meteorological stations with their location, altitude and type of climatic data available;
- a map showing the location of the meteorological stations in the province;
- climatic data tables for the main weather stations:
- rainfall data for all known rainfall stations;
- temperature data for all known temperature stations.

An agro-climatological map, showing main rainfall, temperature and growing season patterns, is included at the back of this report.

Data were obtained from various sources, such as the National Meteorological Service at Douala and the Provincial Meteorological Service at Bamenda, Annual Reports of IRA Bambui Station, the Cameroon Development Corporation, MIDENO and various publications listed in the bibliography. However, many more stations exist, run by mission posts, hydrological services, agricultural posts, etc. For instance, for many stations mentioned in Hawkins and Brunt (1965), no recent data could be obtained. A thorough search, compilation and interpretation of data by a team of agro-meteorologists will undoubtedly be rewarding.

For a few stations outside the province, data are included which help interpretation for areas with sparse or no data. These are Mamfe, Nkoundja and Abong (opposite Abonshie on the Nigerian border; data Nigerian Meteorological Services). Penman reference crop evapotranspiration (ETo) was calculated following the method proposed by Doorenbos and Pruitt (1977).

3.1 CLIMATIC CLASSIFICATION

According to Köppen's classification the areas below about 1500 m have an Am climate, i.e. a tropical rainforest (monsoon) climate, with a short dry season and a mean temperature of the colder months above 18°C (Strahler 1969). Above about 1500 m the climate would classify as a Cwb climate, i.e. a climate with mean temperatures below 18°C in one or more month, and a warm summer with mean temperatures below 22°C in the hottest months and with a dry winter (Griffiths 1972).

3.2 RAINFALL AND LENGTHS OF GROWING PERIODS

Amounts of average annual rainfall vary from less than 1700 mm in Ndop plain to over 3000 mm in highland areas with north-west exposition.

The dates of the onset and the end of the rainy season vary over the Province, which can be largely explained by orographic influences and by the humidity of the air masses to which the different areas are exposed. In accordance best planting dates, the length of the climatic dry season and the length of the growing period (with variations depending on soil type) vary somewhat. Three broad zones can be distinguished, separated by main watersheds (see also the agro-climatological map):

Zone I : exposed to the west, under the influence of year-round humid air masses:

- onset of rains early March
- end of rains end November
- planting maize first half of March
- 2½ to 3 climatic dry months: December through February
- length of growing period 275-300 days

Zone II : exposed to the north, under the influence of dry air masses towards the onset of the rains, of humid air towards the end of the rainy season:

- onset of rains mid-March
- end of rains end November
- planting maize second half of March
- 3 to 3½ climatic dry months: December to mid-March
- length of growing period 250-275 days

Zone III : Ndop plain, virtually enclosed on all sides by higher lands, with predominantly local circulation patterns:

- onset of rains mid-March
- end of rains early November
- planting maize second half of March
- 3½ to 4 climatic dry months: mid-November to mid-March
- length of growing period 225-250 days

The boundary between Zones II and III is not very well defined due to insufficient data. In Mbaw plain, rainfall data are known only for Ntem (Hawkins and Brunt 1965), which tend to the Zone II pattern. The limit is also diffuse on the high plateau north of Kumbo.

It should be borne in mind that large local anomalies in rainfall exist, especially with exposition and topography, notably along escarpments. Along escarpments and at higher elevations the dry season is generally less severe due to fog, dew and, in the latter case, also lower temperatures which reduce evapotranspiration.

3.3 TEMPERATURES

In the Province average annual temperatures are closely correlated with altitude. It is estimated that the following relationship exists:

$$T = 27 - 0.005A \ ^{o}C$$

in which T = average annual temperature
A = altitude in metres

Using this formula and contour lines on topographic maps, the temperature pattern in the NWP was established and presented on the agro-climatological map.

Important anomalies exist, mainly linked to topographic position. Stations in valleys or at the foot of escarpments tend to have somewhat lower values than those on plateaus or ridges, due to local circulation patterns. Also high rainfall areas tend to have somewhat lower temperatures. Temperatures show little variation over the year: 2 to 3.5°C yearly amplitudes with maxima in March and minima in July-August.

Average temperatures for the growing season hardly differ from the average annual temperatures.

Between stations daily amplitudes vary from 8 to 15°C. Again these variations are linked to topographic position with larger amplitudes in valleys and at the foot of escarpments as against stations on plateaus or ridges. Diurnal variations are slightly higher during the dry season than during the rainy season.

3.4 MISCELLANEOUS CLIMATIC DATA

For **relative humidity** data are too scarce to establish patterns over the Province. Average annual values are around 65 percent, highest (over 85 percent) in the wettest months, lowest in the dry season, in some areas as low as 45 percent.

Zone I on the agro-climatological map is expected to be the most humid, Zone III the least.

Average annual rainfall is remarkably reliable with standard deviations of about 10 percent only. The onset of the rains is, however, erratic, and can vary from early February to early April. The end of the rains is more abrupt and between years the variation is generally not more than two weeks.

The **length of the growing period** is taken for annual crops planted at the start of the rainy season. Perennial crops, of course, also benefit from each rain during the dry season and, depending on soil conditions, may benefit from deeper water supplying soil layers.

Solar radiation (sunshine hours) varies from about 1900 (Bambui) to 2500 hours per year (Nkoundja) and is closely related to rainfall amounts and patterns: lowest radiation in Zone I, highest in Zone III.

Values are very low at the height of the rainy season, especially in Zone I where, for instance, Bambui has only about 70 hours of sunshine during August, as against about 130 hours for Nkoundja, representative for Zone III.

Solar radiation is highest in the dry season, though tempered by Harmattan dust. The brightest sunshine is between showers in the first and last months of the rainy season. The daily radiation regime is of 'short day' pattern.

Wind speeds are low, on an annual basis between 1 and 5 metres per second, with higher speeds during the day than at night. Locally somewhat higher speeds may occur in relation to local circulation patterns, such as valley winds. During short periods very high speeds may occur as squalls during thunderstorms.

Penman evapotranspirtion (ETo) could be calculated for only two stations: Bamenda and Ndu. For these stations ETo is around 1500 mm per year, with highest values in the dry season. At Bamenda ETo exceeds rainfall from November through March, at Ndu from November through April. One half ETo exceeds rainfall from November through February at both stations. Highest ETo values are expected in Zone III, lowest in Zone I.

3.5 AGRO-CLIMATOLOGICAL IMPLICATIONS

The growing period is sufficiently long for a number of crops to be planted twice a year. Growing conditions, however, differ between the first and second half of the growing period.

In the course of the first half of the growing period (March to July/August):

- average temperatures decrease somewhat;
- daily temperature amplitudes decrease somewhat;
- sunshine decreases;
- rainfall increases;
- air humidity increases.

The first half of the growing season is further characterized by:

- the advantage of the nitrogen flush at the onset of the rains;
- risks of dry spells at the beginning of the growing period interfering with germination and seedling establishment. Replanting can be done (common local practice), but generally gives lower yields;

- soils are humid (but sometimes wet) at harvest time, an advantage for instance to harvesting of groundnuts on the predominantly rather heavily textured soils;

- risks of crop damage by excessive wetness towards harvest time.

NOTE: Planting of most crops is generally at the onset of the rains, i.e. after the first important rains in March, sometimes as early as the end of February. Early planting has the advantage that the crops can profit longer from the favourable radiation and moisture conditions during the first months of the growing period, before these deteriorate towards July/August. This advantage generally offsets the disadvantages which dry spells may pose early in the growing period.

In the course of the **second half of the growing period** (August/September to December/January:

- average temperatures first rise, decreasing after October
- daily temperature amplitudes increase somewhat
- sunshine increases
- rainfall decreases
- air humidity decreases.

The second half of the growing period is further characterized by:

- the absence of dry spells;

- the absence of a nitrogen flush (though crops may profit from nitrogen accumulated by leguminous crops grown during the first half);

- often excessive wetness of the soil at planting time leading to water-air ratios which are unfavourable for germination of some crops, such as maize, while other crops, such as sorghum, tolerate or even prefer these conditions;

- high incidence of air- and soil-borne pests and diseases at planting time (but decreasing towards harvest time);

- dry soil at harvest time.

NOTE: Planting time of the second crop varies widely from August to end October, largely depending on crop type. Some 'dry season crops' are planted even later and watered. These are also planted in areas with shallow groundwater (valley bottoms, footslopes, etc.).

Chapter 4

LAND EVALUATION CRITERIA

In order to carry out these land evaluation studies a meaningful set of criteria had to be chosen. The retained land qualities and the land characteristics by which they are determined were chosen as a function of specific crop and LUT requirements, the particular ecological conditions in the survey area and the available data base, i.e. the agro-climatological information and the information provided by the soil survey report and map. The precision of the latter information is largely determined by its detailed reconnaissance character. Land evaluation criteria were defined according to the available literature, by consulting specialists and by using field observations.

This chapter lists all land qualities and characteristics that were considered in the evaluation and the crops and LUTs to which they were applied. For the actual rating classes per land characteristic, land quality and overall land potential ratings, reference is made to the specific crop and LUT requirement tables in chapters 5 to 10 and to chapter 2 for the methodology applied*.

s - Radiation regime

- n/N (5 driest months): Arabica, Robusta coffee
- n/N development : maize
- n/N maturation : maize
- Sunshine duration : oil palm

n/N is the ratio of the actual number over the theoretically possible number of hours of bright sunshine.

Sunshine duration is the average annual number of hours with bright sunshine.

t - Temperature regime (climatic hardships for extensive grazing)

- Average annual temperature in °C: all crops and LUTs

In practice average annual temperature classes were in some cases adapted to corresponding minimum and/or maximum temperatures by taking the average daily temperature amplitudes into account.

w - Rainfall availability (water availability for maize)

- Average annual rainfall in mm: Arabica, Robusta coffee, oil palm
- Dry months: with the exception of maize, used for all crops and LUTs, in particular perennials
- Length of growing period: maize

Average annual rainfall: no comments (see chapter 3 for description of rainfall distribution over the year and reliability).

Dry months concern the climatic dry months, i.e. those months when rainfall is less than half the potential evapotranspiration. In the case of the NWP these are the months with less than about 60 mm rainfall. Unfortunately, complete records were not available on 10

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* Rules for reading crop requirement and other rating tables are as follows:

+20 means 20 and more
-20 means less than 20
cSL & -LS means cSL to and including LS

or 7-day periods to determine the length of the dry season more precisely. In chapter 10 the length of the dry season is also evaluated for annual crops. This criterion serves there more as an indication of excessive wetness and related risks of pests and diseases and, possibly, low radiation.

For maize, the length of growing period was applied in classes as defined in FAO (1978). Of the criteria found in the literature, this seemed the best adapted to the NWP conditions and maize cultivars.

p - Pests and diseases

- Air humidity: all crops as far as criteria could be found
- Tse-tse occurrence: extensive grazing.

Air humidity concerns average relative humidity percentage on an annual basis, or for particular periods of the year (maturation stage of maize). As mentioned earlier, limitations posed in chapter 10 on annual crops by lengths of growing season can be used as an indication of risks of pests and diseases where relative humidity data are lacking.

r - Rooting conditions

- Effective soil depth in cm: all crops
- Depth top stoneline in cm : maize, Arabica, Robusta coffee, oil palm, pasture
- Coarse fragment content : all crops and LUTs
- Texture/structure : all crops and LUTs

Effective soil depth is considered to be limited by bedrock, water table, hardpans and layers with more than 60 percent coarse fragments. Exceptions to the latter criterion are Andosols and dystric and humic Cambisols on basalt, on which many crops appeared to perform reasonably well despite very high coarse fragment contents.

Stonelines feature prominently in many of the NWP soils. In chapter 10 an evaluation of stonelines in combination with coarse fragment content is attempted. However, the results are not fully satisfactory.

Coarse fragment content is expressed as a percentage of the whole soil volume.

Classes of texture and structure were applied as shown in chapter 10.

o - Oxygen availability soil drainage classes

n - Nutrient availability

The land characteristics to be considered for this land quality have been extensively debated. Finally, the following were retained:

- C/N : the ratio of organic carbon over nitrogen percentage
- available P: available phosphorus
- TEB : total of the exchangeable bases (Ca + Mg + K)

As most of the NWP soils are high in organic matter and nitrogen content, it was thought more meaningful to use the C/N ratio as an indication of nitrogen availability than to evaluate organic carbon and nitrogen percentages separately.

Available P with the Kurtz-Bray II method.

As K is more or less well balanced with the other bases in most soils of the survey area, the total of exchangeable bases gives a good indication of potassium availability.

f - Nutrient retention and reserves

- Organic carbon %
- CEC7 : cation exchange capacity at pH7 (by ammonium acetate)

Soil organic matter (humus) contains on average 58 percent organic carbon (C), 5 percent nitrogen (N), 0 to 5 percent phosphorus (P) and 0.5 percent sulphur (S) (ILACO 1981). Thus organic matter is a major source of natural soil fertility. It also contributes considerably to the capacity of the soil to retain bases (CEC).

It has been difficult to choose between CEC7 and ECEC, i.e. the effective cation exchange capacity at the soil pH. As ECEC values for all soils were unavailable, and correlation between CEC7 and ECEC appeared poor, and because CEC7 seemed to differentiate soils better according to their actual performance in the field, it was decided to use CEC7. It should further be noted that CEC7 gives an indication of the potential rise in CEC by liming.

Remark: In chapter 10, for selected crops and timber/fuelwood species, nutrient availability and nutrient retention and reserves were evaluated together under the denomination nutrient status.

x - Toxicities

- Aluminium saturation: all crops and LUTs

On the predominantly acid soils of the NWP a number of toxicities can be expected to occur, notably caused by high levels of aluminium, manganese and/or iron. As data on manganese were unavailable, only aluminium was evaluated. For those soils for which aluminium was not analysed, correlations found between soil pH and aluminium saturation were applied as follows:

Aluminium saturation	pH	
	Soils on basalt or volcanic ash	Other soils
-10%	+5.0	+6.0
10-60%	4.5-5.0	5.0-6.0
over 60%	-4.5	-5.0

e - Erosion hazard

A great number of factors feature in soil erosion by water. The Universal Soil Loss Equation (USLE) (Wischmeier and Smith 1978) groups these under six headings in the formula A = R x K x L x S x C x P, where:

A = soil loss (tons/ha/year)
R = rainfall factor
K = soil erodibility factor
L = length of slope factor
S = slope gradient factor
C = crop management factor
P = erosion control practices factor

This expression gives an indication of which factors are to be considered of main influence in determining the amount of soil that is being eroded. The formula does not express the decline in soil productivity resulting from erosion. By taking soil depth into account and by comparing fertility properties of topsoil and subsoil, an indication could be obtained of the fertility decline to be expected. This was, however, not done in the present evaluations. In this paragraph successively the individual factors in the USLE equation and factors contributing to soil fertility decline are discussed.

Rainfall Erosivity

Rainfall erosivity, i.e. the potential of rain to cause erosion, is strongly correlated with rainfall energy, notably during prolonged high rainfall intensities.

For the Eastern United States statistically best correlation was found by a factor R which is the product of the rainfall energy times its maximum 30 minutes sustained intensity (Wischmeier and Smith 1965). Field experiments show that this R factor cannot be applied straight away under different rainfall and soil conditions elsewhere in the world. In equatorial Africa generally, high intensity rainfall makes up a much higher proportion of total rainfall and most soils have developed much higher threshold values (before erosion becomes significant) than in the area studied by Wischmeier and Smith. Experimental data at Barombi Kang near Kumba (Hof 1982) show best correlation of soil erosion with KE over 25 mm (Hudson 1975), i.e. the kinetic energy of all rain falling with an intensity above 25 mm/hour. This is followed by total rainfall energy, EI30, and total rainfall respectively. These data, however, require confirmation by further experimentation. Reviews by other authors (for instance El-Swaify **et al.** 1982; Bergsma 1981) come to similar conclusions.

A number of rainfall stations in the North West Province have automatic rainfall recorders: Bamenda, Ndu and, most probably, WADA Wum and Santa, to name a few. However, these records have never been analysed for rainfall erosivity. The nearest station is Dschang IRA, where Valet (1985) estimated the following EI30 values:

1968 : 1.357 T/ha/year for 1800 mm rainfall
1969 : 1.800 T/ha/year for 2160 mm rainfall

These values correspond remarkably well to the range of about 1200 to 2000 T/ha/year for the North West Province as shown on the FAO iso-erodent map of West Africa (FAO/UNDP/ Unesco 1979).

Over the Province rainfall erosivity is expected to vary with the yearly annual rainfall pattern, but probably not proportionally, as much of the precipitation in high rainfall areas can be attributed to low intensity orographic rains against mountain ranges and escarpments.

In view of the scarcity of information on variations in rainfall erosivity over the Province, an iso-erodent map could not be drawn up.

Soil erodibility

Here the term 'soil erodibility' is used in its strict sense, i.e. referring to soil mechanical properties, such as soil detachability, infiltration capacity, etc., excluding terrain characteristics such as slope gradient and length.

Again very little experimental quantitative information is available. Virtually all soils are out of range of existing erodibility nomographs, primarily due to high organic matter content. Nevertheless, based on field impressions, an attempt was made to develop a rating scale, which can read as a key, to group the soils of the North West Province in erodibility classes (Table 1). Very tentatively USLE ratings have been added. Table 1 could be used in more detailed land evaluations. For the actual land evaluations only a distinction was made between soils on basalt and trachyte as less erodible than other soils, where thus steeper slopes can be accepted for specific uses.

Slope length

The limited detail of the soil map does not allow the use of slope length as a factor in determining soil erosion hazard.

Slope gradient

The effect of slope gradient on soil erosion has an exponential nature (Smith and Wischmeier 1957). Therefore the slope classes of increasing range used here on the soil map are convenient for the purpose of rating the influence of slope gradient on soil erosion.

Table 1 KEY FOR SOIL ERODIBILITY RATING

	Topsoil characteristics	Erodibility rating	Tentative K factor
1.	Soils on basalt and trachyte with over 5% organic carbon	VL (very low)	-0.02
2.	Soils on basalt and trachyte with less than 5% organic carbon; other permeable soils (including ashes) with over 5% organic carbon	L (low)	0.02-0.05
3.	Other permeable soils with 0.8 to 5% organic carbon or over 35% coarse fragments; other permeable well structured soils with clayey texture	M (medium)	0.05-0.12
4.	Other permeable soils with CL, SCL, SiCL, L, SL, LS or fS texture; poorly structured clayey soils	H (high)	0.12-0.30
5.	Other permeable soils with very fine sand, silt or silt loam textures; soils sensitive to surface sealing, or having shallow impermeable layers	VH (very high)	0.30-0.70

Crop management and erosion control practices

For practical reasons, as crop management and erosion control practices are intricately linked in the Province, these factors have been considered in combination and are implied in the acceptable slope classes for each use. Table 2 regroups the main types of vegetation and types of land use in the area in classes indicating the degree of erosion hazard posed by crop management and erosion control practices together. Tentatively a corresponding CP factor for the USLE equation has been added.

Table 2 EROSION HAZARD RATING CROP MANAGEMENT AND EROSION CONTROL PRACTICES

	Type of vegetation or land use	Erosion hazard rating	Tentative CP factor
1.	Natural forest and secondary vegetation	EL	0.001
2.	Good grassland and savanna; eucalyptus plantations; oil palm groves; tea	VL	0.01
3.	Oil palm plantations; mulched shaded coffee	L	0.1-0.2
4.	Overgrazed grasslands; unmulched coffee; mulched mixed annual crops on ridges parallel to the contours on fields with limited downslope length	M	0.2-0.3
5.	Unmulched mixed annual crops on ridges parallel to the contours	H	0.3-0.5
6.	Other mixed and monocultures of annual crops without mulch	VH	0.5-1.0

REMARKS: Heated discussions continue on the effect of downslope ridging, which is a common practice, especially on steep slopes. It has the advantage that the ridges cannot break during excessive rains, which would result in catastrophic erosion. Additionally, runoff water is channelled and cannot flow together, thus avoiding more serious rill and gully formation. Also waterlogging between ridges is thus avoided. Erosion of the fertile topsoil, which is accumulated in the ridges, will be by splash. Soil particles entering the furrows risk being transported far downslope if runoff in the furrows occurs simultaneously.

Soil productivity decline resulting from erosion

Especially in the soils of the wet tropics, nutrients for plant growth are mainly concentrated in the topsoil, i.e. the first 10 to 30 cm of the soil profile. Removal of the topsoil generally results in a striking decline in crop growth and yields. Field trials at Bansoa in the Western Highlands, in which layers of topsoil were removed before planting, demonstrate this very clearly (Mahop 1986). Of course such experiments exaggerate fertility decline as under gradual rainfall erosion simultaneously a number of processes take place in the soil, such as the accumulation of organic matter and nitrogen, structuration, etc.

Another factor influencing soil productivity and the possible alternatives in crop choice is soil depth. Under cultivation, accelerated erosion proceeds at a faster rate than soil formation in the subsoil. Thus soil depth is reduced by erosion. In determining potential soil erosion hazards it is recommended that detailed follow-up studies take into account:

- soil depth
- depth to a very unfavourable layer, contrasting to the topsoil, such as a layer with more than 60 percent aluminium saturation, more than 60 percent coarse fragments and/or an effective CEC of less than 4 meq/100 g soil.

Summary

In summary, to assess erosion hazard in present land evaluation rainfall erosivity, soil erodibility, slope gradient and crop management/erosion control practices were considered, of which soil erodibility and slope gradient are explicitly presented in the crop tables and the others tacitly implied by the accepted slope classes per parent material and per crop/LUT. Criteria for more detailed follow-up studies are included in this paragraph.

y - Workability

Except for mechanized LUTs and LUTs with animal traction, slope class has always been more severely rated for erosion hazard than for workability, and is therefore in most cases not included to evaluate workability. Also soil texture/structure were rated under rooting conditions and not reconsidered under workability.

For all crops, the following were evaluated: surface stoniness; surface rockiness.

Stoniness and rockiness classes are explained in the legend of the soil map. As in the NWP rockiness generally goes together with high degrees of surface stoniness and the soil map only shows the more severe case of either rockiness or stoniness, it was decided to rate rockiness class 3 more severely than generally found in the literature.

d - Availability of drinking water in dry season

- distance to permanent streams : extensive grazing

This criterion was tried out in the NWP. Practically in the whole province permanent streams are within acceptable reach. The proposed classes could, however, not be mapped separately at the 1/200 000 mapping scale, but could be applied in more detailed studies.

a - Accessibility to cattle

Applied to the extensive grazing LUT only:

- slope class
- rock outcrop class
- surface stoniness class
- present land use
- load supporting capacity.

For explanantions see chapter 9.

Chapter 5

EVALUATION OF THE LANDS FOR LOW INPUT MAIZE

5.1 LAND UTILIZATION TYPE

In this land evaluation maize is treated as an example of an individual crop grown in mixed cropping systems as described below.

Crop: Maize cultivars covering a wide altitude range, including Ekona yellow and Ekona white at lower elevations, and Kitali Synt. Two descendants, cocoa white, MLC, and Bacao yellow varieties at higher elevations.

Production method: Rainfed production, no irrigation or water importation, multiple cropping systems, dominantly mixed and row intercropping.

Capital intensity: Low.

Market orientation: Subsistence production, surpluses may be marketed.

Labour intensity: High, including uncosted family labour.

Technical knowledge and attitudes: Farmers have an average schooling level of 4 years primary school and are for the most part willing to adopt improved methods where the benefits can be clearly demonstrated.

Power source: Manual labour with hand tools (mainly hoe and cutlass).

Technology employed: Mainly local cultivars; no, or markedly insufficient, fertilizer; no chemical pest, disease and weed control; fallow periods and limited use of organic manure, such as coffee hull, for nutrient accumulation.

Size and shape of farms: Average size of holdings is 2.5 ha, with variations from less than 1 to 7-10 ha, commonly fragmented, with an average plot size of 0.9 ha. If these farm sizes include land under coffee is not clear from the employed source (McHugh 1983), where no mention of coffee is made. For Arabica coffee average farm size is estimated at 1.1 ha with an average plot size of about 0.5 ha (MIDENO 1984).

Land tenure: Most of the land is considered as belonging to the villages, but holders generally have hereditary rights to use their land.

Infrastructure: Based on the 'Community Development Project Map' (MINAGRI 1984) and field experience, the total length of the **road system** in the Province is estimated at between about 2200 and 2500 km, which corresponds to a density of 0.13 to 0.14 km^2. Most of these roads are concentrated in the southern two-thirds of the Province. Of these roads only about 900 km can be considered as all-weather roads, i.e. impracticable during short periods of heavy rain only. Tarred through-roads are limited to the main road from Santa at the Provincial border to the airport near Bafut, a total of about 40 km. An extensive programme of road upgrading and road construction is underway.

Advisory services and other agricultural facilities were until recently mainly cash crop (coffee) oriented and based in a limited number of towns and villages only. Presently agricultural extension services and demonstration centres are rapidly expanding to all major villages, even in remote areas, and offer packages for a wider range of crops, including major staple foods.

At village level **cooperatives**, often of women, trying to improve marketing of surpluses, are common.

Cropping characteristics and cultivation practices: The cropping systems can best be described as multiple cropping systems with **mixed intercropping**, i.e. two or more crops are grown simultaneously with no distinct row arrangement, and **row intercropping**, i.e. growing two or more crops simultaneously with one or more planted in rows.

Among the wide variety of annual **crops associated with maize**, the more important ones are groundnuts, cowpeas, beans, yams, cocoyams, cassava, Irish potato, sweet potato as staple foods, with, as main vegetables, huckleberry (**Solanum nigrum**), various types of bitter leaf, okra (**Hibiscus esculentus**), cabbage, pumpkins and egussi (**Cucumeropsis Mannii**). Sugarcane and some perennials like bananas, plantains, oil palm, raphia and fruit trees may be included. This list can be further extended with the less abundant annual crops presented in Tables 5.4 and 5.5 in 'Explanatory Note to the Land Use Map of North West Province (Hof **et al.** 1986). **Crop mixtures and abundance** vary mainly with altitude: mainly maize based systems above about 800 m, rootcrop based systems at lower elevations. Besides cultural (for instance sorghum in Fundong-Kom area) and individual preferences, soil type and distance to villages and homesteads play a role in crop choice.

Cultivation intensity can be estimated using the cultivation factor, i.e. the number of years under cultivation as a percentage of the total cultivation/non-cultivation cycle, expressed as R, in percent.

Using the extremes in estimates made by different authors (Hof **et al.** 1987) of 2-10 years cultivation with 3-7 years fallow, R is estimated to range from 20 to 90 percent, with values between 40 and 50 percent dominating. The lowest intensities are generally in areas with poorest soils, with low population densities and farthest from villages.

Most crops are cultivated on ridges, on sloping terrain dominantly parallel to the contours, on very steep land also in a downslope direction. Also tied ridging, cultivation on mounds and on the flat occur.

Various techniques of **land clearing** exist:

- burning followed by ridging, especially common on less intensively used lands with grassy vegetation;
- clearing followed by ridging, incorporating crop and vegetation residues; in some cases, however, crop residues are removed and burnt outside the plot;
- after a first crop, generally residues are dumped between the old ridges and new ridges are formed over these residues. In some systems the residues are then set on fire.

Moderate to high standards prevail in **farm management**, such as timely planting (hand-` weeding, harvesting, etc. There is limited use of organic manures, such as coffee hull and other crop residues, mainly near homesteads and villages.

Material inputs: Low, no significant use of purchased inputs such as artificial fertilizers, improved seeds, pesticides or machinery (traditional farming); limited use of organic manures, such as coffee hull and other crop residues, mainly near homesteads and villages.

Yields and produce: For the first cropping season, maize yields in this LUT are estimated at about 1.8 t/ha for 1983 (MIDENO 1984), at an average plant density of 20 250/ha; 12.5 percent of the farmers applied fertilizers and produced as an average 2.7 t/ha, as against 1.7 tons for non-fertilized fields. It should, however, be taken into account that those applying fertilizers also tend to use improved maize varieties more, to plant at higher densities and to weed more often, all factors contributing to higher yields.

5.2 CROP REQUIREMENTS

As in the NWP maize is produced for local consumption without competition from elsewhere in the country or world, ratings of some land qualities, such as excess rainfall, humidity and radiation, have been somewhat tempered. This approach is to be reconsidered if, in future, maize from elsewhere, for instance mechanized maize farms, threatens to become competitive. It should also be noted that the cultivars presently in use have well closed cobs, giving good protection from rainwater and pests.

Table 3 presents the criteria used to evaluate the lands of the NWP for maize without application of fertilizers. The table is for application to the first cropping season, i.e. immediately after the dry season, which is the preferred period for maize in the NWP. To evaluate the second planting period, additional criteria should be considered such as:

- the total rainfall during the 30 days before planting (suggested ratings S1 = -60 mm, S2 = 60-120 mm, S3 = +120 mm) to evaluate oxygen availability during germination;
- possibly also criteria to evaluate better the incidence of pests and diseases.

In addition planting dates for the second period vary widely from August to October. Overall yields are generally much lower than for the first planting period, an indication that conditions are less favourable then for maize growth.

In the land evaluation for maize, the different cultivars have not been distinguished but a gradual range is assumed, including the local and improved varieties adapted to different altitude zones. In the future, detailed studies may be required to evaluate the lands for individual cultivars. It should also be kept in mind that breeding of maize varieties is continuing and that criteria for temperature, radiation, aluminium toxicity, etc., may have to be adapted in future.

Radiation regime

For n/N development the average of the period June-July was considered. The four weather stations in the Province with data have values ranging from 0.43 to 0.50. It is therefore assumed that this criterion can be classified as S1 for the whole Province.

For n/N maturation the average of the period June-July was considered. The range is 0.28 to 0.38, i.e. all in class S2. Koundja, outside the Province but representative for Ndop plain, is near optimal with a value of 0.44.

Temperature regime

The applied temperature extremes are those of presently known lowland cultivars for the maximum temperatures and of highland cultivars for the minimum temperatures. In practice, maize is seldom cultivated above 2200 m in the NWP.

Water availability

As growing season the whole rainy season is considered, and not just the first maize growing period. Virtually the whole Province is characterized by excess rainfall except Ndop plain and a minor area near the Nigerian border where this constraint is less serious. The excess rainfall not only reduces yields but also poses problems in drying and conservation of the product.

Pests and diseases

For the relative humidity during maturation the average for the period June-July has been applied. Data on relative humidity are scarce. Bamenda has a percentage of 82.5, Ndu of 85.7. Wada Wum has values which are too far out of range to be reliable. Also taking into account values for the surrounding stations of Banyo, Mamfe and Dschang, it

Table 3 LAND SUITABILITY RATINGS FOR MAIZE

Crop : Maize, planted at start of rainy season, without fertilizer
LUT : Low input in mixed cropping systems, rainfed
Area : North West Province, Cameroon

Land characteristics per land quality	Land suitability ratings S1	S2	S3	N1	N2
s - radiation regime					
1. n/N development	0.35-0.75	any	-	-	-
2. n/N maturation	+0.5	any	-	-	-
t - temperature regime					
1. Average annual temp.	18-32	16-18	14-16	-	-14
- corr. altitude NWP	0-1800	1800-2200	2200-2600	-	+2600
w - water availability					
1. Length of growing period	150-225	225-330 120-150	+330 100-120	-	-
p - pests and diseases					
1. Air hum. maturation	24-75	20-90	any	-	-
r - rooting conditions					
1. Rooting depth	+75	50-75	20-50	-	-20
2. Depth top stoneline	+50	-50	-	-	-
3. Coarse fragments av. % 0-75 cm or solum					
- Ando-/Dystr. & Hum. Cambisols on basalt	-15	15-60	+60	-	-
- other soils	-15	15-34	34-60	-	+60
4. Texture/structure (0-20)	C+60s & -SCL	C+60v cSCL & -SL	cSL & -LS	-	any
o - oxygen availability					
1. Soil drainage	W	MW,SE	SP,E	P drainable	any
n - nutrient availability (0-20)					
1. C/N	-12	12-17	+17	-	-
2. Available P	+20	7-20	-7	-	-
3. TEB	+12.0	5.0-12.0	-5.0	-	-
f - nutrient reten. & reserves					
1. Organic carbon % (0-20)	+3.0	1.2-3.0	-1.2	-	-
2. CEC7 (0-20)	+24	16-24	-16	-	-
3. CEC7 (at 50)	+16	5-16	-5	-	-
x - toxicities					
1. Al saturation (0-20)	-10	10-30	30-60	+60	-
e - erosion hazard					
1. Slope class					
- on basalt, trachyte	A,B	C	D	E	F
- others	A	B	C	D,E	F
y - workability					
1. Surface stoniness class	0	1,2	3,4	-	5
2. Rock outcrops class	0	1	2	-	3,4,5

can be assumed that relative humidity during maturation is fairly uniform over the province and can be rated as S2.

Rooting conditions; oxygen availability

No comments.

Nutrient availability

As maize is grown in crop mixtures, the associated crops undoubtedly affect the chemical soil conditions for maize. Unfavourable C/N ratios may be fully or partly compensated by associated leguminous crops. There may be competition for other elements.

Nutrient retention and reserves

As a standard for nutrient retention the effective cation exchange capacity (ECEC) would, at first sight, seem the best criterion, as this reflects best the capacity of the soil to retain and liberate nutrients (bases) at the soil pH in the field, especially as long as fertilizers are not applied and no liming is done. However, for a number of soils ECEC data are not available and correlation between ECEC and the apparent cation exchange capacity (CEC7, i.e. the CEC at pH 7) appeared poor, especially in volcanic soils. ECEC is also low in most soils and does not reflect the important differences in productivity which are noticed in the field between, for instance, soils on basalt and soils on granite. These differences are better reflected in the CEC7. In addition, if liming is practised in the future, CEC7 is a good indicator of the possible increase of CEC in response to liming. CEC7 thus also reflects better the potential of the soil at higher management levels.

Toxicities

In the Province various toxicities are expected to occur, notably caused by excess manganese, aluminium and iron. As laboratory data are only available for aluminium, interpretation is limited to this element only. Emphasis is placed on the topsoil contents, as subsoil influences are lessened by the ridging practices. In the ridges mainly topsoil materials are accumulated, thus increasing the thickness of the topsoil for the plant.

Erosion hazard

Planting in ridges and without mulching or with incomplete mulch is assumed in the evaluation. With a mulch, which covers the soil completely, very good protection can be obtained. Mulch is favourable in the germination and early development stages as it helps to reduce evaporation and as such to bridge drought periods. It also gives protection against the picking of seeds and seedlings by birds. In some cases, a disadvantage may be a higher incidence of pests, such as stemborers. It may also adversely affect C/N ratios, depending much on the timing and way of application.

Workability

No comments.

5.3 LEGEND

Each mapping unit contains a symbol built up of four codes as follows:

climate code -------------------- 2Nc3 -------------------- workability code

soil edaphic code -------------- / \ -------------------- erosion hazard code

The underlined code(s) correspond to those attributes posing the most severe limitations on maize cultivation.

KEY TO OVERALL POTENTIAL CLASSES

To determine the overall potential of the lands for maize, the climate, soil edaphic, erosion hazard and workability codes are ranked as follows in classes of decreasing suitability:

Rank	Climate code	Soil edaphic code	Erosion hazard code	Workability code
I	-	A	a	1
II	1,2	E,F	b	2
III	3	L,M	c,d	3
IV	-	N,Q,R,U	e,f	-
V	-	V,X	g	-
VI	4	Y	h	4

The colours on the map correspond to overall potential classes, which are determined by the lowest suitability of any of the climate, soil edaphic, erosion hazard and/or workability ranks ("law of the minimum").

OVERALL POTENTIAL CLASSES

I. **Land with very good potential for maize**: Non-existent in the North West Province.

II. **Land with good potential for maize**: All land is suitable for maize. Most of these lands have only moderate limitations.

III. **Land with fair potential for maize**: Most of these lands can be planted to maize, but have severe limitations.

IV. **Land with poor potential for maize**: Lands unsuitable for maize associated with minor areas ~~of good or fair~~ potential. → having moderate or severe limitations

V. **Land with very poor potential for maize**: All lands are unsuitable for maize, but parts of these lands can be made suitable, provided presently unfeasible high inputs are made.

VI. **Land without potential for maize**: All lands are permanently unsuitable for maize and cannot be made suitable.

CLIMATE CODES

1. Moderate limitations by low radiation, somewhat excessive length of growing season and pests and diseases.

2. Moderate limitations by low radiation, low temperature, somewhat excessive length of growing season and pests and diseases.

3. Severe limitations by low temperature, moderate limitations by low radiation, somewhat excessive length of growing season and pests and diseases.

4. Too cold for present cultivars.

SOIL EDAPHIC CODES

The soil edaphic codes stand for combinations of suitability classes regarding the physical and chemical properties of the dominant and associated soils within a mapping unit.

E soils with moderate edaphic limitations for maize. Many of the soils will give good response to fertilizers and liming.

F dominant soils with moderate edaphic limitations for maize, associated with soils with severe limitations. Many of the soils will give good response to fertilizers and liming.

L dominant soils with severe edaphic limitations for maize, associated with soils with moderate limitations. Many of the soils will give good response to fertilizers and liming.

M soils with severe edaphic limitations for maize. Many of the soils will give good response to fertilizers and liming.

N dominant soils with severe edaphic limitations for maize, associated with currently unsuitable soils.

Q currently unsuitable soils, requiring presently unfeasible high inputs of lime or drainage improvements for acceptable maize yields, associated with soils with moderate edaphic limitations.

R currently unsuitable soils, requiring presently unfeasible high inputs of lime or drainage improvements for acceptable maize yields, associated with soils with severe edaphic limitations.

U soils permanently unsuitable for maize, associated with soils with severe edaphic limitations.

V currently unsuitable soils, requiring presently unfeasible high inputs of lime or drainage improvements for acceptable maize yields.

X permanently unsuitable soils associated with currently unsuitable soils.

Y soils permanently unsuitable for maize.

EROSION HAZARD CODES

a lands with low erosion hazard. Mulching and contour ridging recommended.

b most of the lands have a moderate erosion hazard requiring contour ridging; mulching recommended.

c lands with low to moderate erosion hazard, associated with currently unsuitable lands with very severe erosion hazards or lands too steep to be worked.

d lands with severe erosion hazard, requiring contour ridging, preferably tied, complete mulch and limitation of downslope field length by erosion breaks. Associated with lands with low to severe erosion hazard.

e lands with severe erosion hazard, requiring contour ridging, preferably tied, complete mulch and limitation of downslope field length by erosion breaks. Associated with currently unsuitable land with very severe erosion hazard, or lands too steep to be worked.

f lands with very severe erosion hazard, currently unsuitable, or land too steep to be worked. Associated with lands with low to severe erosion hazard.

g lands with very severe erosion hazard, currently unsuitable, or associations of such lands with lands too steep to be worked.

h lands too steep to be worked.

WORKABILITY CODES

1. No limitations
2. Moderate limitations by surface rockiness or surface stoniness
3. Severe limitations by surface rockiness or surface stoniness
4. Land too rocky to be worked

5.4 RESULTS AND CONCLUSIONS

The survey area covers about 10 750 km^2. The evaluation of these lands for maize resulted in the following classification:

I.	**Land with very good potential**	:	-	-
II.	**Land with good potential**	:	50 km^2	0.5%
III.	**Land with fair potential**	:	1930 km^2	18%
IV.	**Land with poor potential**	:	1400 km^2	13%
V.	**Land with very poor potential**	:	6085 km^2	56.5%
VI.	**Land without potential**	:	1285 km^2	12%

The lands without potential for maize are primarily those which are too steep. Other areas are too rocky or have unfavourable rooting conditions.

The lands with very poor potential are for the larger part currently unsuitable due to steepness of the terrain and/or high aluminium levels.

In the areas where maize can give acceptable yields, chemical soil conditions are among the major constraints, notably low nutrient availability and high aluminium levels.

5.5 SOIL MANAGEMENT ASPECTS UNDER ANNUAL CROPPING

Soil productivity and cultivation intensity

An average yield figure of 1.8 ton maize/ha, as given earlier in this chapter, is somewhat misleading as it concerns one growth cycle only. It does not take into account the **cultivation factor**, i.e. the number of years under cultivation as a percentage of the total cultivation/non cultivation cycle (commonly expressed as R, in percentage). When taking the cultivation factor into account, yields can be expressed as tons per hectare per year. As the cultivation factor on annual cropland in the NWP is estimated to vary from 20 to 90 percent, with values between 40 and 50 percent dominating, average maize yields per hectare per year are less than half of 1.8 tons. In addition, in the last year(s) of a cultivation cycle, maize is seldom included in the crop mixture.

An estimate of cultivation factors necessary to meet soil rest period requirements at low input annual cropping can be made by using soil organic carbon content and cation exchange capacity (0-20 cm) as indicators of soil nutrient retention and reserves. The following classes are proposed:

OC %	CEC (me/100 g soil)	Required R %
over 3.0	over 24	over 60
2.0 to 3.0	16 to 24	40 to 60
less than 2.0	less than 16	less than 40

Using these criteria, under low input rainfed annual cropping the soils in the NWP would require the following cultivation factors:

Cultivation factor (R)	Soil types NWP
over 60	o1(?), O2, ac1, c2, p4, p5, p6, b1, b2, b3, b4, b5, b7, b8, b10, b13, b14, t1, t2, t3, t4, t5, t12
40-60	ac2, ac5, c1, p2, b6, b9, b11, b12, t6, t7, t8, t9, t10, t11, m13, m14, m16
less than 40	a1, ac3, ac4, c3, c4, c5, p1, p3, m1, m2, m3, m4, m5, m6, m7, m8, m9, m10, m11, m12, m15, m17, m18, m19, m20, g1, g2, g3, g4, g5, g6, g7, g8, g9, g10, g11, g12, g13, g14

Annual crop production with intermediate inputs

It should in the first place be noted that the mixed cropping systems in the NWP are highly efficient production systems making efficient use of soil nutrients and requiring less sanitary measures than monocultures. A main disadvantage is the high labour input required. Improved cultivation systems should therefore as much as possible combine the advantages of the traditional mixed cropping with the advantages of other improved management techniques.

Already with intermediate levels of inputs (including minimum fertilization, use of organic measures, improved fallows and crop mixtures and rotations) cultivation factors could be greatly improved. Such intermediate input annual cropping systems are presently promoted in the NWP and find gradual acceptance by the farmer. They may further include limited chemical pest, disease and weed control, improved cultivars, appreciable proportions of produce marketed and animal traction.

Aluminium toxicity and liming

High levels of aluminium in the soil are a main limitation for maize and many other sensitive crops. To reduce aluminium levels liming could be considered. It is estimated that per hectare 1.65 ton of $CaCO_3$ equivalent are sufficient to neutralize 1 meq of aluminium in the topsoil (Kamprath 1970). This is, however, very costly as there are no nearby lime sources. There is also a potential danger of overliming, especially on soils with low CEC and low available bases, causing imbalances and deficiencies of other nutritive elements. Liming and its combination with other fertilizers should therefore be carefully considered and tested for each soil type individually. Liming to pH 5.0 to 5.5 should be sufficient to largely neutralize aluminium in soils on basalt and ashes, to pH 5.5 to 6.0 on other soils.

Liming further reduces manganese toxicity, improves P availability, stimulates nitrification and N fixation and increases the effective CEC. On the other hand, most micronutrients and K become less available. Also the effect on soil structure is not always positive (dispersion).

Fertilizer application

Nitrogen: The soils in the NWP are generally rich in organic matter and nitrogen. However, the C/N ratio (i.e. the proportion of organic carbon over nitrogen percentage) is in most cases high, which means that nitrogen is not easily available. To reduce the C/N ratio nitrogen fertilizers could be applied, but high doses may be required seeing the high organic carbon contents. Acidifying fertilizers, such as sulphate of ammonia, are to be avoided on most soils.

Phosphorus: Seeing the high phosphorus fixing capacity of many of the soils, they will not give a satisfactory response to phosphorus application. Each soil type should be carefully considered and tested.

Potassium: Potassium levels in the NWP soils are generally quite satisfactory and sufficiently well balanced with the other bases. When applied on soils with very low CEC (CEC7 below 5), split applications of K fertilizer are required, as such soils have insufficient capacity to retain larger quantities of bases, thus leading to leaching losses.

Magnesium: Some of the soils, in particular on basalt, may give rise to magnesium deficiencies, especially when Mg/K ratios are less than 2.

Mulching and organic manures: As most of the terrain in the Province is sloping, mulching with crop residues or hay, leaves and twigs from adjacent land is a sound practice to protect the soils against erosion. Mulches are also a source of nutrients, they conserve soil moisture and protect seeds from eradication by birds.

However, mulch can act as a vector of certain pests and diseases. Also the generally unfavourable C/N ratios in the NWP may still further deteriorate. Mulch and organic manures can therefore best be applied at the beginning of the dry season to allow their decomposition to advance before planting. Composting could improve C/N ratios in applied manures.

Improved fallows: Fallow periods can be shortened by planting leguminous crops, such as **Pueraria** or **Tephrosia**, or by interplanting of leguminous trees. Also forms of alley cropping could be considered.

Some socio-economic considerations: As pointed out earlier, most of the mixed annual cropping systems practised in the NWP are primarily for subsistence production. Under such conditions an increase in material inputs such as fertilizer, lime, pesticides and herbicides can only be envisaged under the condition that benefits of such higher inputs are clearly demonstrated by cost-benefit calculations. The cash required for the higher inputs has to come from other sources than the foodcrops. In most cases, cash income is generated from cash crops, such as coffee. In the case of higher material inputs on annual cropland, less land and less labour are required to produce the same amount of foodcrops, which means that more land and labour could be engaged in cash crop production, generating more cash income. It would be of interest to carry out studies to find out if in this case the overall benefits will be higher for the farmer or not.

Growing towns inside the Province and rapid urbanization elsewhere in the country are opening markets for commercial foodcrop production. In this case, higher inputs will give immediate higher returns. Unfortunately, the NWP will always be somewhat at a disadvantage compared to the Western Province which has a better infrastructure and is closer to the main markets in Yaounde and the coastal provinces.

Chapter 6

EVALUATION OF THE LANDS FOR SMALLHOLDER ARABICA COFFEE

6.1 LAND UTILIZATION TYPE

Much of the information used to describe this land utilization type is taken from MIDENO publications (MIDENO 1984 and 1985).

Crop: Arabica coffee varieties, 9 percent the recently introduced Java variety.

Production method: Rainfed production, no irrigation or water importation, generally intercropped with foodcrops and fruit trees.

Capital intensity: Low to intermediate.

Market orientation: Market production, mainly for export.

Labour intensity: Medium, including uncosted family labour.

Technical knowledge and attitudes: Farmers have an average schooling level of 4 years primary school and are for the most part willing to adopt improved methods where the benefits can be clearly demonstrated.

Power source: Manual labour with hand tools (mainly hoe, cutlass mainly hand spraying and pulping machines, etc.).

Size and shape of farms: Average Arabica coffee farm size is estimated at 1.1 ha, with an average plot size of about 0.5 ha.

Land tenure: Most of the land is considered as belonging to the villages, but holders generally have hereditary rights to use their land.

Infrastructure: As described for the low input maize LUT. The vicinity of feeder roads, preferably all-weather, within 5-10 km distance is desirable. In addition a fairly high degree of organization exists of the coffee farmers in the coffee growers union, together with cooperatives to buy the produce and supply inputs.

Cropping characteristics: Perennial cropping of Arabica coffee, with over 95 percent of the plots intercropped with foodcrops, mainly the same species as listed under the low input annual cropping LUT, but with different abundancies. Bananas and plantains dominate, followed by maize and beans; root crops are markedly less abundant. Also fruit trees are common, such as avocado, citrus and cola. Shading trees, i.e. trees deliberately planted for shading having no other economic use than wood production, occur in about 50 percent of the plots. Shading by shade and fruit trees combined is generally light.

Plot boundaries are generally marked by rows of fruit and other trees, including eucalyptus, which at the same time act as windbreaks. Planting densities are on average about 2100 to 2200 plants/ha (as against a recommended spacing of 1600 per ha). Development stages: about 3 years to first crop, about 7 years to full bearing, which can continue up to year 20 to 25 (average crop age is about 18 years in the North-West Province). Replanting is done of individual bushes, parts of plots or whole plots when bushes die or show an important drop in production.

Material inputs: These are at an intermediate level. Farmers largely follow the advice of agricultural extension services but have limited technical knowledge and capital resources. Agricultural techniques are being improved and inputs are adequate to increase yields but not to achieve maximum yields or maximum economic return. Seedlings are generally purchased. Improved cultivars (Java) now occupy about 9 percent of the land under Arabica and further expand by (re-)planting.

Fertilizer use is estimated at 75 kg sulphate of ammonia plus 90 kg of NPK (20:10:10) per hectare per year, which is well below recommended rates of 600-800 kg NPK (Provincial Coffee Officer); 40 percent of the farmers use no fertilizer at all.

Mulching, including the application of coffee hull, is practised on 60 percent of the plots but provides complete soil coverage on only 40 percent.

Chemical crop protection is common and by purchased or rented hand-spraying machines, or the Phytosanitary Brigade (in total on 35 to 65 percent of the plots).

Processing is mainly done by purchased or rented hand pulping machines.

Standards of management are highly variable.

Cultivation practices: Land preparation December-March; planting first half of rainy season, i.e. April-August; weeding and other maintenance activities mainly throughout rainy season; fertilizer applications recommended twice a year: April-May and September-October; harvesting September-January with peak in November-December.

Yields and production: Yields are estimated at about 265 to 370 kg/ha (MIDENO 1984). Still lower estimates are by Tata Fofong and Babou (1982): 200 kg/ha, a figure which does, however, not account for trading outside the Province.

6.2 CROP REQUIREMENTS

The lands of the NWP are evaluated for Arabica coffee, as grown in the above described smallholder Arabica coffee land utilization type. As Arabica coffee is produced directly for the world market, more or less "universal" land evaluation criteria are applied. This allows direct comparison with environmental conditions in competing producer countries.

Table 4 presents the criteria used to evaluate the lands for Arabica coffee. For Java coffee varieties, which seem less demanding and more resistant to pests and diseases, this table may need adaptation.

Radiation regime

n/N during the five driest months is of importance to trigger flowering and for fruit setting. In the NWP these are the months November-March. The four weather stations in the Province with data have values ranging from 0.5 to 0.7, i.e. in the optimal range. It is possible that in some of the higher areas and along escarpments lower values occur, but as data are lacking, it is assumed that the radiation regime is optimal all over the NWP.

Temperature regime

The maximum and minimum temperatures at which Arabica coffee can be grown are based on the altitude limits to which this crop is generally grown in the Province. The temperature range thus found is narrower than that found in the literature. Possibly other environmental factors, such as excess rainfall, low radiation in the rainy season and high air humidity make Arabica cultivation beyond these limits unprofitable. Possibly in detailed studies N1 temperature zones could be defined where production can reach acceptable levels through higher inputs, for instance by heavy application of pesticides in the warmer lands.

Rainfall availability

No comments.

Table 4 LAND SUITABILITY RATINGS FOR ARABICA COFFEE

LUT : Smallholder, rainfed
Area : North-West Province, Cameroon

Land characteristics per land quality	S1	S2	S3	N1	N2
s - radiation regime					
1. n/N 5 driest months	+0.5	-0.5	-	-	-
t - temperature regime					
1. Average annual temp.	18-20	17-21	16-22	-	any
- corr. altitude NWP	1400-1800	1200-2000	1000-2000	-	any
w - rainfall availability					
1. Av. annual rainfall	1500-1800	1200-2500	+1000	-	-1000
2. Dry months	1-3	3-4	0-6	-	+6
p - pests and diseases					
1. Air hum. driest month	40-60	30-80	20-90	-	any
r - rooting conditions					
1. Rooting depth	+150	100-150	50-100	-	-50
2. Depth top stoneline	+100	50-100	-50	-	-
3. Coarse fragments av. % 0-150 cm or solum					
- Ando-/Dystr. & Hum. Cambisols on basalt	-15	15-60	+60	-	-
- other soils	-15	15-34	34-60	-	+60
4. Texture/structure (at 50)	C+60s & -L	SCL	cSCL & -LvfS	-	any
o - oxygen availability					
1. Soil drainage	W	MW,SE	SP,E	P drainable	any
n - nutrient availability (0-20)					
1. C/N	-17	17-25	+25	-	-
2. Available P	+7	2-7	-2	-	-
3. TEB	+5.0	-5.0	-	-	-
f - nutrient reten. & reserves					
1. Organic carbon % (0-20)	+2.0	-2.0	-	-	-
2. CEC7 (0-20)	+24	5-24	-5	-	-
3. CEC7 (at 50)	+16	16	-	-	-
x - toxicities (at 50 cm)					
1. Al saturation	-60	60-80	+80	-	-
e - erosion hazard					
1. Slope class					
- on basalt, trachyte	A,B	C,D	E	-	F
- others	A	B,C	D	E	F
y - workability					
1. Surface stoniness class	0	1,2	3,4	-	5
2. Rock outcrops class	0	1	2	-	3,4,5

Pests and diseases

Air humidity of the driest month is used as a criterion. All over the Province this is January and the stations with available data all have optimal values. It is assumed that this land quality is optimal all over NWP.

Rooting conditions; oxygen availability; nutrient availability and retention; toxicities

No comments.

Erosion hazard

Rating is for lightly shaded cultivation with a mulch that only partly covers the soil surface. With complete mulch, areas with higher potential erosion hazards can be planted.

Workability

No comments.

6.3 LEGEND

Each mapping unit contains a symbol built up of four codes as follows:

climate code ------------------- 2Nc3 --------------------- workability code

soil edaphic code ---------------/ \------------------ erosion hazard code

The underlined code(s) correspond to those attributes posing the most severe limitations on coffee cultivation.

KEY TO OVERALL POTENTIAL CLASSES

To determine the overall potential of the lands for coffee, the climate, soil edaphic, erosion hazard and workability codes are ranked as follows in classes of decreasing suitability:

Rank	Climate code	Soil edaphic code	Erosion hazard code	Workability code
I	-	-	a	1
II	1,2	C,E,F	b	2
III	3,4	J,K,L,M	c,d	3
IV	-	O,R,T,U	e,f	-
V	-	V,W	g	-
VI	5	Y	h	4

The colours on the map correspond to overall potential classes, which are determined by the lowest suitability of any of the climate, soil edaphic, erosion hazard and/or workability ranks ('law of the minimum').

OVERALL POTENTIAL CLASSES

I. **Land with very good potential for coffee:** Non-existent in the North West Province.

II. **Land with good potential for coffee:** All land is suitable for coffee. Most of these lands have only moderate limitations.

III. **Land with fair potential for coffee:** Most of these lands can be planted to coffee, but have severe limitations.

IV. **Land with poor potential for coffee:** Lands unsuitable for coffee associated with minor areas of good or fair potential.

V. **Land with very poor potential for coffee:** All lands are unsuitable for coffee, but parts of these lands can be made suitable, provided presently unfeasible high inputs are made.

VI. **Land without potential for coffee:** All lands are permanently unsuitable for coffee and cannot be made suitable.

CLIMATE CODES

1. Moderate limitations by length of dry season.
2. Moderate limitations by temperature and length of dry season.
3. Severe limitation by temperature or length of dry season.
4. Severe limitation by temperature and length of dry season.
5. Very severe limitation by temperature.

SOIL EDAPHIC CODES

The soil edaphic codes stand for combinations of suitability classes regarding the physical and chemical properties of the dominant and associated soils within a mapping unit.

C dominant soils with no or only slight edaphic limitations for coffee, associated with soils with severe limitations.

E both dominant and associated soils have moderate edaphic limitations for coffee.

F dominant soils with moderate edaphic limitations for coffee, associated with soils with severe limitations.

J dominant soils with moderate edaphic limmitations for coffee, associated with permanently unsuitable soils.

K dominant soils with severe edaphic limitations for coffee, associated with soils with no or only slight limitations.

L dominant soils with severe edaphic limitations for coffee, associated with soils with moderate limitations.

M both dominant and associated soils have severe edaphic limitations for coffee.

R currently unsuitable soils, requiring presently unfeasible high inputs for acceptable coffee yields, associated with soils with severe limitations.

T soils permanently unsuitable for coffee, associated with soils with moderate limitations.

U soils permanently unsuitable for coffee, associated with soils with severe limitations.

V both dominant and associated soils currently unsuitable, requiring presently unfeasible high inputs for acceptable coffee yields.

W currently unsuitable soils, requiring presently unfeasible high inputs for acceptable coffee yields, associated with permanently unsuitable soils.

Y both dominant and associated soils permanently unsuitable for coffee.

EROSION HAZARD CODES

a lands with low erosion hazard. Mulching recommended.

b lands with moderate erosion hazard requiring contour planting with complete mulch, associated with lands with low, moderate or severe erosion hazard.

c lands with low or moderate erosion hazard, associated with currently unsuitable lands with very severe erosion hazards or lands too steep to be worked.

d lands with severe erosion hazard, requiring contour planting on bench terraces with complete mulch and good shading, associated with lands with low, moderate or severe erosion hazard.

e lands with severe erosion hazard associated with currently unsuitable land with very severe erosion hazards or land too steep to be worked.

f lands with very severe erosion hazard, currently unsuitable, or land too steep to be worked. Associated with lands with low, moderate or severe erosion hazard.

g lands with very severe erosion hazard, currently unsuitable, or associations of such lands with lands too steep to be worked.

h lands too steep to be worked.

WORKABILITY CODES

1. No limitations
2. Moderate limitations by surface rockiness or surface stoniness
3. Severe limitations by surface rockiness or surface stoniness
4. Land too rocky to be worked

6.4 RESULTS AND CONCLUSIONS

The survey area covers about 10 750 km^2. The evaluation of these lands for Arabica coffee resulted in the following classification:

I.	**Land with very good potential**	:	-	-
II.	**Land with good potential**	:	271 km^2	2.5%
III.	**Land with fair potential**	:	4934 km^2	46%
IV.	**Land with poor potential**	:	1211 km^2	11%
V.	**Land with very poor potential**	:	1182 km^2	11%
VI.	**Land without potential**	:	3152 km^2	29.5%

The lands without potential for Arabica coffee are primarily those which are too warm for acceptable growth and yields. Other areas are too steep, have unfavourable rooting conditions, are too rocky, or too cool.

The lands with very poor potential are for the larger part currently unsuitable due to steepness of the terrain, locally due to impeded drainage.

In the areas where Arabica can be grown, physical soil conditions, notably soil depth and coarse fragment content, are among the major edaphic limitations.

Possibly Arabica could be grown at somewhat lower elevations provided adequate sanitary measures are taken.

Chapter 7

EVALUATION OF THE LANDS FOR SMALLHOLDER ROBUSTA COFFEE

7.1 LAND UTILIZATION TYPE

Smallholder Robusta coffee cultivation as practised in the North West Province is less well known than the Arabica coffee LUT. Practices and conditions also vary greatly with altitude. They are much similar to the Arabica LUT at higher elevations on the plateaus, quite a bit different at lower altitudes where dissected land with rain forests and oil palm groves prevails. As this LUT is not well defined, it is thought sufficient to list the main similarities and differences with the previously described smallholder Arabica coffee LUT (see paragraph 6.1).

About similar are production method, market orientation, technical knowledge and attitudes, power source, land tenure, farm size and cultivation practices.

Somewhat lower are capital intensity, labour intensity and material inputs (no pulpers, less fertilizer and pesticides).

Infrastructure: Somewhat weaker with a lower degree of farmer and marketing organization.

Cropping characteristics: Most plots are intercropped with foodcrops, quite similar to the Arabica coffee LUT, but with maize and beans less prominent at lower altitudes. Oil palm is also an important intercrop. In particular on more recently cleared farms, important numbers of remaining forest trees provide shading. Shading is generally more common and intense than for Arabica coffee. Planting densities are not known (recommended planting density is 1500/ha).

Yields and production: For the North West Province, yields are estimated at 640 tons from a 2000 ha planted area, corresponding to only 320 kg/ha (Tata Fofong and Babou 1982), figures which, however, do not account for trading outside the Province.

7.2 CROP REQUIREMENTS

The lands of the NWP are evaluated for Robusta coffee in the smallholder Robusta land utilization type described above. As Robusta coffee is produced directly for the world market, more or less 'universal' land evaluation criteria are applied. This allows direct comparison of environmental conditions in competing producer countries. Table 5 presents the land evaluation criteria applied for Robusta coffee.

Radiation regime

n/N during the five driest months is of importance to trigger flowering and for fruit setting. In the NWP these are the months of November-March. The four weather stations in the Province with data have values ranging from 0.5 to 0.7, i.e. in the optimal range. It is quite possible that along escarpments lower, somewhat suboptimal, values occur. It is, however, assumed that the radiation regime is optimal all over the NWP.

Temperature regime

The applied classes of average annual temperature correlate well with the temperatures of the coldest month as proposed by Sys (1985). Also the low extremes of the average annual temperature correspond with the altitude limit above which Robusta is in general not grown in the NWP.

Table 5 LAND SUITABILITY RATINGS FOR ROBUSTA COFFEE

LUT : Smallholder, rainfed
Area : North-West Province, Cameroon

Land characteristics per land quality	S1	S2	S3	N1	N2
s - radiation regime					
1. n/N 5 driest months	+0.5	-0.5	-	-	-
t - temperature regime					
1. Average annual temp.	+25	23-25	21-23	-	-21
- corr. altitude NWP	0-400	400-800	800-1200	-	+1200
w - rainfall availability					
1. Av. annual rainfall	1600-2400	1400-3000	+1200	-	-1200
2. Dry months	1-2	0-3	3-4	-	+4
p - pests and diseases					
1. Air hum. driest month	45-80	35-90	+30	-	-30
r - rooting conditions					
1. Rooting depth	+150	100-150	50-100	-	-50
2. Depth top stoneline	+100	50-100	-50	-	-
3. Coarse fragments av. % 0-150 cm or solum					
- Ando-/Dystr. & Hum. Cambisols on basalt	-15	15-60	+60	-	-
- other soils	-15	15-34	34-60	-	+60
4. Texture/structure (at 50)	C+60s & -SCL	cSCL & -SL	cSL & -LS	-	any
o - oxygen availability					
1. Soil drainage	W	MW,SE	SP,E	P drainable	any
n - nutrient availability (0-20)					
1. C/N	-17	17-25	+25	-	-
2. Available P	+2	-2	-	-	-
3. TEB	+1.0	-1.0	-	-	-
f - nutrient reten. & reserves					
1. Organic carbon % (0-20)	+1.2	-1.2	-	-	-
2. CEC7 (0-20)	+16	5-16	-5	-	-
3. CEC7 (at 50)	+5	-5	-	-	-
x - toxicities (at 50 cm)					
1. Al saturation	-80	+80	-	-	-
e - erosion hazard					
1. Slope class					
- on basalt, trachyte	A,B	C,D	E	-	F
- others	A	B,C	D	E	F
y - workability					
1. Surface stoniness class	0	1,2	3,4	-	5
2. Rock outcrops class	0	1	2	-	3,4,5

REMARKS: The classes of average annual temperatures correlate well with the temperatures of the coldest months as proposed by Sys (1985).

Rainfall availability

No comments.

Pests and diseases

Air humidity of the driest month is used as a criterion. All over the Province this is January and of the stations with available data in the Province, only Ndu has suboptimal values. This station is, however, far out of range for Robusta because of its high altitude. It is quite possible that somewhat suboptimal values occur in drier areas, such as Ndop plain or towards the Nigerian border towards the north. It is, however, assumed that this land quality is optimal all over the NWP.

Rooting conditions; oxygen availability; nutrient availability and retention; toxicities

No comments.

Erosion hazard

Rating is for lightly shaded cultivation with a mulch that only partly covers the soil surface. With complete mulch and denser shading, areas with higher potential erosion hazards can be planted.

Workability

No comments.

7.3 LEGEND

The same legend is applied as for Arabica coffee (see paragraph 6.3).

7.4 RESULTS AND CONCLUSIONS

The survey area covers about 10 750 km^2. The evaluation of these lands for Robusta coffee resulted in the following classification:

I.	**Land with very good potential**	:	-	-
II.	**Land with good potential**	:	2 km^2	negl.
III.	**Land with fair potential**	:	1734 km^2	16%
IV.	**Land with poor potential**	:	859 km^2	8%
V.	**Land with very poor potential**	:	1963 km^2	18%
VI.	**Land without potential**	:	6192 km^2	58%

The lands without potential for Robusta coffee are primarily those which are too cool for acceptable growth and yields. Other areas are too steep, have unfavourable rooting conditions, or are too rocky.

The lands with very poor potential are for the larger part currently unsuitable due to steepness of the terrain, locally due to impeded drainage.

In the areas where Robusta can be grown, physical soil conditions, notably soil depth and coarse fragment content, are among the major edaphic limitations.

Chapter 8

EVALUATION OF THE LANDS FOR OIL PALM

8.1 LAND UTILIZATION TYPE

In Cameroon oil palm is grown under four distinct land utilization types:

- estate cultivation
- smallholder cultivation
- around homesteads
- in oil palm groves.

Table 6 summarizes the main characteristics of these different LUTS. In the NWP agro-industrial oil palm plantations do not exist since the plantation in Ntem (Mbaw Plain) was abandoned. Groves and cultivation around homesteads are widespread below about 1200 m altitude.

Smallholder plantations are still rather few and, with surface areas of 5 to 50 ha, modest in size. Their importance is, however, increasing. The following land evaluation applies primarily to smallholder cultivation. However, additional remarks are made on groves, as improvement of oil palm groves by gradually replacing dura with tenera varieties is a primary objective of MIDENO.

8.2 CROP REQUIREMENTS

Table 7 presents the criteria used to evaluate the land for oil palm.

Radiation regime

Bright sunshine is very important for oil palm growth and production. The average number of annual sunshine hours gives a broad indication, but does not account for fluctuations during the year. Ideally daily bright sunshine should be at least 5 hours all year round. In the palm growing areas of Cameroon, including the NWP, average radiation values are as low as 2-3 hours a day in July, August and September. This largely explains the low yields of Cameroon estates as compared with those of, for instance, Malaysia and Sumatra.

Temperature regime

With lower temperature, maturation of palms is slowed down and the production of fruit bunches reduced. At temperatures below $15^{\circ}C$ seedling growth is retarded. In practice in the NWP oil palm is seldom grown at altitudes above 1200 m. It is recommended to limit agro-industrial estates to altitudes below 400 m, small plantings to altitudes below 800 m.

Rainfall availability

Ideal conditions are with 2000 mm rainfall, evenly distributed over the year. The lower and more severe the dry season, the slower the maturation and lower the fruit bunch production. Excessive rainfall decreases both pollen density and oil content of the mesocarp.

Rooting conditions; oxygen availability; nutrient availability; nutrient retention and reserves

No comments

Table 6

MAIN OIL PALM LAND UTILIZATION TYPES IN CAMEROON

Characteristics	Estate Type	Smallholder	Around homesteads	Groves
Crops	Tenera varieties	Tenera varieties	Tenera and dura varieties	Mainly dura varieties
Production method	Rainfed, monoculture produce of both mesocarp and kernel oil	Rainfed, monoculture locally intercropped during first years of young plantation depending on processing plant produce mainly mesocarp oil	Rainfed, intercropped with annual and perennial crops; produce mesocarp oil and palm wine	Rainfed, mixed with forest remnants, locally with annual and perennial crops as well; produce mesocarp oil and palm oil
Capital intensity	High	Intermediate	Low	Very low
Market orientation	Market production, largely for export	Market production for local markets and export	For subsistence in first place	For subsistence and local markets
Labour intensity	Medium, mainly hired	Medium, mainly hired	Low, uncosted family labour	Very low, uncosted family labour
Technical knowledge and attitudes	High, improved methods readily accepted and partly self-developed	Medium to high, improved methods accepted where benefits are clearly demonstrated	Average level 4 years primary school. Willing to adopt improved varieties	Average level 4 years primary school. Acceptance of improved methods variable following rights to the land and other factors
Power source	Partly mechanized	Largely manual labour with hand tools	Manual labour with hand tools	Manual labour with hand tools
Size and shape of farms	Several hundred to several thousand ha; field sizes 5 to over 100 ha	From about 5 to several hundred ha; field sizes 1 to 10 ha	Up to several tens of palms	Ill defined
Land tenure	Generally some type of government lease	Privately owned, lease or hereditary rights to use of land; also in cooperatives	Hereditary rights to use of the land	Hereditary rights to use of land near the villages, ill defined in remote areas
Infrastructure	Near main roads, well maintained estate roads, factory at or near the estate; own workshops and marketing organizations	Near main roads and feeder roads; processing at local factories or nearby estates; marketing through cooperatives or local markets	Processing locally at family or village level; marketing of surplus through cooperatives or local market	Processing locally at family or village level; for subsistence and marketing through cooperatives and local markets
Cropping characteristics	Planting at about 9 m equilateral spacing, about 140 palms/ha	Planting at about 9 m equilateral spacing, about 140 palms/ha	Dispersed planting, partly spontaneous growth intercropped with annual and perennial crops	Largely spontaneous growth, densitites vary and seldom exceed 70 to 80 smooth palms/ha; mixed with forest remnants, locally also with crops
Yield/production tons of fresh fruit bunches/ha/year	About 10 ton FFB	5-7 ton FFB	Unknown	1.2-4 ton FFB

Table 7 LAND SUITABILITY RATINGS FOR OIL PALM

LUT : Smallholder, rainfed
Area : North West Province, Cameroon

Land characteristics per land quality	Land suitability ratings S1	S2	S3	N1	N2
s - radiation regime					
1. Sunshine duration	+1500	1200-1500	-1200	-	-
t - temperature regime					
1. Average annual temp.	+25	23-25	21-23	-	-21
- corr. altitude NWP	0-400	400-800	800-1200	-	+1200
w - rainfall availability					
1. Average annual rainfall	1700-3000	1500-6000	+1250	-	-1250
2. Dry months	0-2	2-3	3-4	-	+4
r - rooting conditions					
1. Rooting depth	+100	50-100	25-50	-	-25
2. Depth top stoneline	+100	50-100	-50	-	-
3. Coarse fragments av. % 0-100 cm or solum					
- Ando-/Dystr. & Hum. Cambisols on basalt	-15	15-60	+60	-	-
- other soils	-15	15-34	34-60	-	+60
4. Texture/structure (at 50)	C+60s & -L	SCL	cSCL & -LvfS	-	any
o - oxygen availability					
1. Soil drainage	W,MW	SE,SP	P	-	E,VP
n - nutrient availability (0-20)					
1. C/N	-17	17-25	+25	-	-
2. Available P	+7	2-7	-2	-	-
3. TEB	+5.0	1.0-5.0	-1.0	-	-
f - nutrient reten. & reserves					
1. Organic carbon % (0-20)	+1.2	1.2	-	-	-
2. CEC7 (0-20)	+24	5-24	-5	-	-
3. CEC7 (at 50)	+16	-16	-	-	-
x - toxicities (at 50 cm)					
1. Al saturation	0-30	30-60	60-80	+80	-
e - erosion hazard					
1. Slope class					
- on basalt, trachyte	A,B	C,D	E	-	F
- others	A	B,C	D	E	F
y - workability					
1. Surface stoniness class	0	1,2	3,4	-	5
2. Rock outcrops class	0	1	2	-	3,4,5

Toxicities

Oil palm can stand rather high levels of aluminium saturation. As most of the oil palm root system tends to be concentrated in the upper 40 cm of the soil it is difficult to apply the chosen classes to the 0-20 cm layer or at 50 cm depth that were applied for other perennial crops. Application of the criteria at 50 cm depth may have resulted in too severe a classification of some of the soils.

Erosion hazard

The ratings are for planted palms in monocultures. In areas with S2 rating for erosion hazard, contour planting with mulch is recommended; in areas with S3 rating planting on bench terraces with mulching. In oil palm groves erosion hazard is generally lower due to a more effective vegetation cover and natural mulch. There areas with slopes steeper than 50 percent are still acceptable, but maintenance and harvesting is very difficult.

Workability

No comments.

8.3 LEGEND

Each mapping unit contains a symbol built up of four codes as follows:

climate code ------------------ 2Nc3 ------------------- workability code

soil edaphic code ------------- / \ ----------------- erosion hazard code

The underlined code(s) correspond to those attributes posing the most severe limitations on oil palm cultivation.

KEY TO OVERALL POTENTIAL CLASSES

To determine the overall potential of the lands for oil palm, the climate, soil edaphic, erosion hazard and workability codes are ranked as follows in classes of decreasing suitability:

Rank	Climate code	Soil edaphic code	Erosion hazard code	Workability code
I	1	A	a	1
II	2,3,4	C,E,F	b	2
III	5	K,L,M	c,d	3
IV	-	N,O,Q,R,U	e,f	-
V	-	V	g	-
VI	6	Y	h	4

The colours on the map correspond to overall potential classes, which are determined by the lowest suitability of any of the climate, soil edaphic, erosion hazard and/or workability ranks ('law of the minimum').

OVERALL POTENTIAL CLASSES

I. **Land with very good potential for oil palm:** Non-existent in the North West Province.

II. **Land with good potential for oil palm**: All lands are suitable for oil palm. Most of these lands have only moderate limitations.

III. **Land with fair potential for oil palm:** Most of these lands can be planted to oil palm, but have severe limitations.

IV. **Land with poor potential for oil palm:** Lands unsuitable for oil palm associated with minor areas of good or fair potential.

V. **Land with very poor potential for oil palm:** All lands are unsuitable for oil palm, but parts of these lands can be made suitable, provided presently unfeasible high inputs are made.

VI. **Land without potential for oil palm:** All lands are permanently unsuitable for oil palm and cannot be made suitable.

CLIMATE CODES

1. No or only slight climatic limitations.
2. Moderate limitations by low temperature.
3. Moderate limitations by length of dry season.
4. Moderate limitations by both low temperature and length of dry season.
5. Severe limitations by low temperature.
6. Very severe limitations by low temperature; too cold for oil palm cultivation.

SOIL EDAPHIC CODES

The soil edaphic codes stand for combinations of suitability classes regarding the physical and chemical properties of the dominant and associated soils within a mapping unit.

A both dominant and associated soils have no, or only slight, limitations for oil palm.

C dominant soils with no or only slight edaphic limitations for oil palm, associated with soils with severe limitations.

E both dominant and associated soils have moderate edaphic limitations for oil palm.

F dominant soils with moderate edaphic limitations for oil palm, associated with soils with severe limitations.

K dominant soils with severe edaphic limitations for oil palm, associated with soils with no or only slight limitations.

L dominant soils with severe edaphic limitations for oil palm, associated with soils with moderate limitations.

N dominant soils with severe edaphic limitations for oil palm, associated with currently unsuitable soils requiring presently unfeasible high inputs for acceptable oil palm yields.

O dominant soils with severe edaphic limitations for oil palm, associated with permanently unsuitable soils.

Q dominant soils currently unsuitable for oil palm, requiring presently unfeasible high inputs for acceptable oil palm yields, associated with soils with only moderate limitations.

U soils permanently unsuitable for oil palm, associated with soils with severe limitations.

V both dominant and associated soils currently unsuitable, requiring presently unfeasible high inputs for acceptable oil palm yields.

Y both dominant and associated soils permanently unsuitable for oil palm.

EROSION HAZARD CODES

a lands with low erosion hazard. Mulching recommended.

b lands with moderate erosion hazard requiring contour planting with complete mulch, associated with lands with low, moderate or severe erosion hazard.

c lands with low or moderate erosion hazard, associated with currently unsuitable lands with very severe erosion hazards or lands too steep to be worked.

d lands with severe erosion hazard, requiring contour planting on bench terraces with complete mulch, associated with lands with low, moderate or severe erosion hazard.

e lands with severe erosion hazard, associated with currently unsuitable land with very severe erosion hazards or land too steep to be worked.

f lands with very severe erosion hazard, currently unsuitable, or land too steep to be worked, associated with lands with low, moderate or severe erosion hazard.

g lands with very severe erosion hazard, currently unsuitable, or associations of such lands with land too steep to be worked.

h lands too steep to be worked.

WORKABILITY CODES

1. No limitations
2. Moderate limitations by surface rockiness or surface stoniness
3. Severe limitations by surface rockiness or surface stoniness
4. Land too rocky to be worked

8.4 RESULTS AND CONCLUSIONS

The survey area covers about 10 750 km^2. The evaluation of these lands for oil palm resulted in the following classification:

I.	**Land with very good potential**	:	-	-
II.	**Land with good potential**	:	67 km^2	0.5%
III.	**Land with fair potential**	:	1644 km^2	15%
IV.	**Land with poor potential**	:	953 km^2	9%
V.	**Land with very poor potential**	:	3397 km^2	31.5%
VI.	**Land without potential**	:	4689 km^2	44%

The lands without potential for oil palm are primarily those which are too cool for acceptable growth and yields. Other areas are too steep, have unfavourable rooting conditions, or are too rocky.

The lands with very poor potential are for the larger part currently unsuitable due to steepness of the terrain and/or very high levels of aluminium.

Chapter 9

EVALUATION OF THE LANDS FOR EXTENSIVE GRAZING

9.1 LAND UTILIZATION TYPE

This land utilization type could be called 'Extensive grazing system with transhumance', by Fulani people.

The life of the Fulani is changing from semi-nomadic to more and more sedentary. The settling process is continuing. The transhumance is mainly related to a lack of drinking water and to the decreasing quality of food during the dry season in the highlands. Cattle decend to Mbaw, Ndop, Mfumte, Misage, Nyos, Noni, Baligham plains, and Menchum, Katsina Ala, Kimbi and Mentar valleys. Transhumance has its advantages; it acts as a prophylactic against internal and external parasitic sicknesses, and it permits the animals to consume fodder of different qualities, thus avoiding some deficiencies.

Some veterinarian assistance exists. Campaigns against, for instance, trypanosomiasis, are organized locally; while descending from the highlands, the herds are given a prophylactic treatment, and while going back they are given a curative treatment. Trypanosomiasis is more severe in Mbaw plain. However, White Fulani cattle are trypanosomiasis-tolerant.

With about 500 000 head of cattle, the North West is the third province of Cameroon for livestock production, and has the best marketing facilities. With the livestock market expanding (local consumption and export), animal husbandry has become a paying activity.

In the socio-economic context of the Province, with strong competition for land with arable farmers, the survival of cattle rearing in North-West Province depends on intensification and modernization of methods, and also on the improvement of pasture land productivity. The future could be favourable for semi-intensive to intensive animal husbandry, associated with cultivation.

Produce medium: Cattle, Red-Fulani (Red Longhorn, or Rahaji), White-Fulani (White Aku, Bunaji), Gudali, and cross breeds of the first two with the latter. White-Fulani is trypanosomiasis-tolerant. Available data on animal numbers per seasonal grazing area are insufficient to estimate livestock intensities.

Animal produce: Mainly meat, milk and dairy products for local (national) consumption.

Land use rights and land tenure: Pastoralism; unrestricted use of any land not carrying crops, with no formalized grazing rights, and land insecurity.

Ownership of the animals and their products: Livestock is owned by extended families.

Mobility: Transhumance of about 10 to 50 km, from the higher lands where the herds stay during the rainy season, to the surrounding valleys, lower plateaus and plains. Cattle descend in November-December, and go back to the highlands in March-April.

Labour intensity: Moderate.

Market orientation: Commercial with subsidiary subsistance, evolving to commercial production.

Technical knowledge and attitudes: Traditional knowledge; good receptivity and high interest in innovation and change; training is desirable to implement new methods of livestock and pasture production, if benefits have been clearly demonstrated. It is only recently that Fulani children, especially boys, commonly attend primary school. Average schooling levels are less than 4 years of primary school.

Capital investments: Low (except the herds themselves); sometimes motorized transport of the cattle.

Power source: Manual labour entirely; some animal power in conjunction with human labour; horses for transport and travel.

Material inputs: Low to intermediate.

Management and technology: Virtually uncontrolled burning throughout the dry season; construction of small dams in streams for water reseervoirs; sometimes supplementary feeding practices, restricted to the more productive milk cows; some breeding practices; some disease control measures, particularly against trypanosmoiasis. Locally some forage crop production and annual food crops.

Farm size: Size of the grazing unit is variable, depending on grazing capacity and the size of the herd.

Infrastructure: Based on the "Community Development Project Map" (MINAGRI 1984) and field experience (Hof **et al.** 1987), the total length of the road system in the Province is estimated between about 2200 and 2500 km, which corresponds to a density of 0.13 to 0.14 km/m^2. Most of the roads are concentrated in the southern two-thirds of the Province. Of these roads, only about 900 km can be considered all-weather roads, i.e. impracticable during short periods of heavy rain only. Tarred through-roads are limited to the main road from Santa at the Provincial border to the airport near Bafut, a total of about 40 km. An extensive programme of road upgrading and road construction is underway.

Advisory services: Advisory services and other agricultural facilities were, until recently, mainly cash crop (coffee) oriented, and based in a limited number of towns and villages only. Presently agricultural extension services and demonstration centres are rapidly expanding to all major villages, even in remote areas. In their wake extension services for pastoralism and veterinary facilities increase in quantity and quality. Research centres and demonstration farms such as those at Bambui, Jakiri, Wum, etc., give substantial impetus to improving cattle rearing.

9.2 REQUIREMENTS OF EXTENSIVE CATTLE GRAZING

Table 8 presents the criteria that were applied to evaluate the lands for extensive cattle grazing.

9.2.1 At the Primary Production Level

Moisture availability

During the rainy season, and depending on edaphic conditions, during the first weeks after the rainy season, vegetative growth knows no restrictions by water shortage.

The length of the dry season determines the decrease in quality and quantity of forage, as well as the eventual drinkable water shortage.

In the dry season, however, areas with impeded drainage are of primary importance. This must be considered in more detailed local land evaluations.

Rooting conditions

No comments.

Table 8 LAND SUITABILITY RATINGS FOR EXTENSIVE CATTLE GRAZING

Area : North West Province, Cameroon

Land characteristics per land quality	Land suitability ratings S1	S2	S3	N
I. AT THE PRIMARY PRODUCTION LEVEL				
w - rainfall availability				
1. Dry months	0-2	2-4	4	+9
r - rooting conditions				
1. Rooting depth (cm)	+40	25-40	15-25	-15
2. Coarse fragments av. % 0-40 cm or solum				
- Ando-/Dystr. & Hum. Cambisols on basalt	-15	15-60	+60	-
- other soils	-15	15-34	34-60	+60
3. Texture/structure (0-20)	SiCs & vfS	C+60s & -LS	Cm & -S	-
o - oxygen availability				
1. Drainage	W, MW	P,SE	VP,E	
n - nutrient availability (0-20)				
1. C/N	-17	17-25	+25	-
2. Available P	+2	-2	-	-
3. TEB	+1	-1	-	-
f - nutrient reten. & reserves				
1. Organic carbon % (0-20)	+2.0	1.2-2.0	-1.2	-
2. CEC7 (0-20)	+16	5-16	-5	-
x - toxicities (0-20 cm)				
1. Al saturation	-60	+60	-	-
II. AT THE LIVESTOCK PRODUCTION LEVEL				
d - availability of drinking water in dry season				
1. Distance to permanent streams	-5 km	5-10 km	10-25 km	+25 km
p - pests and diseases				
1. Tse-tse occurrence	no	-	yes	-
a - acessibility to cattle				
1. Slope class	A,B,C	D	E	F
2. Rock outcrops class	0,1,2	3	4	5
3. Surface stoniness class	0,1,2,3	4	-	5
4. Present land use	grasslands & savannas	-	-	any
5. Load supporting capacity	-	-	-	peat, muck
c - climatic hardships				
1. Annual average temp.	18-24	16-30	any	-
- corresponding altitude NWP	600-1800	0-2200	any	-

Oxygen availability

No comments, but it should be noted that plants respond in different ways to impeded drainage. Also, areas with impeded drainage are among the best grazing areas during the dry season.

Nutrient availability, retention and reserves

The native grasses and legumes are well adapted to the limited soil fertility. In the case of fertilization, they are not even efficient in recovering fertilizer nitrogen and phosphorus. They are well adapted to local circumstances, even acid, infertile soil conditions. The quality and availability of nutrients determine the vigour of forage and its nutritive value. Imbalances in nutrient content in the soil may cause toxic levels in forage or the shortage of some elements needed by animals. Special caution should be given to trace elements. Lack of such information inhibits their evaluation at this point.

Toxicities

Some grasses and legumes are tolerant to high levels of aluminium and/or manganese, and some are also tolerant to low levels of available phosphorus (e.g. some **Stylosanthes** sp.). Low levels of P fertilizers are often of little use to bring the soil to the level of full potential for grasses/legumes production, due to the high P-fixing capacity of acid soils. The improvement of the fodder quality is rather done by reseeding of well adapted species, particularly legumes.

A deficiency of certain minerals in the forage, particularly P and Ca, may occur, especially late in the rainy season.

9.2.2 At the Livestock Production Level

The most important land qualities affecting animals include the availability of drinking water (quantity, quality, distance to watering points), incidence of pests and diseases, and accessibility to animals. Climatic hardships are also considered here.

In more detailed land evaluations, land qualities such as carrying capacity, and the distance to be travelled to reach the dry season pasture lands, should be assessed. Nutritive value has to be used to determine the carrying capacity. It can be estimated from crude protein, crude fibre, ash content, contents of N, P, Ca, Mg and micronutrients, as well as the nutrient balances (e.g. Mg/K). Palatibility of the species could also be considered.

Availability of drinking water

Seeing the lack of information about other water points (wells, ponds, springs, taps), the criterion used is the distance to permanent streams. Using topographic maps in the NWP all lands are within suitable reach of permanent streams. It appeared unfeasible to differentiate into suitability levels at the 1/200 000 mapping scale.

Pests and diseases

The North-West Province grass fields have relatively few cattle diseases, probably due to the climate. Being a limitation locally, the land characteristic tse-tse occurrence is applied and indicated as a shading on the land evaluation map.

Trypanosomiasis is caught in the lower dry season grazing areas, where tse-tse flies occur, as for instance Donga and Mbaw plains. The ecological environment of **Glossina** spp. (tse-tse fly) is well known. In addition, local knowledge exists that the fly is restricted to certain types of vegetation (gallery forest, certain bushes), which could be avoided. It is possible to protect the animals (insecticide or trypanosomiasis prophylaxis). To a certain extent vaccination campaigns are organized. It should be noted that the White-Fulani stock is trypanosomiasis-tolerant, if not resistant. Some areas can be used seasonally, when the risk of the disease is less, as for instance Donga plain. Sufficient information is, however, lacking to take this fully into account in the evaluation.

Accessibility to animals

Besides slope steepness, rock outcrops and surface stoniness which have been evaluated here, present land use may prevent or impede livestock movements. Present land use other than grassy vegetation is presented by shadings on the land evaluation map. Accessibility can be locally affected by, for instance, flooding, specific vegetation (thorny shrubs), etc.

Climatic hardships

Bos indicus is well adapted to relatively high temperatures, but is less tolerant of high air humidity. Temperature is the criterion used here, as it varies substantially with the considerable altitude ranges in the Province.

In the North West Province, climatic stress could arise from heavy rains, and high air humidity, that affect mostly young animals. Local cattle become more or less well adapted to the local climatic conditions. Some shelter (trees, hedges, bushes) is found everywhere. Factors that minimize climatic stress include provision of shade and shelter, as well as extra water for heat dissipation (dry season).

9.3 LEGEND

Each mapping unit contains a symbol built up of three codes as follows:

climate code ——————— 2 N 3 ——————— accessibility code

soil edaphic code

The underlined code(s) correspond to those attributes posing the most severe limitations to grazing.

KEY TO OVERALL POTENTIAL CLASSES

To determine the overall potential of the lands for grazing, the climate, soil edaphic, and accessibility codes are ranked as follows in classes of decreasing suitability:

Rank	Climate code	Soil edaphic code	Accessibility codes
I	-	A	1
II	1,2	B,C,D,E,F	2
III	3	J,L,M	3
IV	-	T,U	4
V	-	Y	5

The colours on the map correspond to overall potential classes, which are determined by the lowest suitability of any of the climate, soil edaphic and/or accessibility ranks.

OVERALL POTENTIAL CLASSES

I. **Land with very good potential for grazing**: Non-existent in the North West Province.

II. **Land with good potential for grazing**: All land is suitable for grazing. Most of these lands have only moderate limitations.

III. **Land with fair potential for grazing**: Most of these lands are suitable for grazing, but have severe limitations.

IV. **Land with poor potential for grazing**: Unsuitable lands with minor areas with good or fair potential.

V. **Land without potential for grazing**: All lands are permanently unsuitable for grazing.

Tse-tse risk: indicated by shading on the map.

Inaccessible due to types of land use other than grasslands and savannas: see land use maps (Hof et al. 1987); for the areas north of latter study area the Bawden and Langdale-Brown (1961) maps can be used for an approximation.

CLIMATE CODES

1. Moderate limitations by more than two dry months.
2. Moderate limitations by more than two dry months and somewhat low temperature.
3. Severe limitation by low temperature, moderate limitation by more than two dry months.

SOIL EDAPHIC CODES

The soil edaphic codes stand for combinations of suitability classes regarding the physical and chemical properties of the dominant and associated soils within a mapping unit.

A soils with no or only slight edaphic limitations for pasture.

B dominant soils with no or only slight edaphic limitations for grazing associated with soils with moderate limitations, mostly due to coarse fragments.

C dominant soils with no or only slight edaphic limitations for grazing, associated with soils with severe limitations. The latter will give good response to improved pasture management and/or low inputs of fertilizers.

D dominant soils with moderate edaphic limitations for grazing, mostly due to coarse fragments, associated with soils with no or only slight edaphic limitations. These soils will give good response to pasture management, mainly stocking rate adjustments.

E dominant soils with moderate edaphic limitations for grazing mostly due to coarse fragments, associated with soils with moderate limitations, limitations being mainly due to coarse fragments. These soils will give good response to pasture management, mainly stocking rate adjustments.

F dominant soils with moderate edaphic limitations for grazing, associated with soils with severe limitations. Many of the soils will give good response to pasture management, including eventually low inputs of fertilizers and/or liming.

J dominant soils with moderate edaphic limitations for grazing, associated with permanently unsuitable soils.

K dominant soils with severe edaphic limitations for pasture, associated with soils with no or only slight limitations. Many of the soils will give good response to pasture management, including eventually low inputs of fertilizers and/or liming.

L dominant soils with severe edaphic limmitations for pasture, associated with soils with moderate limitations. Many of the soils will give good response to pasture management, including eventually low inputs of fertilizers and/or liming.

M dominant soils with severe edaphic limitations for grazing, associated with soils with severe limitations. Many of the soils will give good response to pasture management, low inputs of fertilizers and/or liming.

T dominant soils permanently unsuitable for grazing, associated with soils with moderate edaphic limitations.

U dominant soils permanently unsuitable for grazing, associated with soils with severe edaphic limitations.

V currently unsuitable soils, requiring presently unfeasible high cost drainage improvements for acceptable grazing conditions.

Y soils permanently unsuitable for grazing.

ACCESSIBILITY CODES

1. No limitations

2. At least part of the land has moderate limitations by surface stoniness or rockiness, and/or slope.

3. Most or all the land has severe limitations by surface rockiness and/or slope.

4. Most of the land is too steep to be grazed.

5 All land is too steep to be grazed or cannot support the load of grazing cattle.

9.4 RESULTS AND CONCLUSIONS

The survey area covers about 10 750 km^2. The evaluation of these lands for pasture resulted in the following classification:

I.	**Land with very good potential**	:	-	-
II.	**Land with good potential**	:	2980 km^2	28%
III.	**Land with fair potential**	:	4120 km^2	38%
IV.	**Land with poor potential**	:	1950 km^2	18%
V.	**Land without potential**	:	1700 km^2	16%

It should further be noted that of the total surface area of 10 750 km^2, about 4460 km^2 or 41 percent are presently inaccessible due to land uses other than grasslands and savannas.

Tse-tse occurrence reduces suitability of the lands for pasture in about 3920 km^2, or 36 percent of the survey area.

Permanently unsuitable areas are mainly those inaccessible due to very steep slopes, in some places areas with peat, muck or very shallow, stony soils.

Further limitations are the length of dry season, a main reason that transhumance is required, and limited soil fertility.

9.5 PASTURE IMPROVEMENTS

9.5.1 Actual Productivity

The productivity of grazing areas is highly dependent on the degree of grazing pressure and management practices. The productivity could be considerably improved with low inputs only, adapted to the economic situation and the technological level of the herdsmen.

This productivity is strongly related to the management of the herds. Indeed, animals are kept to a very old age and are not sold at the right time, the ratio of productive and non-reproductive females is often not well balanced. This leads to an excessive number of animals being kept on a given pasture, which causes heavy grazing pressure, and grassland deterioration.

The genetic potential for production of meat and milk of the indigenous livestock breeds is not reached due to lack of adequate feed. Therefore, the introduction of exotic breeds will probably not result in increasing livestock production due to the poor quality of feed; they also need more special care as they are more sensitive and less rustic.

Feed supply is the most limiting factor for high productivity of forage consuming animals. The gains in annual liveweight with adapted management which, amongst others, includes improvements of the quality of fodder, may range from 30 to 300 kg/ha (Sanchez 1976). Pasture improvements include grass-legume mixtures, minimum fertilizer inputs or other low inputs such as drinkable water point development. Adequate management consists first of all of suppression, as far as possible, of the limited water and fodder availability during the dry season, when the cattle risk losing a significant porportion of the weight gained rapidly during the rainy season.

Thus, the first aim will be the increase of forage production, and the improvement of feeding, as well as watering during the dry season. Then eventually, when the local livestock production is approaching the genetic potential, crossbreeding becomes rational.

9.5.2 Study of Local Pasture Resources

A study of the local resources, using traditional survey methods, must be carried out to allow the confrontation of vegetation types and their productivity with the ecological factors.

Except for the seasonally flooded and swamp grasslands (which have sustained growth in the dry season), two main groups of pasture lands could be distinguished, according to the lithological factor:

- pastures on basalt and trachyte;
- pastures on basement rocks (granites, gneiss, migmatites).

These two groups can be subdivided into three zones, according to altitude:

- 600 to 800 m
- 1100 to 2100 m
- 1500 to 2100 m.

The investigation centres could be the following:

- Bambui, Jakiri, Nkambe, for altitudes above 1500 m;
- Ndop plain;
- Mbaw plain;
- Dumbo, Kimbi, Misaje area;
- Wum and Menchum valley.

Pragmatic phytosociological surveys are of primary importance to estimate the carrying capacities of the grazing lands. It may be noticed that composition and bromatological value of pasture land are not enough to estimate carrying capacity locally, the latter being somewhat influenced by notably the water point distribution. Effective grazing differences show a radial pattern around any water point. The exploitation system and management level also influence greatly the carrying capacity. A specialist would be needed to ensure a detailed survey.

The animal husbandry amelioration in North West Province supposes management improvements of the existing pasture lands by:

- fire control;
- adequate rotational system (paddocks) according to the vegetation rhythm, implying the need for different grazing pressures at different times of the year;
- periodic resting of the grasslands;
- appropriate weed and bush control;
- increasing quantity and quality of the forage production

In addition, some improvement of the veterinarian services efficiency should be included as regards pests and diseases prevention and cure: pasteurella (**Haemorrhagie septicaemia**), clostridium streptotricosis, trypanosomiasis and ticks (chiefly **Amblyoma** sp. and **Paraboophilus** sp.) that cause, among others, the "heartwater" (cowdriose).

Improvements of the pasture lands would allow higher stocking rates. The stocking rates are increasing, in number of head, but also because of pasture land surface reduction. Stocking rates have to be supervised in some way. The carrying capacity of Bamenda grassfields is known to be one of the highest in Africa. According to Hawkins and Brunt (1965), the highland grassfields of the North-West Province could support a stocking rate of 0.4 to 1.0 UBT/ha.

The issue of successful animal husbandry productivity improvement in the North-West mainly depends on the active participation of the graziers, whose motivations have to be met by the activities of an adequate extension and information service.

9.5.3 Forage Crops and Fallow Lands

Forage crop introduction, the main interest of which would be to provide fodder during the dry season, is one of the most important possibilities for pasture improvement in Bamenda grassfields. Forage crops are already found in some places.

A bibliographic research on trials that have been run in other countries is necessary, followed by setting up of research trials, followed by demonstration plots combined with adequate extension courses.

Multi-local trials in small plots in order to sort them could include the following grasses:

> **Andropogon gayanus - Brachiaria brizantha - B. ruziziensis - Cenchrus ciliaris - Acroceras macrum - Chloris gayana - Cynodon dactylon - Cynodon plectostachyus - Digitaria decumbens - Hyparrhenia rufa - Melinis minutiflora - Panicum maximu - P. purpureum - Setaria sphacelata - S. anceps - Tripsacum laxum**

Regarding legumes, the trials could include the following species:

> **Centrosema pubescens - Desmodium** spp. **- Neonotonia wightii (= Glycine javanica)** (?) **- Leucaena leucocephala - Macroptilium atropurpureus (Phaeseolus atropurpureus) - Pueraria phaseploides - P. thumbergiana - Stylosanthes gracilis (= S. quianensis) - Trifolium** spp. **- Vigna unguiculata**

Some of these species are more suitable for grazing, others more for hay. Others again are recommended where erosion risks are high. It should be noted that ensilage is not a technique that fits the local climatic conditions well.

However, priority should be given first of all to collecting local species ecotypes, and evaluating them agronomically. Thus, a first step should be to test their behaviour in small plots, and to observe if they fit within the local considered biotope. Secondly, they should be produced in multiplication centres (nurseries), installed according to spatial and temporal as well as planification criteria. Simultaneously, demonstration plots of larger shape and, last of all, seed and cutting distribution have to be organized.

Each investigation centre should be limited to its own zone, with priority trials on local ecotypes (especially legumes in the altitude zones). During a second phase, grazing and fodder crop trials could be set up. The optimal exploitation of the aquatic grazing lands found in areas periodically flooded should directly concern the lowland centres (Menchum valley, Ndop plain).

On fallow lands, fodder species could grow, which are beneficial for the cultivators as well as for the graziers. This practice, amongst others, allows the intensification of agriculture on the crop lands, while at the same time decreasing the pressure on 'new' lands, till now under grass or forest. The characteristics of species used on fallow land should be:

- easy and fast propagation,
- fast growing (rooting system and overground parts),
- fertilization effects,
- easy eradication.

Fallows could comprise, for instance, **Setaria** sp., **Tripsacum laxum**, **Pennisetum purpureum**, **Pannicum maximum**, or annual or biannual deeply rooted legumes such as **Lupinus** sp., **Crotalaria** sp., **Tephrosia** sp., **Stylosanthes gracilis**, **Tripsacum laxum**, **Chloris gayana**, **Desmodium entotum**, **D. uncinatum**, **Trifolium** spp., **Leucaena leucocephala**, etc., or grass and legume association (several grass associations are generally less or not recommended here).

One possibility to palliate the decrease of forage production during the dry season should be a combination of the extensive system, and an intensive system restricted to small specific areas. The intensive system could be established on soils that are more fertile or can hold moisture better during the dry season, or may even be on small areas where irrigation by relatively inexpensive gravity systems is possible.

9.5.4 Erosion Control in the Grazing Lands

How erosion develops is more or less well known. Overgrazing causes bare spots, which gradually increase in size. Perennial grasses are replaced by annual grasses and coarse weeds. The trampling by cattle, season after season, compacts the surface of the bare ground. The rain water can no longer infiltrate into the soil but runs off on the surface. Rain, sheet and rill erosion remove the topsoil. On sufficiently long slopes, gully erosion can start.

In cases of severe imbalance, erosion will notably intensify on soils which are developed on basement rock, as there soils are more sensitive to degradation of the herbaceous cover than the more humic soils of the highlands, which are more porous and of which the surface layer is well structured. The latter, however, for cultivation, become dry faster, and therefore more rapidly provoke the wilting of the shallowly rooted plants.

The most important soil conservation measure in these areas is grazing control, if necessary by destocking and by rotational grazing. Soil conservation and erosion control are inherent to grazing land amelioration.

Grazing control should start with closing periodically some of the areas to grazing and thereby allowing natural grasses to establish an overall ground cover. To increase infiltration in these closed areas, ploughing could eventually be done along the contour, thereby retaining water. There may be a spacing of one to four metres between the plough furrows, the width depending on the slope and the severeness of the erosion. Reseeding with suitable species of grasses and legumes, possibly after some land preparation, may also be considered. For reseeding, usually scratch ploughing is preferable. It is preferable to reseed at the beginning of a rainy season. Perennial grasses should be used as far as possible, as they usually live for up to 6 years.

Besides the rational exploitation of the grasslands, in whatever way, another anti-erosion action can be the planting of more Kikuyu grass in those areas where sheet erosion is active, in places with high concentration of cattle, or where cattle pass during transhumance, in areas dominated by ferns or by **Sporobolus** spp.

Special care has also to be given locally to the layout of tracks.

In addition, live hedges may be planted as fences. Bushes and trees planted in rows are commonly found in the traditional hedged landscape of North-West Province. Hedges are an essential anti-erosion measure. They are constituted by **Ficus** spp., **Dracaena** spp., **Leucaena glauca, Gliricida sepium, Tephrosia vogelii, Erythrina** spp. and **Baugainvillaea** etc., which provide wood, fruits, poles, firewood. The traditional 'bocage' has to be preserved absolutely.

9.5.5 Establishment of improved pastures

Establishing improved pastures involves heavy burning followed, if possible, by disk harrowing to incorporate the ashes, and eventually some fertilization and/or liming, and at last seeding. High stocking rates after seeding or planting are often recommended in order to suppress regrowth of unwanted species.

The best technique and the choice of the species are site-specific. However special attention has to be given to the selection of species that permit improvement of yield and nutritive value of the pasture during the dry season. Self-reseeding ability, tolerance to acidity, low P levels and other local soil conditions also have to be considered.

Application of fertilizers may be kept to a minimum by using species and varieties of local types well adapted to the specific soil conditions and fertility limitations, such as exchangeable aluminium, low exchangeable calcium, low availability of phosphorus content.

Fertilization seems to be too expensive to be economical most of the time. Because the native grasslands are rather low in available nitrogen, the most successful way to improve the productivity has been to plant legumes. In the case of fertilization, it is known that sowing of legume species with superphosphate, eventually enriched with molybdenum applications, helps to increase the proportion of well established, well adapted legumes. The depth of fertilizer incorporation, if any, with harrowing, is shallow (less than 10 cm).

Species well adapted to acid conditions respond to lower rates of lime or phosphorus than the susceptible ones. Also, considering the high P-fixing capacity of most of the North-West Province soils, low levels of P fertilizers are insufficient to bring these soils to the level of full potential for species that are more sensitive to acid soil conditions. Small quantities of lime are used to provide Ca and Mg rather than to neutralize the exchangeable aluminium. For acid-tolerant species, small amounts of 0.10 to 1.00 ton $CaCO_3$/ha give good results in improving the pasture productivity. The species well adapted to acid soil conditions have considerably lower requirements for Ca and Mg than those susceptible to aluminium.

After the establishment phase, mixed pastures enter into a fairly efficient nutrient cycle through the grazing animals. Fertilization strategy is toward replacing losses due to urea volatilization from faeces and to nutrient leaching through the soil. Most of the N, P and K consumed by the animals is excreted in their urine and faeces and may be fairly well distributed over the pasture lands.

9.5.6 Species selection

Improved pasture lands rely rather on a grass/legume mixture than on single stands of grass or legume species. Grasses provide the bulk of the energy because of their large dry matter production. Legumes contribute to nitrogen dynamics, and to improving the overall nutritional content of the pasture. The best alternative known to improve pasture lands in extensive grazing systems therefore is to oversow adapted legume species with moderate fertilization.

Thirty percent legume mixtures seem optimal. Increasing the legume proportion beyond 30 percent is likely to decrease cattle production, because it depends on grass consumption for the bulk of its energy requirements. In fact, the amount of legume dry matter present in the pasture, which is correlated with nitrogen fixation, can be related to the effect of grazing management (Sanchez 1976).

Besides soil conditions, the tolerance of frequent defoliation and/or cuttings must be taken into account. Some species are more sensitive, such as **Desmodium** spp., or **Macroptilium atropurpureum**, and require more time to recover fully from grazing. **Stylosanthes humilis** withstands heavy grazing.

Tolerant to high exchangeable aluminium and manganese, and to low calcium, magnesium and available phosphorus contents are: **Stylosanthes guyanensis**, **S. humilis**, **Pueraria phaseoloides**, **Centrosema pubescens**, **Hyparrhenia rufa**, **Melinis minutiflora**, **Brachiaria decumbens**, **Panicum maximum**, **Digitaria decumbens**.

Tolerant to high exchangeable aluminium, but sensitive to high manganese levels are: **Phaseolus atropurpureus**, **Desmodium uncinatum**.

Tolerant to high exchangeable aluminium, but requiring somewhat high fertility status, is, for instance, **Pennisetum purpureum**.

Well adapted to acid conditions in general are: **Stylosanthes** spp., **Centrosema** spp., **Phaseolus atropurpureus**, **Pueraria phoseoloides**, **Centrosema pubescens**.

Susceptible to acid conditions are: **Leucaena leucocephala**, **Glycine wightii**, **Trifolium** spp., **Medicago sativa**.

Chapter 10

EVALUATION OF THE LANDS FOR OTHER CROPS AND USES

The previous five chapters evaluate the lands in detail for maize, Arabica coffee, Robusta coffee, oil palm and extensive grazing. In this chapter, an attempt is made to give a general overview of the suitability of the lands for other crops and uses. Most of these crops are grown in the mixed annual cropping systems as described in chapter 5. In places they are grown at an intermediate technology level with animal traction, low fertilization, and improved fallow and crop rotations. Others are grown mainly as estate crops (for instance tea) or under particular conditions (for instance raphia, rice, market garden crops). Some of the lands have potential for mechanized farming of annual crops but, except for research and demonstration farms, this is hardly practised in the Province. A number of crops are presently not cultivated in the NWP but might have some potential. Other crops of importance elsewhere in the country (for instance rubber, cotton) have been included to demonstrate their poor potential in the NWP, for example rubber because of unfavourable conditions to lay out large fields and poor infrastructure in suitable areas; cotton because of poor climatological conditions.

A full land evaluation for forestry is not included in this report. However, a number of species with potential in the NWP, some of which are already grown, are included in this chapter. In particular the information on eucalyptus is quite accurate and adapted to the NWP ecological conditions.

It should be noted that much of the information in this chapter, especially the crop requirements, is based on literature search only and the accuracy is therefore highly variable, differing from crop to crop and criterion to criterion. Nevertheless, the information may be helpful when considering the suitability of particular individual tracts of land for specific uses.

10.1 EVALUATION OF LANDS FOR SELECTED CROPS

To evaluate the lands the following types of information are to be used:

- The **soil map** to locate soil types, slope classes, surface stoniness and rockiness classes.
- The **agro-climatological map** to locate average annual temperatures and lengths of dry season.
- Table 12 giving **soil edaphic codes** for a number of soil characteristics of all soil types.
- Table 14 where **land characteristics are rated for individual crops**, to be used together with Table 10 where coarse fragment classes are rated for major crop groups.
- Table 15 presenting **recommended soil conservation measures** under different types of land use.
- Table 13 presenting **workability ratings** at different management levels based on slope, surface rockiness and surface stoniness class.

The procedure to follow is then to match the crop requirements with the climatic classes, soil edaphic ratings, required soil conservation measures and the workability ratings, to determine the overall suitability of the land and its main limitations for the specific use. This procedure is similar to the one presented in the diagram of Figure 2.

10.2 CLIMATIC CLASSES AND CODES

Temperature and **length of dry season** classes and their codes can be read from Table 14. For **air humidity** average annual relative humidity was classified and coded as follows:

high air humidity	more than 60 percent
medium air humidity	40-60 percent
low air humidity	less than 40 percent

Possibly with the exception of Ndop plain the whole NWP has high air humidity in this classification.

10.3 SOIL EDAPHIC CLASSES AND CODES

The following soil characteristics were included to define edaphic conditions:

- effective soil depth
- soil texture
- coarse fragment content
- drainage class
- nutrient status
- aluminium saturation.

Effective soil depth: classes and codes as presented in Table 14.

Soil texture/structure: In soil mapping the following texture/structure classes were employed:

cS	:	coarse sand
S	:	sand
fS	:	fine sand
LcS	:	loamy coarse sand
LmS	:	loamy medium sand
vfS	:	very fine sand
LfS	:	loamy fine sand
cSL	:	coarse sandy loam
SL	:	sandy loam
cSCL	:	coarse sandy clay loam
SCL	:	sandy clay loam
L	:	loam
SC	:	sandy clay
SiL	:	silt loam
Si	:	silt
CL	:	clay loam
SiCL	:	silty clay loam
Cg	:	granular structured clay
SiCs	:	blocky structured silty clay
C-60s	:	blocky structured clay
C-60v	:	vertisol structured clay
C+60s	:	blocky structured fine clay
C+60v	:	vertisol structured fine clay
SiCm	:	massive silty clay
Cm	:	massive clay

For the purposes of this report these texture/structure classes were regrouped and coded as follows:

a	-	very light	:	cS, S, fS, LcS, LmS
b	-	light	:	vfS, LfS, cSL, SL, cSCL
c	-	medium	:	SCL, L, SC, SiL, Si, CL, SiCL, Cg
d	-	heavy	:	SiCs, C-60s, C-60v, C+60s
e	-	very heavy	:	C+60v, SiCm, Cm

Coarse fragment content

The soils in the NWP show a great variety in in-profile coarse fragment distributions as a result of stoniness at various depths and with various abundancies. A not fully satisfactory classification and coding of coarse fragments was derived, presented in Table 9 followed by Table 10, where ratings are given per code and major crop group. In using these tables it should be kept in mind that layers with more than 60 percent of coarse fragments are considered as limiting the rooting depth. An exception to this rule are Andosols and Dystric and Humic Cambisols on basalt, soils which showed good performance of (non-root) crops in the field. Seeing the great number of classes and codes, it was decided not to include them in Table 9 for lack of space.

Table 9 COARSE FRAGMENT CODES

Soil layer (cm)	Codes a	b	c	d	e	f	g	h	i	j	k	l
0-20	- 3	- 3	- 3	3-15	3-15	-15	-15	-15	15-35	15-35	-35	+35
20-50	-15	-15	-15	-15	-15	-15	15-35	15-35	-35	-35	+35	+35
50-100	-15	-15	15-35	-15	-35	+35	-35	+35	-35	+35	any	any
100-150	-35	+35	any	-35	any	any	any	any	any	any	any	any

Table 10 COARSE FRAGMENT RATINGS FOR MAJOR CROP GROUPS

Crop Group*	Coarse Fragment Codes a	b	c	d	e	f	g	h	i	j	k	l
Shallow root crops	1	1	1	2	3	3	3	3	4	4	4	6
Deep root crops	1	1	2	3	3	4	4	4	4	4	6	6
Tree crops	1	2	3	1	3	4	3	4	3	4	4	4
Other crops	1	1	1	1	1	2	2	2	3	3	4	4

* Crops are grouped in the major crop groups In Table 14.

Drainage class

Classes and codes as presented in Table 14.

Nutrient status

For the evaluation of soil fertility the following classes were used for individual chemical soil characteristics.

Table 11 NUTRIENT STATUS CODING

Code	Level	TEB	CEC7	OC%	C/N	avP
a	very high	+30.0	+40	+5.0	-8	+20
b	high	12.0-30.0	24-40	3.0-5.0	8-12	+20
c	medium	5.0-12.0	16-24	2.0-3.0	12-17	7-20
d	low	1-0-5.0	5-16	1.2-2.0	17-25	2-7
e	very low	-1.0	-5	-1.2	+25	-2

The code is arrived at by the 'law of the minimum', i.e. the overall nutrient status code is as low as the lowest of the evaluated chemical soil characteristics.

Aluminium saturation

Aluminium saturation classes and codes are presented in Table 14. It is assumed that soils with less than 10 percent aluminium saturation are optimal for all crops, except tea as an aluminium accumulator, and possibly rubber.

Edaphic coding of the soils

Table 12 presents the codings for each edaphic condition and each soil type.

Table 12 EDAPHIC CODING OF THE SOILS

Soil type	Effective depth	Coarse fragm.	Texture	Drainage Class	Nutrient Status	Al Sat.
SOILS ON ORGANIC MATERIALS						
o1	abcd	a	peat	f	e	–
o2	abc	a	peat	f	c	–
SOILS ON ALLUVIAL DEPOSITS						
a1	f	a	var.	e	d	b
SOILS ON ALLUVIO-COLLUVIAL DEPOSITS						
ac1	ef	a	mucky	f	c	c
ac2	def	a	var.	e	d	b
ac3	abcd	a	var.	d	d	c
ac4	abcd	a	c	d	d	b
ac5	a	a	c	c	d	b
SOILS ON COLLUVIAL DEPOSITS						
c1	a	a	c	c	d	c
c2	a	a	c	c	d	b
c3	a	a	c	d	d	b
c4	a	a	c	c	d	a
c5	a	a	c	c	d	b
SOILS ON VOLCANIC ASH AND SCORIA						
p1	cd	c	b	b	e	c
p2	ab	c	b	b	e	c
p3	f	l	c	b	d	c
p4	a	h	c	b	d	c
p5	ab	k	c	b	e	c
p6	a	a	c	b	c	c
SOILS ON BASALT						
b1	c	j	c	b	c	c
b2	b	e	c	b	c	b
b3	c	c	c	b	d	b
b4	c	k	c	b	d	b
b5	b	k	c	b	d	b
b6	b	k	c	b	d	b
b7	a	k	c	b	d	var.
b8	a	b	c	b	d	var.
b9	e	k	c	b	d	var.
b10	a	a	c	b	e	b
b11	a	a	c	b	d	b
b12	a	a	c	b	d	b
b13	a	a	c	b	c	c
b14	a	a	c	b	d	c

Table 12 (Cont'd)

Soil type	Effective depth	Coarse fragm.	Texture	Drainage Class	Nutrient Status	Al Sat.
SOILS ON TRACHYTE						
t1	e	k	c	b	d	b
t2	c	k	c	b	c	b
t3	b	c	c	b	c	b
t4	d	f	c	b	d	b
t5	b	e	c	b	d	b
t6	d	k	c	b	d	b
t7	a	k	c	b	d	b
t8	b	k	c	b	d	c
t9	a	k	c	b	d	c
t10	a	f	c	b	d	b
t11	a	a	c	b	d	b
t12	a	f	c	b	c	b
SOILS ON MIGMATITE AND MESOTYPE BASEMENT ROCK						
m1	e	k	c	b	d	var.
m2	b	l	c	b	d	var.
m3	c	h	c	b	d	b
m4	b	a	c	b	d	b
m5	c	k	c	b	d	b
m6	b	l	c	b	d	b
m7	b	k	c	b	d	a
m8	a	k	c	b	d	a
m9	a	f	c	b	d	a
m10	a	k	b	b	d	c
m11	a	a	c	b	d	c
m12	a	a	cd	b	e	a
m13	a	f	c	b	d	c
m14	a	f	c	b	d	a
m15	a	a	c	b	d	c
m16	a	c	c	b	d	a
m17	a	k	c	c	e	a
m18	a	f	c	c	e	a
m19	a	a	b	c	e	a
m20	d	f	c	c	e	a
SOILS ON GRANITE AND LEUCOCRATIC BASEMENT						
g1	e	l	b	a	e	b
g2	b	l	b	b	d	b
g3	b	e	b	b	d	a
g4	a	d	b	b	e	a
g5	c	k	b	b	d	a
g6	a	k	b	b	e	a
g7	b	k	b	b	e	a
g8	a	k	b	b	e	a
g9	a	f	bc	b	d	a
g10	a	l	ab	a	e	a
g11	a	h	ab	a	e	a
g12	a	g	b	a	d	a
g13	a	a	b	b	d	b
g14	a	f	c	b	d	c

10.4 CROP REQUIREMENTS

Table 14 presents the crop requirements of selected crops in the form of ratings per land characteristic code (class). The meaning of the rating figures is as follows:

1. No limitation
2. Slight limitation
3. Moderate limitation
4. Severe limitation
5. Very severe limitation, but amendable (currently unsuitable)
6. Very severe limitation, not amendable (permanently unsuitable).

10.5 RECOMMENDED SOIL CONSERVATION MEASURES

At this stage of the evaluation, the danger of soil erosion and its control are to be considered. As pointed out earlier full information on soil erodibility is not available, but based on field impressions the soils on basalt and trachyte are in general markedly less erosion sensitive than other soils. Therefore steeper lands can be allowed on these soils for some uses. Table 15 summarizes the recommended soil conservation measures per land use type.

10.6 WORKABILITTY

The main land characteristics determining the ease of working the land, and which have not been accounted for under other headings (for instance soil texture and structure under soil edaphic rating) are surface stoniness and surface rockiness. In the cases of mechanized farming and employment of animal traction, also slope class needs to be reconsidered.

Table 13 summarizes the workability ratings which are proposed for different types of cultivation.

Table 13 WORKABILITY RATINGS

		S1	S2	S3	N1	N2
Slope Class	H	AB	C	DE	-	F
	A	AB	C	D	E	F
	M	AB	C	D	E	F
Stoniness class	H	0	1,2	3,4	-	5
	A	0	1,2	3	-	4,5
	M	0	1	2,3	-	4,5
Rockiness class	M	0	1	2	-	3,4
	A	0	1	2	-	2,3,4
	M	0	-	1	-	2,3,4

H = with hand tools; A = with animal traction; M = mechanized

Suitability depends greatly on stone size and the distribution of stones and rock outcrops over the land.

On the soil map the more limiting of either surface stoniness or surface rockiness is indicated. In fact, in the NWP, surface rockiness is generally accompanied with high degrees of surface stoniness. Rockiness class 3 is therefore more severely rated than generally found in the literature.

Table 14

LAND CHARACTERISTICS RATING FOR SELECTED CROPS

LAND QUALITIES	Temperature Regime						Rainfall availability			Pests and diseases		
LAND CHARACTERISTICS	Av. annual temperature						Length dry season			Air hum.		
	25-27°C	22-25°C	20-25°C	18-20°C	15-18°C	12-15°C	2.5-3.0 months	3.0-3.5 months	3.5-4.0 months	high	medium	low
	a	b	c	d	e	f	a	b	c	a	b	c
SHALLOW ROOT CROPS												
Carrot	6	4	2	1	2	4						
Ginger	2	2	1	3	6	6	3	2	1	3	3	1
Groundnut	1	2	2	4	6	6	3	2	1	1	1	1
Irish potato	6	6	2	1	1	3	2	2	1			
Onion	6	6	2	1	1	3						
Sweet potato	3	2	1	2	4	6	3	1	2	1	1	3
Radish	6	2	1	1	2	3				1	1	3
DEEP ROOT CROPS												
Cassava	1	1	2	3	6	6	3	1	1	1	1	1
Tannia (Xanthosoma)	2	1	1	3	6	6	1	2	3	1	1	3
Taro (Colocasia)	2	1	1	2	4	6	1	2	3	1	1	3
Yam (D. alata)	1	1	2	3	4	6	1	1	1			
TREE CROPS												
Avocado	2	1	1	2	4	6	1	2	3	1	1	3
Banana/plantain	1	2	3	4	6	6	1	2	3	1	1	3
Cashew nut	1	3	6	6	6	6	4	3	2	6	3	1
Citrus	1	1	2	3	4	6	3	1	1	3	1	3
Cloves	1	2	4	6	6	6						
Cocoa	1	2	4	6	6	6	1	3	4	1	1	3
Coconut	1	2	4	6	6	6	2	1	2	1	1	3
Cola	4	2	1	1	4	6	2	1	1			
Mango	1	2	3	6	6	6	1	1	1			
Papaya	1	1	2	3	4	6	1	1	2			
Raphia	2	1	1	3	4	6	1	1	2	1	1	3
Rubber	1	3	6	6	6	6	1	4	6	1	1	3
Tea	6	4	2	1	3	6	2	3	4	1	1	3

LAND QUALITIES	Rooting conditions										
LAND CHARACTERISTICS	Effective soil depth						Soil texture/structure				
	+150 cm	100-150 cm	75-100 cm	50-75 cm	20-50 cm	-20 cm	very light	light	medium	heavy	very heavy
	a	b	c	d	e	f	a	b	c	d	e
SHALLOW ROOT CROPS											
Carrot	1	1	1	2	6	6	4	2	1	3	6
Ginger	1	1	1	2	3	6	4	2	1	3	6
Groundnut	1	1	2	2	4	6	4	3	1	3	6
Irish potato	1	1	1	2	4	6	6	2	1	3	6
Onion	1	1	1	2	4	6	4	2	1	3	6
Sweet potato	1	1	1	1	2	4	4	2	1	3	6
Radish	1	1	1	2	3	4	4	2	1	3	6
DEEP ROOT CROPS											
Cassava	1	1	2	3	6	6	4	2	1	3	6
Tannia (Xanthosoma)	1	1	1	2	4	6	6	3	1	2	6
Taro (Colocasia)	1	1	2	3	6	6	6	3	1	2	6
Yam (D. alata)	1	1	2	3	6	6	6	1	1	4	6
TREE CROPS											
Avocado	1	1	2	4	6	6	6	3	1	2	6
Banana/plantain	1	1	1	2	3	6	6	4	1	2	6
Cashew nut	1	1	1	2	6	6	4	1	1	2	6
Citrus	1	1	1	2	6	6	6	3	1	2	6
Cloves	1	2	3	4	6	6	4	1	1	4	6
Cocoa	1	1	4	6	6	6	6	4	1	2	6
Coconut	1	1	2	4	4	6	4	1	1	2	6
Cola	1	2	3	4	6	6	6	3	1	2	6
Mango	1	2	3	4	6	6	4	2	1	2	6
Papaya	1	1	1	2	4	6	6	2	1	2	6
Raphia	1	1	1	1	2	4	6	3	1	1	4
Rubber	1	1	3	4	6	6	6	3	1	2	6
Tea	1	2	3	4	6	6	6	3	1	2	6

LAND QUALITIES	Oxygen availability						Fertility					Toxicity		
LAND CHARACTERISTICS	Drainage class						Nutrient status					Al. sat.		
	somewhat excess.	well	mod. well	somewhat poor	poor	very poor	very high	high	medium	low	very low	+60%	30-60%	-30%
	a	b	c	d	e	f	a	b	c	d	e	a	b	c
SHALLOW ROOT CROPS														
Carrot	2	1	3	5	5	6	1	1	1	4	5	5	3	2
Ginger	1	1	3	4	5	6	1	1	1	2	3	5	2	2
Groundnut	1	1	3	4	5	6	1	1	1	3	4	5	3	2
Irish potato	4	1	3	4	5	6	1	1	1	3	4	3	2	1
Onion	2	1	3	5	5	6	1	1	1	4	5	5	3	2
Sweet potato	3	1	2	4	5	6	1	1	1	2	4	5	3	1
Radish	3	1	2	3	4	6	1	1	1	3	5	5	4	1
DEEP ROOT CROPS														
Cassava	2	1	3	4	5	6	3	1	1	2	3	3	2	1
Tannia (Xanthosoma)	4	1	1	2	4	4	1	1	1	3	4	5	2	1
Taro (Colocasia)	6	4	1	1	1	2	1	1	1	3	4	4	2	1
Yam (D. alata)	3	1	2	3	4	6	1	1	1	3	4	5	2	1
TREE CROPS														
Avocado	3	1	3	4	5	6	1	1	2	3	4	5	3	1
Banana/plantain	3	1	2	3	4	6	1	1	2	3	5	5	4	1
Cashew nut	1	1	2	3	5	6	6	6	1	2	3	5	2	2
Citrus	1	1	3	4	5	6	1	1	1	3	4	5	4	2
Cloves	3	1	3	4	5	6	1	1	1	3	4	3	2	1
Cocoa	3	1	3	4	5	6	1	1	1	4	4	3	2	1
Coconut	1	1	2	3	5	6	1	1	1	2	3	5	2	1
Cola	3	1	3	4	5	6	1	1	2	3	4	5	2	1
Mango	2	1	2	4	5	6	3	2	1	2	4	5	4	1
Papaya	3	1	2	3	5	6	1	1	1	3	5	5	2	1
Raphia	4	2	2	2	1	1	1	1	1	1	3	3	1	1
Rubber	2	1	3	4	5	6	6	3	1	1	3	2	1	1
Tea	3	1	2	3	4	5	1	1	1	2	4	2	1	1

Table 14 (Cont'd) LAND CHARACTERISTICS RATING FOR SELECTED CROPS

LAND QUALITIES	Temperature Regime						Rainfall availability			Pests and diseases			Rooting conditions											Oxygen availability						Fertility					Toxicity		
LAND CHARACTERISTICS	Av. annual temperature						Length dry season			Air hum.			Effective soil depth						Soil texture/ structure					Drainage class						Nutrient status					Al. sat.		
	a 25-27°C	b 22-25°C	c 20-25°C	d 18-20°C	e 15-18°C	f 12-15°C	a 2.5-3.0 months	b 3.0-3.5 months	c 3.5-4.0 months	a high	b medium	c low	a +150 cm	b 100-150 cm	c 75-100 cm	d 50-75 cm	e 20-50 cm	f -20 cm	a very light	b light	c medium	d heavy	e very heavy	a somewhat excess.	b well	c mod. well	d somewhat poor	e poor	f very poor	a very high	b high	c medium	d low	e very low	a +60%	b 30-60%	c -30%
TIMBER AND FUELWOOD SPECIES*																																					
Acacia	1	1	2	4	6	6	1	2	2				1	1	1	2	4	6	4	2	1	3	4	1	1	1	2	3	4	1	1	1	2	3	5	3	2
Agathis	2	1	1	2	6	6	2	3	4				1	2	3	4	6	6	6	2	1	3	4	3	1	1	3	5	6	1	1	1	2	3	4	2	1
Albizia	1	1	2	3	4	6	2	2	3				1	1	2	3	4	6	3	2	1	1	4	1	1	1	3	5	6	1	1	1	2	3	4	2	1
Altingia	4	2	1	1	3	6	3	6	6				1	2	3	4	6	6	6	3	1	3	4	3	1	3	4	5	6	1	1	1	2	3	4	2	1
Eucalyptus	3	1	1	2	3	6	2	2	2	3	1	3	1	1	2	3	4	6	4	3	1	3	4	1	1	1	3	5	6	1	1	1	2	3	4	2	1
Leucena	1	1	2	3	4	6	2	1	1				1	1	1	2	4	6	3	2	1	1	4	1	1	1	2	3	4	1	1	1	2	3	5	3	2
Melaleuca	1	1	1	2	4	6	1	1	1				1	1	2	3	4	6	4	3	1	1	3	1	1	1	3	5	6	1	1	1	2	3	5	3	2
Pinus	4	2	1	2	4	6	2	3	4				1	1	2	3	4	6	4	3	1	3	4	1	1	1	4	5	6	1	1	1	2	3	4	2	1
Swietenia	1	1	2	6	6	6	2	3	4				1	2	3	4	6	6	6	2	1	3	4	3	1	3	4	5	6	1	1	1	2	3	4	2	1
Tectona	1	1	3	6	6	6	2	1	2	1	1	3	1	2	3	4	6	6	6	2	1	3	4	3	1	3	4	5	6	1	1	1	2	3	4	2	1
OTHER CROPS																																					
Barley	6	6	4	2	1	2	6	6	4	3	1	1	1	1	1	2	3	4	6	4	1	2	6	2	1	2	3	4	6	1	1	1	3	4	5	2	1
Beans	4	3	2	1	1	3	3	1	1	3	1	3	1	1	1	3	4	6	4	3	1	4	6	3	1	2	2	4	6	1	1	1	3	4	5	3	2
Cabbage	6	6	3	1	1	3				3	1	3	1	1	1	2	4	6	6	3	1	2	6	3	1	2	3	4	6	1	1	2	3	5	5	4	1
Cauliflower	6	6	2	1	2	4				3	1	3	1	1	1	2	4	6	6	3	1	2	6	3	1	2	3	4	6	1	1	2	3	5	5	4	1
Celery										1	1	3	1	1	1	1	3	6	6	3	1	3	6	3	1	2	3	4	6	1	1	1	3	5	5	4	1
Cotton	1	2	6	6	6	6	6	4	3	3	1	1	1	1	2	3	4	6	6	4	1	2	6	3	1	1	2	3	6	1	1	1	3	4	5	4	2
Cowpea	1	2	2	3	6	6				3	1	3	1	1	1	2	4	6	4	3	1	4	6	3	1	2	4	4	6	1	1	1	3	4	4	2	1
Cucumber	1	1	3	4	6	6	6	4	3	1	3	3	1	1	1	2	6	6	6	2	1	3	6	2	1	3	5	5	6	1	1	1	4	5	5	3	2
Lettuce	6	4	2	1	1	2				1	1	3	1	1	1	2	4	6	4	2	1	4	6	3	1	2	3	4	6	1	1	1	3	5	5	4	1
Millet pearl	1	2	2	3	4	6	4	3	2	4	3	1	1	1	1	2	3	4	4	3	1	1	4	1	1	1	2	4	6	1	1	1	2	3	5	3	2
Parsley										1	1	3	1	1	1	2	3	6	4	2	1	4	6	2	1	3	4	5	6	1	1	1	3	5	5	4	1
Pepper (hot)	2	2	1	1	3	4	3	1	2	1	1	3	1	1	1	3	4	6	6	3	1	2	6	4	1	2	2	4	6	1	1	1	1	4	3	1	1
Pineapple	2	1	1	2	4	6	1	1	1	1	1	3	1	1	1	1	2	4	4	2	1	2	6	1	1	3	4	5	6	1	1	1	3	4	4	1	2

* Full names respectively: **Acacia auriculformia, Agathis lorantifolia, Albizia falcataria, Altingia excelsa, Eucalyptus grandis, Leucena falcataria, Melaleuca leucadendron, Pinus Merkusii, Swietenia macrophylla** (Mahogany), **Tectona grandis** (teak).

Table 14 (Cont'd) LAND CHARACTERISTICS RATING FOR SELECTED CROPS

LAND QUALITIES	Temperature Regime	Rainfall availability	Pests and diseases	Rooting conditions		Oxygen availability	Fertility	Toxicity
LAND CHARACTERISTICS	Av. annual temperature	Length dry season	Air hum.	Effective soil depth	Soil texture/ structure	Drainage class	Nutrient status	Al. sat.
	a 25-27°C b 22-25°C c 20-25°C d 18-20°C e 15-18°C f 12-15°C	a 2.5-3.0 months b 3.0-3.5 months c 3.5-4.0 months	a high b medium c low	a +150 cm b 100-150 cm c 75-100 cm d 50-75 cm e 20-50 cm f -20 cm	a very light b light c medium d heavy e very heavy	a somewhat excess. b well c mod. well d somewhat poor e poor f very poor	a very high b high c medium d low e very low	a +60% b 30-60% c -30%
	a b c d e f	a b c	a b c	a b c d e f	a b c d e	a b c d e f	a b c d e	a b c
Pyrethrum	6 6 6 3 1 1	1 1 2	1 3 1	1 1 1 2 3 4	6 3 1 2 6	3 1 2 3 4 6	3 2 1 3 4	5 4 1
Rice (upland)	1 1 1 2 4 6	3 1 1	1 1 3	1 1 1 1 3 6	6 3 1 2 6	4 2 1 1 1 1	1 1 1 3 5	4 2 2
Rice (wetland)	1 1 3 4 6 6	1 1 1	1 1 3	1 1 1 1 3 6	6 6 3 1 1	6 4 1 1 1 1	1 1 1 3 5	4 2 2
Sesame	1 2 3 6 6 6	3 1 1	3 1 1	1 1 3 4 6 6	6 3 1 3 6	3 1 2 4 4 6	1 1 1 3 4	5 2 1
Sorghum	2 2 2 2 3 6	4 2 2	3 1 1	1 1 1 2 4 4	4 4 1 1 4	3 1 1 2 3 4	1 1 1 1 4	5 2 1
Soybean	1 1 2 4 6 6	3 1 1	3 1 1	1 1 1 3 4 6	6 2 1 3 6	3 1 1 2 4 6	1 1 1 3 4	5 2 1
Spinach			1 1 3	1 1 1 2 6 6	6 2 1 2 6	2 1 3 5 6 6	1 1 1 4 5	5 3 2
Sugarcane	1 2 4 6 6 6	1 2 3	2 1 3	1 1 1 3 4 6	6 3 1 2 4	4 1 1 2 4 5	1 1 1 3 5	5 2 1
Tobacco	1 1 1 2 4 6	3 1 1	3 1 3	1 1 1 2 4 6	4 2 1 3 6	2 1 2 4 5 6	1 1 2 3 4	5 2 1
Tomato	2 1 1 1 3 6		3 1 3	1 1 1 2 4 6	6 2 1 2 6	3 1 2 3 4 6	1 1 1 3 5	5 4 1
Watermelon	1 1 2 3 6 6	6 6 4	3 1 1	1 1 1 2 4 6	4 2 1 3 6	1 1 2 4 5 6	1 1 1 3 5	5 4 2
Wheat	6 6 4 2 1 2	6 4 3	3 1 1	1 1 1 2 3 4	6 4 1 2 6	2 1 2 3 4 6	1 1 1 3 4	5 2 1

Table 15

RECOMMENDED SOIL CONSERVATION MEASURES

	SLOPE CLASS*					
Soils on basalt/trachyte	A,B	C	D	E	–	F
Other soils	A	B	C	D	E	F
1. Forests, dense natural vegetation	no special measures	no special measures	no special measures	no special measures	locally upstream from reservoirs	local measures required
2. Timber and fuelwood plantations, oil palm groves, rubber, tea	no special measures	mulching recommended	contour planting with mulch	contour planting on bench terraces; strip or spot clearing; locally further measures required	contour planting on bench terraces; strip or spot clearing; locally further measures required	planting not recommended except for conservation purposes
3. Oil palm plantation, coffee, orchards	mulching recommended	contour planting and/or complete mulch	contour planting with complete mulch	contour planting on bench terraces with mulch; coffee well shaded	presently unfeasible high inputs required	too steep to be worked
4. Mixed annual crops	mulching recommended	contour ridging preferably with mulch	contour ridging, preferably tied, with complete mulch; downslope field lengths to be limited by erosion breaks	presently unfeasible high inputs required	presently unfeasible high inputs required	too steep to be worked
5. Monocultures of erosion sensitive annual crops	mulching recommended	strip cropping	presently unfeasible high inputs required	presently unfeasible high inputs required	presently unfeasible, high inputs required	too steep to be worked

* Slope classes: A 0-2%; B 2-8%; C 8-16%; D 16-30%; E 30-50%; F over 50% slope

GLOSSARY*

AGROCLIMATIC ZONE: a land unit defined in terms of major climate (q.v.) and growing period (q.v.) which is climatically suitable for a certain range of crops and cultivars.

BENEFIT/COST RATIO: the present value of benefits divided by the present value of costs.

COMPOUND LAND UTILIZATION TYPE: a land utilization type consisting of more than one kind of use or purpose, either undertaken in regular succession on the same land, or simultaneously undertaken on separate areas of land which for purposes of evaluation are treated as a single unit (cf. multiple land utilization type).

CONDITIONALLY SUITABLE: a phase of the land suitability order Suitable, employed in circumstances where small areas within the survey are unsuitable or poorly suitable for a particular use under the management specified for that use, but suitable given that certain other land improvements or management practices are employed.

CONSERVATION REQUIREMENTS: the land use requirements (q.v.) largely or entirely related to conservation and sustained use (q.v.).

CRITICAL VALUE: a value of a diagnostic factor (q.v.) which forms the boundary between suitability rating classes.

CROP REQUIREMENTS: the land use requirements (q.v.) specifically related to an individual crop.

CROPPING INDEX: the number of crops harvested in relation to years in the cropping cycle. Expressed as C, in percent.

CROPPING SYSTEMS: <u>Single cropping system</u> is the growing of a single crop in any one field in a year. <u>Multiple cropping system</u> (q.v.) is the growing of two or more crops on the same field in a year. <u>Perennial cropping system</u> is the growing of a crop which occupies land for a minimum of two years.

CULTIVATION FACTOR: the number of years under cultivation as a percentage of the total cultivation/non-cultivation cycle. Expressed as R, in percent.

CURRENT LAND SUITABILITY CLASSIFICATION: a land suitability classification based on the suitability of land for a specified use in its present condition, without major land improvements (cf. potential land suitability classification).

DEGREES OF LIMITATION: the scaling of a single land quality (or land characteristic used to assess the quality) according to its adverse affects on a specified land utilization type (cf. suitability rating).

ECONOMIC LAND SUITABILITY CLASSIFICATION: see quantitative land suitability classification.

DIAGNOSTIC FACTOR (this replaces the term 'diagnostic criterion' and is equivalent to the term 'class-determining factor'): a variable, which may be a land quality, a land characteristic or a function of several land characteristics, that has an understood influence on the output from, or the required inputs to, a specified kind of land use, and which serves as a basis for assessing the suitability of a given type of land for that use. For every diagnostic factor there will be a critical value (q.v.) or set of critical values which are used to define suitability class limits.

* cf. = compare; q.v. = see term elsewhere in this Glossary

FACTOR RATING: a set of critical values (q.v.) which indicates how well a land use requirement is satisfied by particular condition of the corresponding land quality.

Note: Suitability rating refers to the land use requirement for a land quality; when this rating is combined with the value of that land quality possessed by a given land unit, it becomes a land suitability rating (q.v.).

GENERAL PURPOSE LAND EVALUATION: a land evaluation in which the potential land utilization types are not closely specified at the beginning of evaluations (cf. special purpose land evaluation).

GROSS MARGIN: the revenue from a farming enterprise (crop yields x prices) minus the variable costs.

GROWING PERIOD: the duration, in days, of the period when both temperature and soil moisture permit crop growth (cf. growing season, growth cycle).

Note: Growing period relates to the land, growth cycle to the crop.

GROWING SEASON: used in a general way, not as a technical term, to refer to the period of the year when crops are grown, e.g. the rainy season.

GROWTH CYCLE: the period required for an annual crop to complete its annual cycle of establishment, growth and production of harvested part. See also note under growing period.

HIGH INPUTS: see levels of inputs.

INPUTS: the material inputs (e.g. seed, fertilizers, fuel, chemical sprays) and other inputs (e.g. labour hours) applied to the use of land (cf. levels of inputs, outputs).

INTERMEDIATE: see levels of inputs.

INTERNAL RATE OF RETURN: the rate of discountng at which the present value of benefits becomes equal to the present value of costs.

KIND OF LAND USE: this term refers to either a major kind of land use or a land utilization type (q.v.), whichever is applicable; where the meaning is clear it is abbreviated to 'kind of use' or 'use'.

LAND: an area of the earth's surface, the characteristics of which embrace all reasonably stable, or predictably cyclic, attributes of the biosphere vertically above and below this area including those of the atmosphere, the soil and underlying geology, the hydrology, the plant and animal populations, and the results of past and present human activity, to the extent that these attributes exert a significant influence on present and future uses of the land by man.

LAND CHARACTERISTIC: an attribute of land that can be measured or estimated, and which can be employed as a means of describing land qualities or distinguishing between land units of differing suitabilities for use.

LAND EVALUATION: the process of assessment of land performance when used for specified purposes, involving the execution and interpretation of surveys and studies of landforms, soils, vegetation, climate and other aspects of land in order to identify and make a comparison of promising kinds of land use in terms applicable to the objectives of the evaluation.

LAND FACET: a land unit (q.v.) with climate, landforms, soils and vegetation characteristics which for most practical purposes may be considered as uniform. A subdivision of a land system (q.v.).

LAND IMPROVEMENT: an alteration in the qualities of land which improves its potential for land use (cf. major land improvement, minor land improvement).

LAND MAPPING UNIT: see land unit.

LAND QUALITY: a complex attribute of land which acts in a manner distinct from the actions of other land qualities in its influence on the suitability of land for a specified kind of use.

LAND SUITABILITY: the fitness of a given type of land for a specified kind of land use.

LAND SUITABILITY CATEGORY: a level within a land suitability classification. Four categories of land suitability are recognized:

Land suitability order: a grouping of land according to whether it is Suitable or Not Suitable for a specified kind of use.

Land suitability class: a subdivision of a land suitability order serving to distinguish types of land which differ in degree of suitability.

Land suitability subclass: a subdivision of a land suitability class serving to distinguish types of land having the same degree of suitability but differing in the nature of the limitations which determine the suitability class.

Land suitability unit: a subdivision of a land suitability subclass serving to distinguish types of land having minor differences in management of improvement requirements.

LAND SUITABILITY CLASSIFICATION: an appraisal and grouping, or the process of appraisal and grouping, of specific types of land in terms of their absolute or relative suitability for a specified kind of use.

LAND SUITABILITY RATING: the partial suitability of a land unit for a land utilization type, based on one land quality or a partial set of land qualities. Land suitability ratings are combined to give a land suitability class (cf. note on suitability rating).

LAND SYSTEM: a land unit (q.v.) with relatively uniform climate and with a repeating pattern of landforms, soils and vegetation. A land system may be divided into land facets (q.v.).

LAND UNIT: an area of land possessing specified land qualities and land characteristics, which can be demarcated on a map as a (land) mapping unit.

LAND USE SYSTEM: a specified land utilization type practised on a given land unit, and associated with inputs, outputs, and possibly land improvements.

LAND USE REQUIREMENT: the conditions of land necessary or desirable for the successful and sustained practice of a given land utilization type (cf. crop requirements, management requirements, conservation requirements).

LAND USE TYPE: the same as land utilization type.

LAND UTILIZATION TYPE: a kind of land use described or defined in a degree of detail greater than that of a major kind of land use (q.v.). In the context of rainfed agriculture, a land utilization type refers to a crop, crop combination or cropping system with a specific technical and socio-economic setting.

LEVELS OF INPUTS: a means of differentiating farming systems in generalized terms according to inputs and technology used. Three levels of inputs are commonly recognized:

Low inputs: no significant use of purchased inputs such as artificial fertilizers, improved seeds, pesticides or machinery. Traditional farming in developing countries.

Intermediate inputs: methods practised by farmers who follow the advice of agricultural extension services but who have limited technical knowledge and/or capital resources; improved agricultural techniques; inputs adequate to increase yields but not to achieve maximum yields or maximum economic return; some fertilizers (e.g. 50-100 kg per hectare, combined weight of nutrients expressed as elements); possibly some use of chemical weed or pest control.

High inputs: methods based on advanced technology and high capital resources; fertilizers at levels of maximum economic return; chemical weed and pest control at advanced technical levels; modern methods of mechanization are employed to maximize yields or economic return.

LIMITATION: a land quality, or land characteristic which adversely affects the potential of land for a specified kind of use (cf. degrees of limitation).

LOW INPUTS: see levels of inputs.

MAJOR CLIMATE: a broad climatic division, defined in terms of monthly temperatures, seasonability of rainfall, and temperature regime.

MAJOR KIND OF LAND USE: a major subdivision of rural land use, such as rainfed agriculture, annual crops, perennial crops, swamp rice cultivation, irrigated agriculture, grassland, forestry, recreation.

MAJOR LAND IMPROVEMENT: a large non-recurrent input in land improvement which causes a substantial and reasonably permanent (i.e. lasting in excess of about 10 years) change in the suitability of the land, and which cannot normally be financed or executed by an individual farmer or other land user (cf. minor land improvement).

MANAGEMENT REQUIREMENTS: the land use requirement (q.v.) largely or entirely related to management of a land utilization type.

MATCHING: this term is employed in two senses, broader (i) and restricted (ii).

(i) The process of mutual adaptation and adjustment of the descriptions of land utilization types and the increasingly known land qualities.

(ii) The (specific) process of comparing land use requirements with land qualities of land units.

MINOR LAND IMPROVEMENT: a land improvement which has relatively small effect on the suitability of land, or is non-permanent, or which normally lies within the capacity of an individual farmer or other land user (cf. major land improvement).

MULTIPLE CROPPING SYSTEMS (q.v.):

Intercropping: growing two or more crops on the same field per year. Crop intensification is in both time and space dimensions. There is intercrop competition during all or part of crop growth. Farmers manage more than one crop at a time in the same field.

Mixed intercropping: growing two or more crops simultaneously with no distinct row arrangement.

Row intercropping: growing two or more crops simultaneously with one or more crops planted in rows.

Strip intercropping: growing two or more crops simultaneously in different strips wide enough to permit independent cultivation but narrow enough for the crops to interact agronomically.

Relay intercropping: growing two or more crops simultaneously during part of each one's cycle. A second crop is planted after the first crop has reached its reproductive stage of growth but before it is ready for harvest.

Sequential cropping: growing two or more crops in sequence on the same field per year. The succeeding crop is planted after the preceding one has been harvested. Crop intensification is only in the time dimension. There is no intercrop competition. Farmers manage only one crop at a time in the same field.

Double cropping: growing two crops a year in sequence.

Triple cropping: growing three crops a year in sequence.

Quadruple cropping: growing four crops a year in sequence.

Ratoon cropping: cultivation crop regrowth after harvest.

MULTIPLE LAND UTILIZATION TYPE: a land utilization type consisting of more than one kind of use or purpose simultaneously undertaken on the same land, each with its own inputs, requirements and produce or other benefits.

NET FARM INCOME: the combined gross margins (q.v.) from enterprises on a farm, minus the fixed costs.

NET PRESENT VALUE: the present value of benefits minus the present value of costs.

OUTPUTS: the products (for rainfed agriculture, crops), services (e.g. water supply, recreational facilities), or other benefits (e.g. wildlife conservation) resulting from the use of land.

PARALLEL APPROACH: a land evaluation methodology in which economic criteria are included throughout the process of identifying land use requirements, and land suitability classification.

POTENTIAL LAND SUITABILITY CLASSIFICATION: a land suitability classification based on the suitability of land for a given use after specified major land improvements (q.v.) have been completed.

PRODUCE, PRODUCTS: see outputs.

QUALITATIVE LAND SUITABILITY CLASSIFICATION: a land suitability classification in which the results are expressed in qualitative terms only, without specific estimates of outputs (crop yields), inputs, or costs and returns (cf. quantitative land suitability classification). Note that the description 'qualitative' refers to the results of the suitability classification, not to the conduct of the land evaluation.

QUANTITATIVE LAND SUITABILITY CLASSIFICATION: a land suitability classification in which the results are expressed in numerical terms which permit comparison between suitabilities for different kinds of use (cf. quantitative physical land suitability classification and economic land suitability classification).

QUANTITATIVE PHYSICAL LAND SUITABILITY CLASSIFICATION: a land suitability classification in which the results are expressed in physical numerical terms (e.g. grain yields, amounts of fertilizer inputs) (cf. economic land suitability classification).

QUANTITATIVE ECONOMIC LAND SUITABILITY CLASSIFICATION: a quantitative land suitability classification in which the results are expressed, at least in part, in economic terms.

SPECIAL PURPOSE LAND EVALUATION: a land evaluation in which the potential forms of land use are limited in number and are closely defined in the objectives of the evaluation (cf. general purpose land evaluation).

SUITABILITY ASSESSMENT: a judgement of land suitability, or the process of judging land suitability; not employed as a technical term.

SUITABILITY ORDER, CLASS, SUBCLASS: abbreviations of land suitability order, class, subclass, see definitions Chapter 2, paragraph 2.

SUSTAINED USE: continuing use of land without severe or permanent deterioration in the resources of the land.

TWO-STAGE APPROACH: a land evaluation methodology in which a first approximation of land suitability is made on the basis of physical criteria, and in which economic and social analysis is carried out as a second stage on the land use alternatives which appear most promising on the basis of physical evaluation (cf. parallel approach).

VARIABLE COSTS: the farming costs which can be assigned to specific farm enterprises (cf. fixed costs).

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APPENDIX I

CLIMATIC DATA

Table I.1 CLIMATE STATIONS

No.	Station	Division	Altitude (m)	Long. E	Lat. N	Available data
1	Abong	(Nigeria)	240	10°44'	6°59'	P
2	Baba I	Mezam	1200	10°30'	6°04'	P
3	Babessi (Ndop)	Mezam	1180	10°35'	6°02'	P
4	Babungo	Mezam	1171	10°26'	6°04'	P
5	Bali	Mezam	1299	10°01'	5°54'	P
6	Balikumbat	Mezam	1300	10°22'	5°54'	P
7	Bambui (Station)	Mezam	1600	10°17'	6°02'	PT a.o.
8	Bambui (Plain)	Mezam	1330			P
9	Bamenda	Mezam	1608	10°09'	5°58'	PT a.o.
10	Bamessing	Mezam	1190	10°09'	5°52'	P
11	Bamukumbit	Mezam	1216	10°21'	5°51'	P
12	Bamunka	Mezam	1162	10°29'	5°59'	P
13	Bangolan	Mezam	1390	10°23'	5°55'	P
14	Banso (Kumbo)	Bui	1730	10°41'	6°12'	P
15	Dzeng	Bui	2160	10°48'	6°13'	T
16	Fundong	Mentchum	1551	10°18'	6°17'	PT
17	Jakiri	Bui	1684	10°40'	6°06'	P
18	Kimbi (Bum)	Donga M.	900	10°15'	6°35'	P
19	Mamfe	(South W.P.)	126	9°20'	5°46'	PT a.o.
20	Mbengwi	Momo	1206	10°01'	6°02'	P
21	Mbiyeu	Donga M.	2000	10°46'	6°27'	T
22	Menda Nkwe	Mezam	1650	10°12'	5°56'	P
23	Ndu Tea	Donga M.	2058	10°47'	6°22'	PT a.o.
24	Nkambe	Donga M.	1700	10°41'	6°35'	P
25	Nkoundja	(Western P.)	1208	10°45'	5°39'	PT a.o.
26	Nyen	Momo	1250	10°00'	6°00'	T
27	Santa Coffee	Mezam	1750	10°13'	5°48'	PT a.o.
28	Shissong	Bui	1770	10°42'	6°11'	P
29	Tingo	Mezam	590	10°06'	6°10'	P
30	Tobin	Bui	?	?	?	P
31	Wada Wum	Mentchum	1100	10°04'	6°24'	PT a.o.
32	Widekum	Momo	520	9°47'	5°53'	P

P = precipitation
T = temperature
a.o. = and other parameters

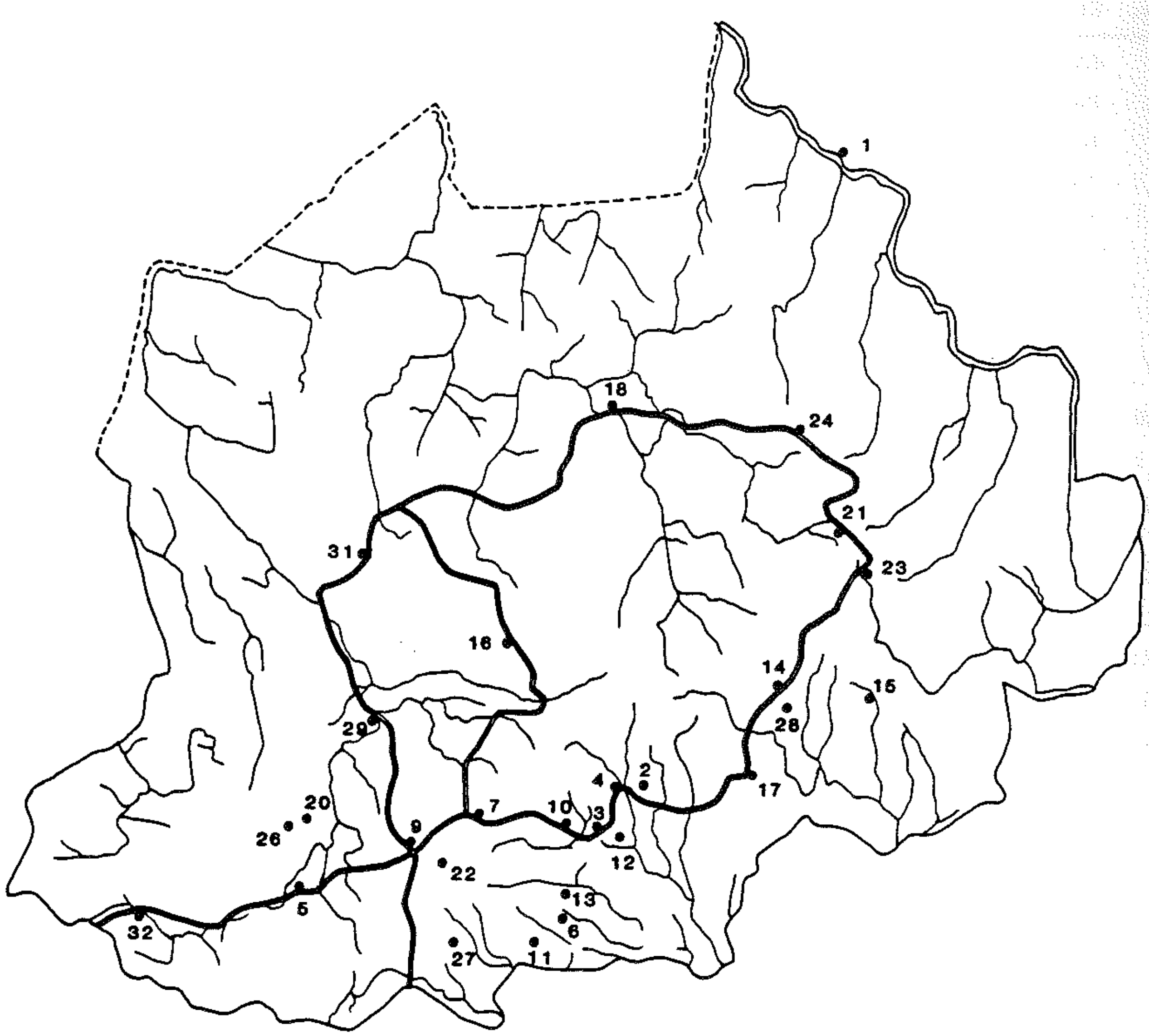

Figure 4 Climate stations in the North-West Province (numbers correspond to numbers in Table I.1)

Table I.2

CLIMATIC DATA FOR SELECTED STATIONS

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug	Sept.	Oct	Nov.	Dec.	Year	Period
BAMBUI (Station) 1600 m														
Temp. mean min	15.2	17.1	17.4	17.5	16.9	16.3	15.7	15.6	15.8	16.2	15.9	15.6	16.3	80-84
mean max	26.6	27.9	27.0	25.4	24.8	23.7	22.4	22.4	22.6	23.8	24.6	25.3	24.7	80-84
average	20.9	22.5	22.2	21.4	20.9	20.0	19.0	19.0	19.2	20.0	20.3	20.4	20.5	80-84
Precipitation	7.2	33.9	119.4	192.9	181.7	271.9	336.6	445.9	390.3	220.6	39.6	6.2	2246.2	75-84
Sunshine	248.3	198.8	174.4	157.6	163.4	133.3	78.0	69.8	93.7	145.3	226.5	233.5	1922.6	71-80
Windspeed	2 to 5 m/s													
BAMENDA 1608 m														
Temp. mean min	15.0	16.0	16.6	16.4	16.2	15.3	14.9	15.0	15.5	15.0	15.0	14.5	15.5	71-80
mean max	25.4	25.8	25.1	24.6	24.3	22.9	21.0	21.1	21.8	23.3	23.8	24.6	23.6	71-80
average	20.2	20.9	20.9	20.5	20.2	19.1	18.0	18.0	18.4	19.4	19.4	19.6	19.5	71-80
Precipitation	17.3	42.1	138.6	265.7	156.5	264.3	446.3	457.0	437.6	205.5	41.6	16.8	2489.0	76-85
Sunshine	285.7	230.0	194.8	164.2	181.0	130.5	80.5	77.1	91.0	145.3	244.1	289.0	2113.2	71-80
Relative Humidity														
mean min	32	33	47	54	57	62	73	73	71	60	49	38	54	71-80
mean max	73	75	89	94	96	97	98	98	97	96	92	83	91	71-80
Windspeed	mostly 2 to 4 m/s													
ETo Penman	163.2	151.4	142.5	126.8	124.4	102.9	85.9	86.4	90.3	113.3	133.1	149.2	1469.4	71-80
Evaporation	243.1	217.7	126.8	87.6	74.0	55.3	31.0	32.1	43.0	68.7	120.2	199.4	1294.9	72
MAMFE 126 m														
Temp. mean min	19.7	20.5	22.2	22.0	22.4	21.9	21.9	21.7	21.7	21.6	21.2	20.3	21.4	62-72
mean max	31.6	33.6	33.0	32.8	32.5	30.9	29.6	28.8	30.3	30.9	31.7	31.3	31.4	62-72
average	25.7	27.0	27.6	27.4	27.5	26.4	25.7	25.3	26.0	26.2	26.4	25.8	26.4	62-72
Precipitation	17.0	104.8	119.6	209.9	274.4	368.2	439.2	456.9	484.4	403.9	72.5	25.8	2976.6	71-80
Sunshine	175.1	177.0	169.1	166.9	168.1	121.9	75.4	68.4	90.7	133.4	164.3	177.0	1687.3	61-72
Relative Humidity														
mean min	54	49	50	61	63	66	70	73	67	66	61	57	61.42	71-80
mean max	97	96	96	97	97	98	98	98	98	97	98	97	97.25	71-80
Windspeed	mostly 2 to 4 m, sometimes 1 m/s													
ETO Penman	133.2	137.9	152.7	136.8	136.1	111.8	97.4	96.0	108.3	123.0	125.5	130.0	1488.7	61-72

Table I.2 (Cont'd)

CLIMATIC DATA FOR SELECTED STATIONS

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug	Sept.	Oct	Nov.	Dec.	Year	Period
NDU TEA 2058 m														
Temp. mean min	11.0	11.9	13.4	14.2	13.6	13.1	12.3	12.2	12.1	16.2	11.4	10.4	12.6	81-85
mean max	23.4	24.7	25.1	23.5	22.4	21.1	20.1	19.7	20.5	21.0	22.0	22.9	22.2	81-85
average	17.2	18.3	19.3	18.9	18.0	17.1	16.2	16.0	16.3	16.6	16.7	16.6	17.4	81-85
Precipitation	37.2	15.6	117.6	112.8	179.0	227.9	282.2	328.4	339.2	241.5	42.8	24.4	162.4	81-85
Sunshine	236.1	235.4	188.2	182.3	188.7	154.7	103.6	81.4	118.7	176.3	234.8	265.6	180.5	81-85
Relative Humidity														
mean min	32.7	26.1	39.1	52.8	67.4	73.5	79.5	77.1	75.2	68.7	52.0	34.7	56.6	81-85
mean max	56.5	44.3	60.9	79.9	89.5	93.3	96.4	94.1	93.5	86.1	68.7	54.2	76.5	81-85
Windspeed	2 to 3 m/s on average													
ETo Penman	196.9	160.7	157.8	135.9	119.0	99.0	84.6	84.0	92.4	111.9	131.7	150.7	1524.6	81-85
Evaporation	237.7	235.2	192.2	98.6	57.9	43.9	38.4	38.6	48.3	77.0	146.5	230.6	1444.8	81-85
NKOUNDJA 1208 m														
Temp. mean min	16.0	16.1	18.0	17.8	17.0	16.7	17.0	17.0	16.2	16.5	16.8	16.3	16.8	51-72
mean max	29.5	29.8	28.7	28.0	27.0	25.7	25.2	25.6	26.0	26.5	27.3	28.5	27.3	51-72
Average	22.8	22.9	23.3	22.9	22.0	21.2	21.1	21.3	21.1	21.5	22.1	22.4	22.1	51-72
Precipitation	2.5	20.0	110.7	174.7	166.7	188.0	308.2	351.4	329.3	255.5	69.2	5.2	1981.4	71-80
Sunshine	278.4	246.7	229.4	215.8	222.5	194.0	136.1	128.2	136.5	184.4	251.6	277.6	2501.2	71-80
Relative Humidity														
mean min	26	24	35	53	59	61	65	66	63	58	40	30	48	71-80
mean max														
Windspeed	1 to 4 m/s													
Evaporation	212.7	220.8	175.9	103.2	82.6	62.0	51.2	50.2	53.9	77.5	134.8	101.9	1326.7	51-72
SANTA COFFEE 1759 m														
Tamp. mean min	11.7	13.3	14.9	14.6	14.6	13.5	13.4	13.3	13.5	13.8	13.1	12.5	13.5	83-85
mean max	25.5	27.2	27.0	24.3	23.8	22.7	22.1	25.2	22.9	23.2	25.2	26.9	24.7	83-85
average	18.6	20.3	20.9	19.4	19.2	18.1	17.8	19.2	18.2	18.5	19.3	19.7	19.1	83-85
Precipitation	12.0	17.1	101.5	182.9	220.4	255.7	260.3	311.1	360.2	265.3	55.8	13.6	2055.9	76-85
Sunshine	270.8	232.7	186.5	172.9	184.9	159.5	130.5	117.6	114.6	169.7	135.6	122.6	1997.9	83-85
Windspeed	2 to 5 m/s													

Table I.2 (Cont'd)

CLIMATIC DATA FOR SELECTED STATIONS

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug	Sept.	Oct	Nov.	Dec.	Year	Period
WADA WUM 1100 m														
Temperature														
mean min	13.8	16.0	17.1	16.4	16.0	15.2	16.0	15.6	16.4	16.9	16.7	14.4	15.9	71-73/75/79-80
mean max	28.3	28.4	28.2	27.8	27.6	27.0	25.6	27.7	25.9	26.4	27.2	28.3	27.2	71-73/75/79-80
average	21.0	22.2	22.7	22.1	21.8	21.1	20.8	20.6	21.2	21.6	22.0	21.3	21.5	71-73/75/79-80
Precip.	13.4	49.0	170.1	262.7	376.9	392.7	403.3	427.7	432.4	380.5	61.2	10.8	2980.7	76-85
Rel. Humidity														
mean min	31	22	32	36	45	47	46	52	57	44	32	30	39	71-75
mean max	76	68	77	90	77	84	80	84	86	93	87	83	82	71-75

Table I.3

AVERAGE MONTHLY RAINFALL

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug	Sept.	Oct	Nov.	Dec.	Year	Period
Abong (Nigeria)	10.5	39.5	85.5	133.3	286.3	320.5	392.0	303.5	395.8	440.8	114.0	3.0	2524.7	57-67?
Baba I	2.2	20.9	117.7	142.1	167.3	182.7	234.1	306.0	308.4	193.4	57.5	12.2	1744.7	76-85
Babessi (Ndop)	8.7	16.1	88.6	131.8	143.3	182.6	255.8	283.6	245.8	164.4	38.6	3.3	1562.6	76-81/84-85
Babungo	6.4	21.5	97.0	152.9	144.6	184.7	231.0	269.2	276.3	164.9	44.6	0.5	1593.6	76-85
Bali	23.2	46.8	194.4	227.7	257.1	289.0	296.8	362.4	352.9	308.2	68.5	10.5	2437.5	78-83/85
Balikumbat	7.6	14.8	86.1	143.1	174.1	232.1	215.5	264.0	254.6	212.6	50.8	6.9	1662.2	76-85
Bambui (Station)	7.2	33.9	119.4	192.9	181.7	271.9	336.6	445.9	390.3	220.6	39.6	6.2	2246.2	75-84
Bambui (Plain)	24.8	15.3	116.9	219.5	134.2	244.4	393.5	453.8	377.7	240.9	26.6	12.3	2259.9	80-84
Bamenda	17.3	42.1	138.6	265.7	156.5	264.3	446.3	457.0	437.6	205.5	41.6	16.8	2489.0	76-85
Bamessing	7.1	20.3	95.5	162.1	174.7	224.1	214.6	275.0	318.2	219.3	45.7	5.2	1761.8	76-85
Bamunka	7.1	15.9	85.6	122.7	160.3	213.4	230.0	264.8	292.3	211.7	37.4	6.0	1647.2	76-85
Bamunkumbit	13.0	19.1	64.4	140.9	182.7	224.4	216.0	256.1	246.5	212.7	61.6	3.7	1641.1	76-85
Bangolan	5.0	10.3	67.0	94.4	141.8	180.0	209.6	229.5	251.0	201.0	33.3	2.0	1424.9	76-85
Banso (Kumbo)	8.8	23.1	110.8	128.4	157.7	196.5	312.2	346.5	257.8	190.0	34.9	2.7	1769.5	76-85
Fundong	36.3	53.5	146.3	284.4	379.7	413.0	572.8	615.3	474.7	300.7	73.7	3.9	3354.3	76-85
Jakiri	8.3	15.9	110.6	157.9	201.0	207.7	291.6	346.8	316.9	193.6	45.5	2.1	1897.9	76-85
Kimbi (Bum)	17.4	23.0	111.9	220.3	289.5	433.8	443.0	530.1	524.1	332.6	80.4	6.9	3013.0	76-85
Mamfe (SWP)	17.0	104.8	119.6	209.9	274.4	368.2	439.2	456.9	484.4	403.9	72.5	25.8	2976.6	71-80
Mbengwi (Monstery)	21.2	66.4	153.7	192.6	208.5	325.1	336.6	370.2	402.0	276.4	65.4	12.7	2430.8	76-85
Menda Nkwe	16.9	89.7	122.7	190.4	156.5	270.6	425.0	461.2	416.6	206.1	51.3	16.8	2423.8	76-85
Ndu (Tea)	10.1	15.8	114.1	128.3	201.5	217.9	270.2	305.3	299.4	219.2	47.6	5.1	1834.5	76-85
Nkambe	5.8	18.2	54.0	121.0	130.8	297.4	439.5	509.4	396.6	237.6	69.9	0.0	2280.2	76-85
Nkoundja (Western P.)	2.5	20.0	110.7	174.7	166.7	188.0	308.2	351.4	329.3	255.5	69.2	5.2	1981.4	71-80
Santa Coffee	12.0	17.1	101.5	182.9	220.4	255.7	260.3	311.1	360.2	265.3	55.8	13.6	2055.9	76-85
Shissong	7.7	13.3	114.6	147.5	198.8	245.8	319.5	392.4	361.4	238.4	49.6	4.9	2093.9	76-85
Tingo	15.8	27.6	124.3	144.0	148.2	202.8	353.4	272.2	295.4	225.3	41.9	9.4	1960.3	76-85
Tobin	15.4	26.8	115.9	122.3	177.6	187.4	177.1	337.1	289.7	216.4	69.5	27.4	1762.6	76-79/84-85
Wada Wum	13.4	49.0	170.1	262.7	376.9	392.7	403.3	427.7	432.4	380.5	61.2	10.8	2980.7	76-85
Widikum	12.7	41.0	167.8	186.5	183.2	263.4	352.1	518.6	341.2	243.5	95.0	14.4	2419.4	78-81/83-85

Table I.4 MEAN MINIMUM, MEAN MAXIMUM AND AVERAGE MONTHLY TEMPERATURE, NORTH-WEST PROVINCE

		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug	Sept.	Oct	Nov.	Dec.	Year	Period
Bambui	min	15.2	17.1	17.4	17.5	16.9	16.3	15.7	15.6	15.8	16.2	15.9	15.6	16.3	80-84
1600 m	max	26.6	27.9	27.0	25.4	24.8	23.7	22.4	22.4	22.6	23.8	24.6	25.3	24.7	80-84
	av.	20.9	22.5	22.2	21.4	20.9	20.0	19.0	19.0	19.2	20.0	20.3	20.4	20.5	80-84
Bamenda	min	15.0	16.0	16.6	16.4	16.2	15.3	14.9	15.0	15.0	15.5	15.0	14.5	15.5	71-80
1608 m	max	25.4	25.8	25.1	24.6	24.3	22.9	21.0	21.1	21.8	23.3	23.8	24.6	23.6	71-80
	av.	20.2	20.9	20.9	20.5	20.2	19.1	18.0	18.0	18.4	19.4	19.4	19.6	19.5	71-80
Dzeng	min	11.9	9.6	12.8	12.9	12.3	-	-	11.1	12.8	12.7	11.9	10.3	(11.8)	85
2160 m	max	24.9	25.9	25.5	23.1	22.8	-	-	21.8	21.8	21.4	22.6	23.0	(23.3)	85
	av.	18.4	17.7	19.2	18.0	17.5	.	.	16.5	17.3	17.0	17.3	16.6	(17.5)	85
Fundong	min	13.9	12.5	15.9	15.4	14.4	13.6	13.6	13.3	13.7	14.4	13.5	12.8	13.9	85
1551 m	max	26.4	27.4	26.9	24.6	25.3	24.1	22.7	23.2	23.7	24.8	26.0	26.7	25.1	85
	av.	20.1	20.0	21.4	20.0	19.8	18.9	18.1	18.3	18.7	19.6	19.7	19.8	19.5	85
Mamfe	min	19.7	20.5	22.2	22.0	22.4	21.9	21.9	21.7	21.7	21.6	21.2	20.3	21.4	62-72
126 m	max	31.6	33.6	33.0	32.8	32.5	30.9	29.6	28.8	30.2	30.9	31.7	31.3	31.4	62-72
	av.	25.7	27.0	27.6	27.4	27.5	26.4	25.7	25.3	26.0	26.2	26.4	25.8	26.4	62-72
Mbiyeu	min	13.5	12.0	14.0	14.1	13.6	12.8	12.1	12.5	12.3	12.5	13.4	12.6	12.9	85
2000 m ?	max	23.4	25.0	24.0	21.6	21.4	20.0	18.8	19.8	20.4	20.5	21.7	22.1	21.6	85
	av.	18.4	18.5	19.0	17.9	17.5	16.4	15.4	16.2	16.3	16.5	17.5	17.4	17.2	85
Ndu	min	11.0	11.9	13.4	14.2	13.6	13.1	12.3	12.2	12.1	16.2	11.4	10.4	12.6	81-85
2058 m	max	23.4	24.7	25.1	23.5	22.4	21.1	20.1	19.7	20.5	21.0	22.0	22.9	22.2	81-85
	av.	17.2	18.3	19.3	18.9	18.0	17.1	16.2	16.0	16.3	16.6	16.7	16.6	17.4	81-85
Nkoundja	min	16.0	16.1	18.0	17.8	17.0	16.7	17.0	17.0	16.2	16.5	16.8	16.3	16.8	51-72
1208 m	max	29.5	29.8	28.7	28.0	27.0	25.7	25.2	25.6	26.0	26.5	27.3	28.5	27.3	51-72
	av.	22.8	22.9	23.3	22.9	22.0	21.2	21.1	21.3	21.1	21.5	22.1	22.4	22.1	51-72
Nyen	min	11.6	9.5	15.3	16.3	16.3	16.0	15.7	15.5	16.0	16.1	15.0	11.5	14.6	85
(Mbengwi)	max	30.3	30.9	30.4	29.0	28.7	27.0	25.5	27.2	27.6	29.0	29.7	29.8	28.8	85
1250 m ?	av.	20.9	20.2	22.9	26.6	22.5	21.5	20.6	21.4	21.8	22.5	22.4	20.6	21.9	85
Santa	min	11.7	13.3	14.9	14.6	14.6	13.5	13.4	13.3	13.5	13.8	13.1	12.5	13.5	83-85
1750 m	max	25.5	27.2	27.0	24.3	23.8	22.7	22.1	25.2	22.9	23.2	25.2	26.9	24.7	83-85
	av.	18.6	20.3	20.9	19.4	19.2	18.1	17.8	19.2	18.2	18.5	19.3	19.7	19.1	83-85
Wada Wum	min	13.8	16.0	17.1	16.4	16.0	15.2	16.0	15.6	16.4	16.9	16.7	14.4	15.9	71
1100 m	max	28.3	28.4	28.2	27.8	27.6	27.0	25.6	25.7	25.9	26.4	27.2	28.3	27.2	71
	av.	21.0	22.2	22.7	22.1	21.8	21.1	20.8	20.6	21.2	21.6	22.0	21.3	21.5	71

APPENDIX II

EDAPHIC RATING OF SOILS FOR MAJOR CROPS AND EXTENSIVE GRAZING

Table II.1 EDAPHIC RATING OF SOILS FOR MAJOR CROPS AND EXTENSIVE GRAZING

Soil type	Maize	Arabica coffee	Robusta coffee	Oil palm	Extensive grazing
SOILS ON ORGANIC MATERIALS					
o1	N2ro	N2ro	N2ro	N2ro	S3on
o2	N2ro	N2ro	N2ro	N2ro	S3o
SOILS ON ALLUVIAL DEPOSITS					
al	N2r	N2r	N2r	N2r	S3r
SOILS ON ALLUVIO-COLLUVIAL DEPOSITS					
ac1	N2o	N2ro	N2ro	N2o	S3ro
ac2	N10	N2r	N2r	S3ro	S2rof
ac3	S3of	S3o	S3o	S2of	S2o
ac4	S3onfx	S3o	S3o	S3x	S2onf
ac5	S3nx	S2onfx	S2o	S3x	S1
SOILS ON COLLUVIAL DEPOSITS					
c1	S3nf	S2onf	S2of	S2nf	S2f
c2	S3nx	S3n	S3n	S3nx	S3n
c3	S3ofx	S3o	S3o	S2ofx	S2of
c4	N1x	S3x	S2ox	N1x	S2fx
c5	S3nx	S2onfx	S2o	S3x	S2f
SOILS ON VOLCANIC ASH AND SCORIA					
p1	S3nf	N2r	S3rn	N2r	S3n
p2	S3n	N2r	S3rn	N2r	S3n
p3	N2r	N2r	N2r	N2r	N2r
p4	S3n	S2rn	S2n	S2rn	S2n
p5	S3n	S3n	S3n	S3n	S3n
p6	S2nx	S1	S1	S1	S1
SOILS ON BASALT					
b1	S2rnx	S3r	S3r	S3x	S2r
b2	S3x	S2rx	S2r	S3x	S1
b3	S3nx	S3r	S3r	S3x	S1
b4	S3n	S3r	S3r	S3rx	S2r
b5	S3n	S3r	S3r	S3rx	S2r
b6	S3nfx	S3r	S3r	S3rfx	S2r
b7	S3nx	S3r	S3r	S3r	S2r
b8	S3nx	S2nf	S1	S2rnfx	S1
b9	S3rnx	N2r	N2r	S3r	S3r
b10	S3nx	S3n	S2n	S3x	S2n
b11	S3nx	S2nfx	S1	S3x	S1
b12	S3nx	S2nfx	S1	S3nx	S1
b13	S2nx	S1	S1	S2x	S1
b14	S3n	S2n	S2n	S2nx	S2n

Codes for main limitations:
- r - rooting
- o - oxygen availability
- n - nutrient availability
- f - nutrient retention
- x - toxicities

Table II.1 (Cont'd) EDAPHIC RATING OF SOILS FOR MAJOR CROPS AND EXTENSIVE GRAZING

Soil type	Maize	Arabica coffee	Robusta coffee	Oil palm	Extensive grazing
SOILS ON TRACHYTE					
t1	S3rnx	N2r	N2r	S3r	S2r
t2	S3rx	S3r	S3r	S3x	S3r
t3	S3x	S2rx	S2r	S3x	S1
t4	S3nfx	S3r	S3r	S3x	S1
t5	S3nx	S2rnfx	S2r	S3x	S1
t6	S3nx	S3r	S3r	S3rx	S3r
t7	S3nx	S3r	S3r	S3r	S3r
t8	S3n	S3r	S3r	S3r	S3r
t9	S3nf	S3r	S3r	S3r	S3r
t10	S3nx	S2rnf	S2r	S2rnfx	S1
t11	S3nx	S2nf	S1	S2nfx	S1
t12	S3nx	S3r	S3r	S2rf	S1
SOILS ON MIGMATITE AND MESOTYPE BASEMENT ROCK					
m1	S3rnfx	N2r	N2r	S3r	S3r
m2	S3rnfx	S3r	S3r	S3r	S3r
m3	S3nfx	S3rx	S3r	N1x	S2f
m4	S3nfx	S2rnfx	S2rf	S3x	S2f
m5	S2rnfx	S3r	S3r	S3rx	S3r
m6	S3nfx	S3r	S3r	S3rx	S3r
m7	N1x	S3r	S3r	S3rx	S3r
m8	N1x	S3r	S3r	S3rx	S3r
m9	N1x	S3r	S3r	S3x	S2fx
m10	S3nf	S3r	S3r	S2nfx	S2rnf
m11	S3nf	S2nf	S2nf	S2nfx	S2nf
m12	N1x	S3n	S2f	S3x	S2nfx
m13	S3n	S2rnf	S2r	S2rnf	S1
m14	S3n	S2rnf	S2r	S2rnf	S2f
m15	S3nf	S2nf	S2f	S2nf	S2f
m16	S3n	S2nf	S1	S2nf	S2f
m17	N1x	S3r	S3r	N1x	S2rnfx
m18	N1x	S3fx	S3f	N1x	S3f
m19	N1x	S3fx	S3f	N1x	S3f
m20	N1x	S3rfx	S3rf	N1x	S3f
SOILS ON GRANITE AND LEUCOCRATIC BASEMENT					
g1	N2r	N2r	N2r	S3rn	N2r
g2	S3rnfx	S3r	S3r	S3r	S3r
g3	N1x	S3r	S2rf	S3r	S2fx
g4	N1x	S3rf	S3f	S3r	S3f
g5	N1x	S3r	S3r	S3rx	S3r
g6	N1x	S3r	S3r	S3r	S3r
g7	N1x	S3r	S3r	S3rnx	S3r
g8	N1x	S3r	S3r	S3rnx	S3r
g9	N1x	S2rnfx	S2rf	S2rnfx	S2fx
g10	N1x	S3rn	S3r	S3r	S3r
g11	N1x	S3r	S2ronf	S3r	S2r
g12	N1x	S3rx	S2ronfx	N1x	Sonfx
g13	S3nfx	S3x	S2fx	N1x	S2f
g14	S3nf	S2rnf	S2rf	S2rnf	S2f