REPUBLIC OF CAMEROON

MINISTRY OF SCIENTIFIC AND
TECHNICAL RESEARCH

INSTITUTE OF AGRICULTURAL
RESEARCH FOR DEVELOPMENT

AGRICULTURAL RESEARCH
CENTRE EKONA

SOILS PROGRAMME

SOILS AND LAND SUITABILITY OF THE EKUNDU KUNDU VILLAGE RESETTLEMENT AREA FOR KORUP PROJECT

NDJIB G.
AWAH E.T.
TCHUENTEU F.

Soils Programme
Technical Report No. 96/01

June 1996

"We strongly believe that soil, as a medium for crop growth, is of paramount importance for human activities, especially in rural development. We hope that the little information collected during the field trips to the survey area will help to ensure a proper resettlement for the welfare of the Ekundu Kundu people".

Soils Unit IRA Ekona
June 1996

TABLE OF CONTENTS

PART IV

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGEMENT

The authors wish to acknowledge the assistance of the following:

KORUP PROJECT, especially Mr. Paul Symonds (former Project Manager), Mr. Balinga, Project Manager and Mr. Besong Ntui OGORK, Senior Rural Development Officer for all their assistance and understanding.

IRA EKONA - Chief of Centre and Administrative staff for providing the facilities for the work.

- The Soils Laboratory personnel for analysis of samples.

- The Soils Unit Cartography technicians Messrs Fritz Fombad and Essama Dieudonné for drawing the maps.

- The Soils Unit Secretary Mr. Paul Takem for his patience during the production of this report.

- Mr. Ehabe Eugene for his great assistance in the final editing of this report.

- The team leaders and workers recruited in Mundemba and who participated in the trace cutting and field work.

- Finally Lt. John Fungwa Jinka of the Gendarmerie Mundemba and Martha 'Sure' Enterprises who made pleasant the social part of our stay in Mundemba.

SUMMARY

A 5500 ha piece of land under virgin forest near the Korup Reserve was recently surveyed by Soil Scientists of the Institute of Agronomic Research (IRA) Ekona Centre. The aim of the survey was to produce soil and land suitability maps of the area and to make recommendations for the resettlement of the village of Ekundu Kundu. The survey was done along traces cut in the forest in a grid pattern and the land suitability was based on the limitations method.

Three major soil types were identified:

- Soils on basalt which are deep, clayey, well drained and rather rich in N & K. Major problems of these soils would be the low pH (4.0), low levels of available phosphate and the rather high level of coarse fragments in the soil. These are the best soils in the area but unfortunately they cover only about 13% of the total surface area.

- Soils on gneiss and other basement complex rocks: These are sandy clay loam and sandy clay soils which are mostly very gravelly, poor and are on steep slopes. They are only marginally suitable for the crops considered in the evaluation. Their major problems include susceptibility to degradation (fertility and erosion), low nutrient levels, high gravel content. In addition these soils are mostly shallow. These cover more than 86% of the area.

- Soils on alluvial and colluvial material: These are in two small units in the survey area (about 1%). They are deep and suitable for all the crops considered.

Of the total area of 5500 ha more than 50% is suitable for all the crops considered (except oil palm) but most of this land is only marginally suitable, the major limitations being soil physical conditions, depth, slope and gravel content. Although these lands are recommended for various crops, appropriate soil improvement methods which are easily adoptable at farmer level should be practised.

PART I

1. INTRODUCTION

Upon offer of bids[1] for the Service Contract N° 04/KP/95 and award of this contract to IRA Ekona by the Korup Project, the Soils Unit of the Agronomic Research Centre Ekona recently carried out a semi-detailed soil survey of 5500 ha of land in the Project area at Mundemba bordered by the Ndian, Medidiba and Mana rivers. The aim of the survey was to produce land suitability maps of the area for resettlement and general agricultural purposes.

The survey area is located about 8 km NNE of Mundemba town in the form of an irregular hexagon enclosed by three main rivers as stated above. The longest dimensions NS and EW are in the order of 12.25 and 7.5 km respectively.

2. MATERIALS, PERSONNEL AND METHOD

2.1 Materials

The materials used included:

a) Soil survey equipment: compasses, 50 m tapes, cutlasses, files, clinometers, satellite locating equipment (G.P.S), altimeters, soil augers, pick-axes, spades, shovels, markers, soil sampling forms, topography, hydrography and vegetation description forms, sampling bags and twine.

b) All relevant and available maps

- Topographic map MAMFE NB-32-X, scale 1/200.000, 1979 (3rd edition) C.G.N, Yaounde.

- Topographic Map of The Korup Project area Cameroon, scale 1/200.000, 1989, O.D.N.R.I.

- Soil, Parent material, Landform maps of the Korup Project area Cameroon, scale 1/100.000, 1987, Land Resources Development Centre, Overseas Development Administration.

c) Aerial photographs

- Southern Cameroons black and white panchromatic photographs, scale 1/50.000, 1958 covering the northern part of the resettlement area.

- Mission A.E. NB-32-IX-X black and white panchromatic photographs, scale 1/50.000, 1964, N.G.C. Yaounde.

---

[1] An initial bid involving the use of aerial photographs was later revised when it was found that the available aerial photographs were of poor quality and could not be used.

2.2 Personnel

The following personnel of the Soils Programme of the Agronomic Research Centre Ekona participated actively in the study:

Field work and report writing done by Messrs **Gilbert Ndjib** and **Emmanuel Tah Awah**.

Laboratory Analyses conducted by Mr. **Frédéric Tchuenteu**.

2.3 Method

All existing maps and aerial photographs were studied with the aim of identifying the main relief components (topography) so as to select the sites for trace cutting where soil augering would be carried out to show soil differences due to topography and other soil forming factors such as parent material, etc... A layout map of scale 1/50.000 (field reconnaissance map) was then produced for the trace cutting which in fact were 1 to 2 km apart in the field. This was followed in the field by trace cutting over the whole survey area as a first step.

The second phase consisted of observations by soil augerings to a depth of 110 cm every 100 metres along the pre-cut and additional traces crossing different landforms. These additional traces (18.2 km) were useful as "filling in" in areas where we needed to be sure of the boundaries. Slopes were measured every 50 metres and the natural vegetation or the land-use described.

Altitudes were also recorded every 100 metres. Direction and azimuth of traces were also checked. At each point of observation soil depth, colour, texture and coarse fragments were recorded. The width and altitude of streams were also measured. These observations were then studied and grouped according to their similarities. Soil profiles representing each group were dug to a depth of 150 cm, described and sampled for analysis. By the end of the survey a total of 900 observations by auger and 15 soil profile pits were dug and described.

The 900 observations were plotted on the revised field reconnaissance map and similar areas in terms of landform and soil delineated taking into account all the data collected during the field work. The resulting soil map was used as a basis for land suitability study and compilation of subsequent maps.

The land suitability study was done according to the 'matching' process (FAO, 1976) in which the land characteristics or qualities are compared with the requirements of the crops under consideration. The limitation method was used to determine the suitability classes and sub-classes. Suitability maps for the various crops were produced from the soil map.

PART II : THE ENVIRONMENT

3. NATURAL SETTING OF THE SURVEY AREA

3.1 Location and Extent

The survey area for the resettlement of the Ekundu-Kundu village is on both sides of the only motorable fair weather road from Mundemba to Fabe over a distance of 7.5 km between the bridge over river Medidiba and the foot-bridge over river Mana. This area is about 5500 ha and lies between latitudes 5°0'19" - 5°8'9" N and longitudes 8°52'49" - 8°56'57" E and is bordered by the rivers Ndian, Medidiba and Mana about 8 km NNE of Mundemba town in Ndian Division.

3.2 Relief and Geology

The whole survey area is low in elevation (<400 m above mean sea level) and most of it is less than 200 m. The elevation increases from about 80 m by the Ndian river in the SW to about 160 m in the NE and 360 m along the foot of the Rumpi Hills in the SE where the highest areas are found. The terrain is generally rugged, with rock outcrops and steep to very steep slopes. The North eastern and South eastern parts of the area are the most steeply dissected. The main landforms in the field are plateau-like areas and narrow crested ridges, both having edges which are usually steep. These various basic units are separated by flat, gently sloping to sloping lands or gully bottoms and valley floors that are narrow with small, discontinuous, relatively flat areas which are poorly drained (swamps).

These landform units are related to some extent to the types of soil parent material. The plateau-like areas and some of the ridges consists of tertiary basalt (about 13% of the area), especially in the Centre and South East. Precambrian basement rock occupies the rest of the area. This rock complex consists mainly of coarse to medium grained leucocatric gneiss, rich in quartz and feldspars. This type of gneiss is very resistant to weathering, with the result that most of the soils are shallow, very gravelly or stony. In some places (SE, Centre and NW), the gneissic rocks are fine-grained and relatively rich in ferro-magnesium minerals giving rise to deep sandy clay soils.

3.3 Climate

No recent climatic data was available to us. Old data from Pamol Ndian for the period 1968-1981 have been used (Table 1). The average annual total rainfall for this period of 5470 mm is very high and over 3000 mm falls in June-September, while less than 300 mm falls in December-February. This total is more than sufficient for most of the locally grown crops, but the distribution is poor. The average monthly maximum and minimum temperatures are also ideal for the same crops.

Table 1: **Climatic data of Ndian Estate** (1968-1981 averages)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Rainfall(mm)	**48.3**	**138.3**	**309.0**	**324.6**	**359.4**	**642.3**	**846.4**	**945.5**	**836.4**	**594.0**	**319.6**	**106.1**	**5470**
N° of Rainy days	**3.9**	**8.7**	**17.2**	**19.6**	**20.9**	**26.0**	**26.7**	**29.4**	**27.1**	**25.1**	**12.4**	**8.2**	**230.2**
Max. Temp. °C	**31.2**	**32.5**	**31.8**	**31.6**	**31.2**	**29.6**	**28.1**	**27.2**	**28.5**	**29.4**	**30.5**	**30.7**	
Min. Temp. °C	**23.1**	**24.3**	**24.3**	**24.4**	**24.1**	**23.9**	**23.6**	**23.6**	**23.3**	**23.5**	**23.8**	**23.3**	
Mean Temp. °C	**27.2**	**28.4**	**28.1**	**28.0**	**27.7**	**26.8**	**25.9**	**25.4**	**25.9**	**26.5**	**27.1**	**27.0**	

The soil moisture regime is Udic while the temperature regime is Isohyperthermic.

Source: Awah, 1984.

3.4 Hydrography

The area is drained from the foot of Rumpi Hill in the SE by the rivers Medidiba and Mana with their tributaries into the Ndian river, which flows in the western part southwards. Most of these rivers and streams, including the upper part of river Ndian, flow in deeply incised valleys and vales cut through the basement rock complex with the result that their courses are very irregular. Under the previous and present climatic conditions, these rivers and streams were and are still aggressive, leading to the formation of a rugged terrain around the basalt landscape in the Centre and SE with virtually no permanent streams and which is the main watershed of the area.

3.5 Natural vegetation and land-use

The survey area is covered with dense, lowland evergreen forest dominated by the family of Caesalpiniaceae. It is largely in an untouched state. However, where the soils are rocky (especially on basalt soils) or swampy, the forest is replaced by narrow glades or narrow swampy areas respectively, the latter dominated by the raphia palms (*Rhizophora mucronata*).. Cleared areas, especially along the road between the two rivers Medidiba and Mana, are invaded by fast growing herbaceous species like *Chromolaena odorata*, etc... The main users of the forest are hunters and fishermen who have built huts in the forest and planted some food and perennial crops around them. The presence of these groups of people is attested by many tracks, hunters' huts with chop farms, perennial tree crops, palms, cocoa, around not exceeding 1/2 ha in size and mostly on basalt soils.

PART III: RESULTS

4. THE SOILS

The major geologic formations in the area are precambrian basement complex rocks, intrusive basalt of tertiary age and alluvial deposits near river Ndian. The soils formed in these materials reflect these parent materials. The major soil groups identified in the area are:

4.1 Soils on Tertiary Basalt (Map symbol B)

These are generally deep reddish brown clayey soils in the Centre East and South East of the survey area. They are usually stony, gravelly and well drained. These soils have a good structure and reasonable chemical properties (Appendices 1 & 2). The major limitation for village level farmers will be the stones and gravel which will hamper seedbed preparation in addition to the steep slopes sometimes encountered in the mapping units of basalt soils. The soils are very acid with pH less than 4.5 which is limiting to some crops. These basalt soils are the best soils of the area (Table 2).

4.2 Soils on Precambrian Basement Complex (Map symbol G)

These soils, developed in gneiss, granites and micaschists occupy about 86% of the survey area. The topography is rather difficult, with steeply dissected and few flat areas. The soils are varied but all are sandy clayey (sandy loam - sandy clay loam topsoil) mostly gravelly and shallow, in view of the fact that the gravel content of the subsoil is very high. The gravel is usually coarse-grained quartz, some lateritic rubble and rock fragments. They have poor physical and chemical properties (Appendices 3 to 5) but the level of exchangeable potassium is not very low in all the units.

For these soils to be brought under cultivation strict soil management practices should be maintained otherwise the topsoil in which most of the nutrients are found will be eroded or degraded.

4.3 Soils on River Flood Plains (Map symbol A)

Two very small units were mapped in the SW and NW parts of the survey area and were found to consist of deep, well drained clay loam and sandy clay loam soils. No representative soil profile pits were dug in the units because of their extent and distances from any resettlement village(s).

Table 2: **Characteristics of the Land Mapping Units.**

Characteristics	**LAND MAPPING UNIT**														
	Bft	Bss	Gad	Gaf	Gag	Gal	Gam	Gao	Gas	Gbf	Gbg	Gbm	Gbo	Af	Ag
CLIMATE															
Rainfall (mm)	All units 5470mm average annual														
Temperature (°C)	All units 27°C average mean monthly														
PHYSICAL SOIL FACTORS															
Depth (cm)	150	150	150	50	75	75	50	50	40	150	50-150	50-150	50	150	150
Texture	C	C	SC	SC	SC	SC	SC	SC	SC	SC	SC	SC	SC	CL	SCL
Drainage	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W
Stones (%)	25	25	0	35	40	20	10	40	25	5	0	5	50	0	0
Gravel (%)	50	40	25	50	50	40	50	50	50	10	10	20	20	0	0
CHEMICAL SOIL FACTORS															
CEC(cmol(+)/kg)	30	23	13	8.6	13	13	13	13	13	11	8.6	8.6	13		
Exch. K^+ (")	0.4	0.4	0.2	0.15	0.2	0.2	0.2	0.2	0.2	0.05	0.2	0.2	0.2		
Exch. bases (")	3.6	2.0	1.6	0.9	1.6	1.6	1.6	1.6	1.6	0.3	0.99	0.99	1.6		
Total N (%)	0.4	0.5	0.1	0.1	0.1	0.1	0.1	0.1	0.1	.08	0.11	0.11	0.1		
P (ppm)	3	4	7	7	7	7	7	7	7	6	7	7	7		
Org. C (%)	6.0	6.0	.8	1.4	.8	.8	.8	.8	.8	0.7	1.4	1.4	0.8		
pH	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.4	4.1	4.1	4.0		
Al Sat. (%)	30	30	38	34	38	38	38	38	38	52	34	34	38		

C = Clay; SC = Sandy Clay; CL = Clay Loam; W = Well drained

5. MAP SYMBOLS AND LAND MAPPING UNITS

The characteristics of the land mapping units are shown in Table 2. Map symbols used in the soil map are self explanatory (Table 3). Soils developed in basalt are designated B soils, those in basement rock complex G soils and those in alluvium A soils. Table 3 also shows the area covered in hectares by each mapping unit.

Table 3: **Description of the Land Mapping Units (LMU) and their extent.**

LMU	Description	Area
B.	Soils developed in tertiary basalt	
Bft	Deep gravelly to very gravelly (mainly lateritic gravel) clay soils on flat to almost flat (0-2% slopes) (locally gently sloping) surfaces.	220.0 ha
Bss	Deep to moderately deep, fairly stony or stony clay soils (locally stony and boulder-paved surfaces) on moderately steep to steep slopes (13-55%).	473.0 ha
G.	Soils developed in precambrian basement complex rocks	
Gad	Deep sandy loam to sandy clay soils on flat lands (0-2% slopes)	16.5 ha
Gaf	Shallow to moderately deep fairly stony and gravelly (mainly quartz fragments) sandy loam to coarse sandy clay soils on flat lands (0-2% slopes).	466.5 ha
Gag	Shallow (locally moderately deep) gravelly or stony sandy loam to coarse sandy clay soils on gently sloping to sloping lands (2-13% slopes).	1051.5 ha
Gal	Shallow (locally moderately deep) gravelly, (locally stony) sandy loam to coarse sandy clay soils on sloping lands (6-13% slopes).	378.0 ha
Gam	Shallow gravelly sandy loam to coarse sandy clay soils (locally paved with stones) on sloping to moderately steep lands (6-25% slopes).	443.5 ha
Gao	Shallow, gravelly and stony sandy loam to coarse sandy clay soils on moderately steep lands (13-25% slopes), locally rocky.	233.5 ha

Gas	Very shallow to shallow stony and gravelly (mainly quartz fragments) sandy loam to coarse sandy clay soils on steep to very steep slopes (25-55% slopes or more), locally bouldery or rocky.	1288.0 ha
Gbf	Deep sandy clay loam (locally sandy loam) soils on flat to gently sloping lands (0-6% slopes).	39.0 ha
Gbg	Shallow (locally deep) gravelly sandy clay loam soils on gently sloping to sloping lands (2-13% slopes.	312.5 ha
Gbm	Shallow, (locally deep) gravelly sandy clay loam soils on sloping to moderately steep lands (6-25% slopes).	410.5 ha
Gbo	Shallow (locally deep) gravelly sandy clay loam soils on moderately steep to steep lands (13-55% slopes).	98.5 ha

A. <u>Alluvial and Colluvial soils</u>

Af	Deep well drained clay loam soils on flat narrow river flood plain (0-2% slopes).	52.5 ha
Ag	Deep well drained sandy clay loam soils on gently sloping lands (2-6% slopes)	16.5 ha

6. LAND SUITABILITY

Land suitability is the fitness of a piece of land for a specific purpose. Suitability in this context does not only mean that land is fit for that purpose. It also means that the piece of land will sustain that use without in itself being degraded in the process. Thus a land which is suitable for a given crop means that the crop will grow and produce on that land for a long time without irreversibly degrading the land. Unsuitable lands are lands which will not sustain the production of a crop even though the crop can grow on it for short periods.

6.1 Basic concepts

In every exercise to evaluate the suitability of a piece of land for any purpose there are certain basic concepts to be defined. These concepts include :-

- The objectives of the exercise: these must be made clear by the person asking for the evaluation.

- Land utilization type (LUT): this involves the definition of the type of crop (or crops) and the level of management to be used, amongst other aspects. In this survey Korup project specified that the land would be for subsistence farmers growing annual and perennial crops in association with little inputs.

- Description of the land mapping units (LMU): this is done in the soil survey part of the report.

- Description of the requirements of the land utilization types.

- Matching the requirements of the land utilization types with the description of the land mapping units (LMU) by means of degrees of limitation of the LMU's to the various LUT's. The result of this exercise is the suitability sub-class.

6.2 Structure of the Suitability Classification

6.2.1 Land Suitability Orders.

Land suitability orders indicate whether the land is suitable or not suitable for the use under consideration. The symbols are: S = Suitable, N = Not Suitable.

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 the land.

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

Land may be classed *Not suitable* for various reasons. There might be physical as in the case of very steep lands whose cultivation will cause serious erosion, or economic then the input will be more than the output in terms of money.

6.2.2 Land Suitability Classes

Land suitability classes reflect the degree of suitability. The classes are numbered 1-3 in decreasing degrees of suitability.

Class S1: Highly Suitable - Land having no limitation to sustained use or only minor limitations which will not significantly reduce productivity or benefits and which can be controlled easily.

Class S2: Moderately Suitable - Land having limitations which in aggregate are moderately severe for sustained use. The limitations will reduce productivity and benefits and increase required inputs to the extent that the overall advantage to be gained from the use, although still attractive, will be inferior to that expected from class S1 lands.

Class S3: Marginally Suitable - Land having limitations which on the whole are severe for sustained use. The limitations will reduce production/or increase cost but not to unacceptable levels.

Class N2: Permanently Unsuitable - Land having limitations which appear so severe as to preclude successful sustained use of land.

6.2.3 Terminology used in this study:

Land Suitability Orders: These reflect the kind of suitability. In this study S = Suitable and N = Not Suitable.

Land Suitability Classes: These reflect the degree of suitability within the order. S1 = Highly Suitable, S2 = Moderately Suitable, S3 = Marginally Suitable.

Land Suitability sub-classes: These reflect the kind(s) of limitation(s) within the classes: e.g. S2f = limitation due to fertility, S2s = limitation due to slope.

6.3 Land Qualities

For the purposes of this evaluation the following land qualities were considered:-

6.3.1 Climate: The limitation of the LMU's due to climatic conditions was evaluated from the characteristics of annual average rainfall, annual average mean temperature which are very uniform through out the area.

6.3.2 Physical soil conditions: The factors used for this evaluation included the following: texture, soil depth, slope, drainage condition, amount of stones and gravel.

6.3.3 Chemical soil conditions: The factors used included the exchange properties, exchangeable bases, total N, available P, C/N, organic carbon, etc.

6.4 Crop Requirements

6.4.1 Plantains and Bananas (*Musa spp.*)

These plants are giant perennial herbs with an underground rhizome which grow in tropical areas where there is no frost. Ideally, areas for their cultivation should have temperatures of 25-28°C and rainfall of 1000-1500 mm per year.

Plantains and bananas thrive on free-draining, well-aerated, deep fertile loamy soils, but can be produced on a wide range of soil types provided these soils respond to improvements. The soil should have a high water-holding capacity as these plants are susceptible to water stress. Mulching, which is one of the soil improvement practices recommended to farmers, is a good way of improving the water balance of a soil.

Table 4: **Environmental requirements for Plantains and Bananas**

	Quality/ Characteristics	Suitability Sub-class			
		S_1	S_2	S_3	N_2
Climate	1. Temp. (°C)	25-28	15-25	>25	<15
	2. Rainfall (mm/yr)	1500-2000	<1500	Poor Distribution	Dry areas
	3. Altitude (m)	0-200	200-400		
	4. Wind speed (km/h)	<50	50-100		>100
Soil	**1-Physical**				
	-Texture	loam & fine sand	clay & silts	coarse sands	heavy, com-pact clay
	-Structure	Crumby sub-angular blocky	Angular blocky and prismatic	-	Massive and compact
	-Drainage	Well (free)	Moderate	Moderate	Poor
	-Depth to water table (cm)	>150	100-150	100	<100
	-Avail. water	high			low
	-Slope (%)	<2	2-5	5-8	>10
	2-Chemical				
	-pH	6-6.5	5-6	4-5 & 6-7	<4 & >7
	-Avail. P (ppm)	85-100	50-85	20-50	-
	-Exch. K (cmol(+)/kg)	>0.5	<0.5	-	-
	-Total N (ppm)	>1200	<1200	-	-
	-C/N	10	10-20	>20	-
	-CaO/MgO/K_2O	10:5:0.5	-	-	-

Source: J.R. Landon, 1984.

Musa spp requires slightly acid to neutral soils (pH 5.5-7.5) but ideally the pH should be around 6.5 for optimum productivity. Nitrogen and potash are required in high amounts for sustainable production. Critically low levels of nutrients have been quoted as 1.200 ppm for Nitrogen, 50 ppm for Phosphate and 150 ppm for Potash (Simmonds, 1966). Bananas and plantains are also susceptible to nematodes and over attacks which destroy the underground rhizome and render the plant weak and unable to feed well and resist high winds. They should therefore not be planted for long periods on the same land if these pests are not controlled. These requirements are summarized in Table 4.

6.4.2 Cocoa (*Theobroma cacao*)

Cocoa grows in tropical regions with temperatures ranging from 15-30°C but ideally 21-28°C and the diurnal range should not be more than 9°C. Rainfall in cocoa area should vary from 1200-2500 mm per annum and is best when evenly distributed with no marked dry season.

As with most crops, cocoa thrives in deep loamy well drained soils rich in plant nutrients. In high rainfall areas the soil should be freely draining because cocoa does not withstand prolonged periods of water logging. Good cocoa soils should have pH of 5.5-7.0, sum of bases of >10 cmol(+)/kg and total nitrogen content of >0.2%. Shading is a requirement for cocoa, especially where soil conditions are not ideal as the case in the resettlement areas. Table 5 summarizes these requirements.

Table 5: **Environmental Requirements for Cocoa.**

Land Quality/ characteristics	Suitability class			
	S1	S2	S3	N2
1. CLIMATE				
-Rainfall (mm)	1200-2500	2500-5000	1000-1200	< 1000
-Av.an.temp.(°C)	21-28°C	15-21°C	28-30°C	<15°C & >30°C
2. SOIL PHYSICAL FACTORS				
-Texture	loamy		clayey	sands & heavy clays
-Drainage	well drained	mod.well drained	imperfect	poorly drained
-Soil depth (cm)	>150	100-150	50-100	<50
3. SOIL CHEMICAL FACTORS				
-pH	6.5-7.5	5.5-6.5	5-5.5	<5.0
-Total N (%)	>3.0	2.0-3.0	0.05-2.0	
-C/N ratio	11.5	9.5-11.5	7.5-9.5	
-P_2O_5 (ppm)	>120	60-120	20-60	
-Exch. K (cmol(+)/kg)	>0.4	0.3-0.4	<0.25	
-Sum of bases "	>10	<10	-	

Adapted from de Geus (1973)

6.4.3 Robusta Coffee (*Coffee canephora*)

Robusta coffee is grown largely in the warm lowlands of tropical areas. Its environmental requirements are:
Rainfall 1000-2500 mm per annum, 18-32°C average annual temperature and can be grown on shallow soils in high rainfall areas. Ideally, coffee soils should be deep loamy (Table 6). Although, well drained soils rich in plant nutrients are satisfactory, robusta coffee is known to grow and produce in poorer soils.

Table 6: **Environmental requirements of Robusta Coffee.**

Land Quality /Characteristics	Suitability Class			
	S1	S2	S3	N2
1. CLIMATE -Annual rainfall (mm) -Av. annual temp.(°C)	>1700 18-32°C	1500-1700	1000-1500	<1000
2. PHYSICAL SOIL FACTORS				
-Texture -Drainage	loamy well		imperfect	sands, heavy clays poor
3. CHEMICAL SOIL CONDITIONS				
-CEC (cml(+)/kg) -Base sat. (%)	>10 >35	<10 <35		

6.4.4 Root and Tuber Crops (cocoyams, yams & cassava)

These are the food crops which are normally grown in the Mundemba area. These crops require a reasonable rainfall (1000 mm per annum), deep rich soils with little coarse fragments. Well drained soils (except some cocoyam species), are best. These crops remove a lot of plant nutrients from the soil hence this must be replaced periodically through proper land management.

6.4.5 Maize (*Zea mays L.*)

Also known as corn, maize is a stout annual grass with a single stem.

Maize requires high light intensities especially for the synthesis of carbohydrates. For germination maize requires temperatures above 10°C. High temperatures above 35°C disrupt maize pollination and fertilization. The length of the growing cycle is longer at high altitude than at sea level. High windspeeds are detrimental to maize plants.

The availability of oxygen during germination is crucial. Rainfall during the 30 days preceding germination should be less than 60 mm. If this rainfall is more than 120 mm, there would be poor germination percentage. Water shortage 30-40 days either side of flowering is critical, especially in soils that do not store adequate amounts of water. Best yields are on well-drained and deep loamy soils.

Maize performs well on well-drained, deep, loamy and fertile soils with a good water holding capacity. Areas with high exchangeable Aluminium and low pH (< 5) should be avoided (Table 7).

Table 7: **Environmental requirements for Maize**

Quality/ Characteristics		Suitability Sub-class			
		S_1	S_2	S_3	N_2
A Climate	1-Temp (°C)	18-35	15-18	14-15	<14+frost + hails
	2-Rainfall (mm/yr)	>750	300-750	-	<300
	3-Altitude(m)	0-1800	1800-2200	2200-2600	>2600
	4-Windspeed	low	-	-	high
B Soils	I-Physical				
	1-Texture	L, SiL, fSCL	high C cSCL,SL	cSL,LS	C,S
	2-Drainage	well	moderate to excessive	moderate to poor	poor
	3-Water table	-	-	high	low
	4-Avail water	high	-	-	water-logged
	5-Slope (%)	Flat gently sloping	Gently sloping	-	>10
	II-Chemical				
	1-pH	6-7	4 5-6	>7	<4 5
	2-Avail. P	>20	7-20	-	<7
	3-Exch. K	>0 5	-	-	-
	4-Total N	high	-	-	-
	5-C/N	<12	12-17	>17	-
	6-CaO/MgO/K_2O	-	-	-	-
	7-Al sat., %	<10	10-30	30-60	>60
	8-Org C., %	>3	1 2-3	1-1.2	<1
	9-CEC7	>24	16-24	<16	-
	10-TEB	>12	5-12	<5	-

Texture: S - Sand or Sandy, Si - Silt or Silty, C - Clay or Clayey, c - coarse, f - fine, L - Loam.

Source: J.R. Landon, 1984.

6.4.6 Oil palm (*Elaeis guineensis*)

Oil palm is a crop of tropical regions requiring for optimum yields:

a) a constant temperature of 24-28°C with mean maximum and minimum of less than 32°C and 18°C respectively throughout the year;

b) a well distributed rainfall of at least 1500 mm per year without prolonged dry periods;

c) an adequate number of sunshine hours. 1500 hours per year has been suggested as the minimun requirement but oil palms are known to grow and produce well in areas with less than 1500 hours (CDC West Coast has 1200 hours);

d) the oil palm can grow in a wide variety of soil types but a deep loamy soil rich in humus with a well developed structure, a loose, friable consistency and without any root-hindering layers within 150cm of the surface is the best soil. Altitudes should not exceed 600m. The oil palm requires soils rich in plant nutrients. Where these are not available in the soil, management practices which aim at improving soil fertility should be put in place. These requirements are summarized in Table 8.

Table 8: **Environmental requirements for Small Holder Oil Palm**

Quality/ Characteristics		Suitability Sub-class			
		S_1	S_2	S_3	N_2
A Climate	1-Temp.(°C)	24-28	<24 >32		
	2-Rainfall (mm/yr)	1500-3000	<1500		<500
	3-Length of dry season	<1 month	2-3 moths	>3 months	
B Soils	I-Physical				
	1-Texture				
	2-Drainage	well	moderate	imperfect	poor and excessive
	3-Soil depth (cm)	>100	<100		
	4-Stoniness (%)	none	10-25		rubble land
	5-Slope (%)	<10	>10	>50	
	II-Chemical				
	1-pH	5 5-7		<4.5	>7 5, <3 5
	2-CEC (cmol(+)kg 1)	>20	<20		
	3-Base saturation %	>50	<50		
	4-Exch.K^+ (cmol(+)kg 1)	>0 4	<0 4		

Adapted from FAO-UNDP Soil Science Project, 1977 and Awah, 1984.

6.5 Suitability of the lands for various crops

The limitations of the land mapping units for various crops are shown in Tables 4 to 8. The evaluation of the lands has been done for crops grown in monoculture but usually in traditional farming systems, farmers practice multiple cropping where more than one crop is grown on the same piece of land. The usual mixtures in the area of Ndian are root and tuber crops plus maize and/or tree crops. The interactions of such crops grown in association has not been studied so there is no available data on which to base an evaluation. The suitability sub-classes in the tables below indicate the most important limitation of the land mapping units. In the sub-classes the following low case letters are used:

f = limitation due to poor chemical soil conditions,
p = limitation due to poor physical conditions,
s = limitation due to steep slopes,
d = limitation due to shallow soils,
t = limitation due to stone and/or gravel,

and the degrees of limitation are as follows:
1 = no limitation,
2 = slight limitation,
3 = moderate,
4 = severe limitation.

6.5.1 Plantains and bananas

Out of the total area of 5500 ha, 3880 ha are suitable for plantains and bananas, but most of this is marginal land which should only be used in extreme cases (Table 9). These marginal lands have soils with a lot of gravel and/or stones, shallow depth, and most of the slopes are not ideal for plantains and bananas, especially as the topsoils are sandy. Only 289 ha consisting of the units Bft (on basalt) and Af and Ag (on colluvium/alluvium) are moderately suitable and can be used for the crops without much difficulty.

Table 9: **Degrees of limitations of the Land Mapping Units (LMU) for Plantains/Bananas.**

LMU	DEGREE OF LIMITATION					
	Chem. soil cond. (f)	Phys. soil cond. (p)	slope (s)	Soil depth(d)	Stones/ gravels(g)	suitability sub-class
Bft	2	1	1	1	2	S2fg
Bss	2	1	3	2	2	S3s
Gad	3	3	1	1	1	S3fp
Gaf	3	3	1	2	2	S3fp
Gag	3	3	2	2	2	S3fp
Gal	3	3	2	2	2	S3fp
Gam	3	3	2	2	2	S3fp
Gao	3	3	3	3	2	N2sp
Gas	3	3	4	3	3	N2s
Gbf	3	3	1	1	2	S3fp
Gbg	3	3	2	2	1	S3fp
Gbm	3	3	3	2	2	S3fp
Gbo	3	3	4	3	3	N2s
Af	2	1	1	1	1	S2f
Ag	2	1	1	1	2	S2fg

S1 = Highly suitable lands = 0.0 ha
S2 = Moderately suitable lands = 289.0 ha
S3 = Marginally suitable lands = 3591.0 ha
N2 = Unsuitable land = 1620.0 ha
Total area = **5500.0** ha

6.5.2 Cocoa

The overall suitability of the land for cocoa is poorer than that for plantains and bananas also due to the same constraints. Units Bft, Af and Ag are quite suitable for cocoa while the rest are either only marginally suitable or unsuitable (Table 10).

Table 10: **Degrees of limitations of the Land Mapping Units (LMU) for Cocoa.**

LMU	DEGREE OF LIMITATION					
	Chem. soil cond. (f)	Phys. soil cond. (p)	slope (s)	Soil depth (d)	Stones/ gravels (g)	suitability sub-class
Bft	2	1	1	1	2	S2fg
Bss	2	1	3	1	2	S3s
Gad	3	2	1	1	1	S3f
Gaf	3	2	1	3	2	S3fd
Gag	3	2	1	3	2	S3fd
Gal	3	2	1	3	2	S3fd
Gam	3	2	2	4	2	N2d
Gao	3	2	3	4	2	N2d
Gas	3	2	4	4	2	N2sd
Gbf	3	2	1	1	1	S3f
Gbg	3	2	1	3	1	S3fd
Gbm	3	2	3	3	2	N2fs
Gbo	3	2	4	3	2	N2s
Af	2	1	1	1	1	S1
Ag	2	1	1	1	1	S1

S1	=	Highly suitable lands	=	69.0 ha
S2	=	Moderately suitable lands	=	220.0 ha
S3	=	Marginally suitable lands	=	2737.0 ha
N2	=	Unsuitable land	=	2474.0 ha
		Total area	=	**5500.0** ha

6.5.3 Robusta Coffee

Robusta coffee seems to be the crop which could be adapted to the soils of the area. Only the unit Gas is unsuitable for this crop while more than 700 ha is both highly and moderately suitable (Table 11). This crop needs to be encouraged in the farmers' crop associations as its demands on soil fertility are lower than all the other crops assessed.

Table 11: **Degrees of limitations of the Land Mapping Units (LMU) for Robusta Coffee.**

LMU	DEGREE OF LIMITATION					
	Chem. soil cond. (f)	Phys. soil cond. (p)	slope (s)	Soil depth(d)	Stones/ gravels(g)	suitability sub-class
Bft	1	1	1	1	1	S1
Bss	1	1	2	1	1	S2s
Gad	2	2	1	1	1	S2f
Gaf	3	2	1	2	2	S3f
Gag	2	2	1	3	2	S3d
Gal	2	2	1	3	2	S3d
Gam	2	2	2	3	3	S3dg
Gao	2	2	3	3	3	S3sd
Gas	2	2	4	3	3	N2s
Gbf	2	2	1	1	1	S2sp
Gbg	3	2	1	3	2	S3d
Gbm	3	2	2	3	2	S3d
Gbo	2	2	3	3	2	S3sd
Af	1	1	1	1	1	S1
Ag	1	1	1	1	1	S1

S1	=	Highly suitable lands	=	289.0 ha
S2	=	Moderately suitable lands	=	528.5 ha
S3	=	Marginally suitable lands	=	3394.5 ha
N2	=	Unsuitable land	=	1288.0 ha
		Total area	=	**5500.0** ha

6.5.4 Maize

On the whole much of the units are suitable for maize (Table 12) but as it is a crop with high demands on soil nutrients the yields will fluctuate from year to year, especially on the soils on basement complex rocks. Improved farming methods which aim at maintaining or even increasing the fertility of the soils are to be considered.

Table 12: **Degrees of limitations of the Land Mapping Units (LMU) for Maize.**

LMU	DEGREE OF LIMITATION					
	Chem. soil cond. (f)	Phys. soil cond. (p)	slope (s)	Soil depth (d)	Stones/ gravels (g)	suitability sub-class
Bft	2	1	1	1	1	S2f
Bss	2	1	3	1	2	S3s
Gad	3	1	1	1	1	S3f
Gaf	3	1	1	1	2	S3f
Gag	3	1	1	1	2	S3f
Gal	3	1	1	1	2	S3f
Gam	3	1	2	1	2	S3f
Gao	3	2	2	1	2	S3s
Gas	3	1	4	2	3	N2s
Gbf	3	1	1	1	1	S2f
Gbg	3	1	1	2	2	S2f
Gbm	3	1	2	2	1	S3f
Gbo	3	1	4	2	2	N2s
Af	2	1	1	1	1	S2f
Ag	2	1	1	1	1	S2f

S1	=	Highly suitable lands	=	0.0 ha
S2	=	Moderately suitable lands	=	601.5 ha
S3	=	Marginally suitable lands	=	3512.0 ha
N2	=	Unsuitable land	=	1386.5 ha
		Total area	=	**5500.0** ha

6.5.5 Root and tuber crops

The suitability for root and tuber crops (Table 13) indicates that the most severe limitations are soil depth and stones/gravel content. These crops form their usable parts underground, so the factors soil depth and amount of coarse fragments were given a higher weight than other factors.

Table 13: **Degrees of limitations of the Land Mapping Units (LMU) for Root and Tuber Crops.**

LMU	DEGREE OF LIMITATION					
	Chem. soil cond. (f)	Phys. soil cond. (p)	slope (s)	Soil depth(d)	Stones/ gravels(g)	suitability sub-class
Bft	2	1	1	1	2	S2fg
Bss	2	1	3	1	3	S3fg
Gad	3	2	1	1	1	S3f
Gaf	3	2	1	3	3	S3fd
Gag	3	2	1	3	3	S3fd
Gal	3	2	2	3	3	S3f
Gam	3	2	3	4	4	S3fs
Gao	3	2	3	4	4	N2dg
Gas	3	2	4	4	4	N2dg
Gbf	3	2	1	1	1	N2dg
Gbg	3	2	1	3	1	S3f
Gbm	3	2	3	3	2	S3f
Gbo	3	2	3	4	3	N2d
Af	2	1	1	1	1	S2f
Ag	2	1	1	1	1	S2f

S1 = Highly suitable lands = 0.0 ha
S2 = Moderately suitable lands = 289.0 ha
S3 = Marginally suitable lands = 3147.5 ha
N2 = Unsuitable land = 2063.5 ha
Total area = **5500.0** ha

6.5.6 Oil palm

Even though the oil palm is considered as a major cash crop in the area, much of the land is unsuitable for it (Table 14). The oil palm, to produce well, needs high well distributed rainfall, fertile and deep soils. The climate of Mundemba area does not pose any limitation to the oil palm but the soils are shallow and poor. At small holder level of oil palm cultivation, this is not very encouraging. Oil palms, of course, could be planted even on the areas indicated as not suitable, but the yields will be very low and/or the level of inputs so high that it would be uneconomic.

Table 14: **Degrees of limitations of the LMUs for Oil Palm**

LMU	DEGREE OF LIMITATION					
	Chem. soil cond. (f)	Phys. soil cond. (p)	slope (s)	Soil depth(d)	Stones/ gravels(g)	suitability sub-class
Bft	2	2	1	1	2	S2fg
Bss	2	2	3	1	2	S3s
Gad	2	2	1	1	1	S2fg
Gaf	4	3	1	3	2	N2f
Gag	3	3	1	2	3	S3fp
Gal	3	3	1	2	2	S3fp
Gam	3	3	2	3	1	N2fp
Gao	3	4	2	3	3	N2p
Gas	3	3	4	4	2	N2sd
Gbf	3	2	1	1	1	S3f
Gbg	4	2	1	2	1	N2f
Gbm	4	2	2	2	1	N2f
Gbo	3	3	4	3	4	N2s
Af	2	1	1	1	1	S2f
Ag	2	1	1	1	1	S2f

S1	=	Highly suitable lands	=	0.0 ha
S2	=	Moderately suitable lands	=	258.5 ha
S3	=	Marginally suitable lands	=	1941.5 ha
N2	=	Unsuitable land	=	3300.0 ha
		Total area	=	**5500.0** ha

Table 15: **Suitability Sub-classes of the LMUs for various crops.**

LMU	SUITABILITY SUB-CLASS						
	Plantains	Cocoa	Robusta Coffee	Maize	Root & Tuber	Oil Palm	Best crops
Bft	S2fg	S2fg	S1	S2f	S2fg	S2fp	Robusta coffee
Bss	S3s	S3s	S2s	S3s	S3sg	S3s	Robusta coffee
Gad	S3fp	S3f	S2f	S3f	S3f	S2fp	Robusta coffee
Gaf	S3fp	S3fd	S3f	S3f	S3fd	N2f	All crops except oil palm
Gag	S3fp	S3fd	S3d	S3f	S3fd	N2fp	All crops except oil palm
Gal	S3fp	S3fd	S3d	S3f	S3fs	S3fp	All crops
Gam	S3fp	N2d	S3dg	S3f	N2dg	N2fp	Robusta coffee, plantains, maize
Gao	N2sp	N2d	S3sd	S3f	N2dg	N2p	Robusta coffee, maize
Gas	N2s	N2sd	N2s	N2s	N2dg	N2sd	None
Gbf	S3fp	S3f	S2sp	S2f	S3f	S3f	Robusta coffee, maize
Gbg	S3fp	S3fd	S3d	S3f	S3f	N2f	All crops except oil palm
Gbm	S3fp	N2fs	S3d	S3f	S3fs	N2f	Plant. R.coffee, maize, root & tuber
Gbo	N2s	N2s	S3sd	N2s	N2d	N2s	Robusta coffee
Af	S2f	S1	S1	S2f	S2f	S2f	Cocoa, R. coffee
Ag	S2fp	S1	S1	S2f	S2f	S3f	Cocoa, R.coffee

Most of the land is only marginally suitable for most crops; the major constraints being soil fertility, soil depth and slope in that order (Tables 10 to 15). Slope alone is responsible for the rejection of some units for all crops. Erosion hazard is very high on the soils which are sandy, so some units have a lower suitability class than would be expected from the other characteristics.

Soil fertility is an important aspect of the land to be considered when making an evaluation for rain-fed subsistence level farming. It has been given a high rating in our evaluation because the soils of the area, except those developed in basalt, are marginal and very prone to fertility degradation once cultivation takes place and good soil management practices are not put into place. The fertility of all the soils lies in the topsoil (Appendices 1 to 5), so any misuse of the soil will result in loss of the fertility and consequently poor yields. The pH of all the soils is very low, as is normally the case in soils under tropical forests. It is desirable that the pH of these soils be increased through farmer-level methods.

The evaluation done has not taken into account the fact that the farmers usually plant all crops in association but Table 15 gives a clue on which crops can be combined on which mapping unit.

Despite the dispersed state of the suitable lands, the results mentioned above indicate clearly that the 65 families can conveniently be resettled within the area. An average household can own 5 to 10 hectares of land.

PART IV

7. RETAINED AREA AND SETTLEMENT PATTERNS

The following lines are based on field observations and interpretation of data collected during the field work.

One of the prerequisites of a proper resettlement scheme is the availability of enough arable land within the area. In addition to this, an adequate road network (farm to market roads) is needed.

7.1 Settlement Patterns and Additional Infrastructure

The settlement points for household can be grouped or spread along the main and secondary roads, depending on the wish of the people to resettle and the presence of streams and springs as a source of drinkable water. Every household should have a small compound area (homestead garden) around the house. The present village site chosen by Korup Project as indicated on the Soil Map is then the central point of the whole scheme.

In selecting the resettlement area, care has been taken to retain the land mapping units which have the highest percentage of good soils and which are within bearable walking distance (6 km max.) from the roads. The presence of a small colony of elephants in the eastern part of the area (around trace H(2-3) between V(1-2) and V(2-3) has also been taken into account. Crops like oil palm, plantains, bananas, etc. are not recommended in this area.

Since additional roads can be constructed, all the land mapping units (Gas excluded) extending on both sides of the road to Fabe from H_0 to H_4, can be brought into cultivation provided that a good soil management policy is applied. The layout of the access tracks for about 18.5 km is shown on Text Map 1. This layout is only tentative and should be finalised with field studies. First priority tracks (7.5 km) are those linking the road to Fabe with basaltic areas. The remaining part (11 km) constitutes second priority tracks.

The retained area has a total surface area of 3390 ha. After deduction of 20% for roads, housing and swampy areas, streams and streamlets, very bouldery and rocky areas, the net settleable area totals 2712 ha as follows:

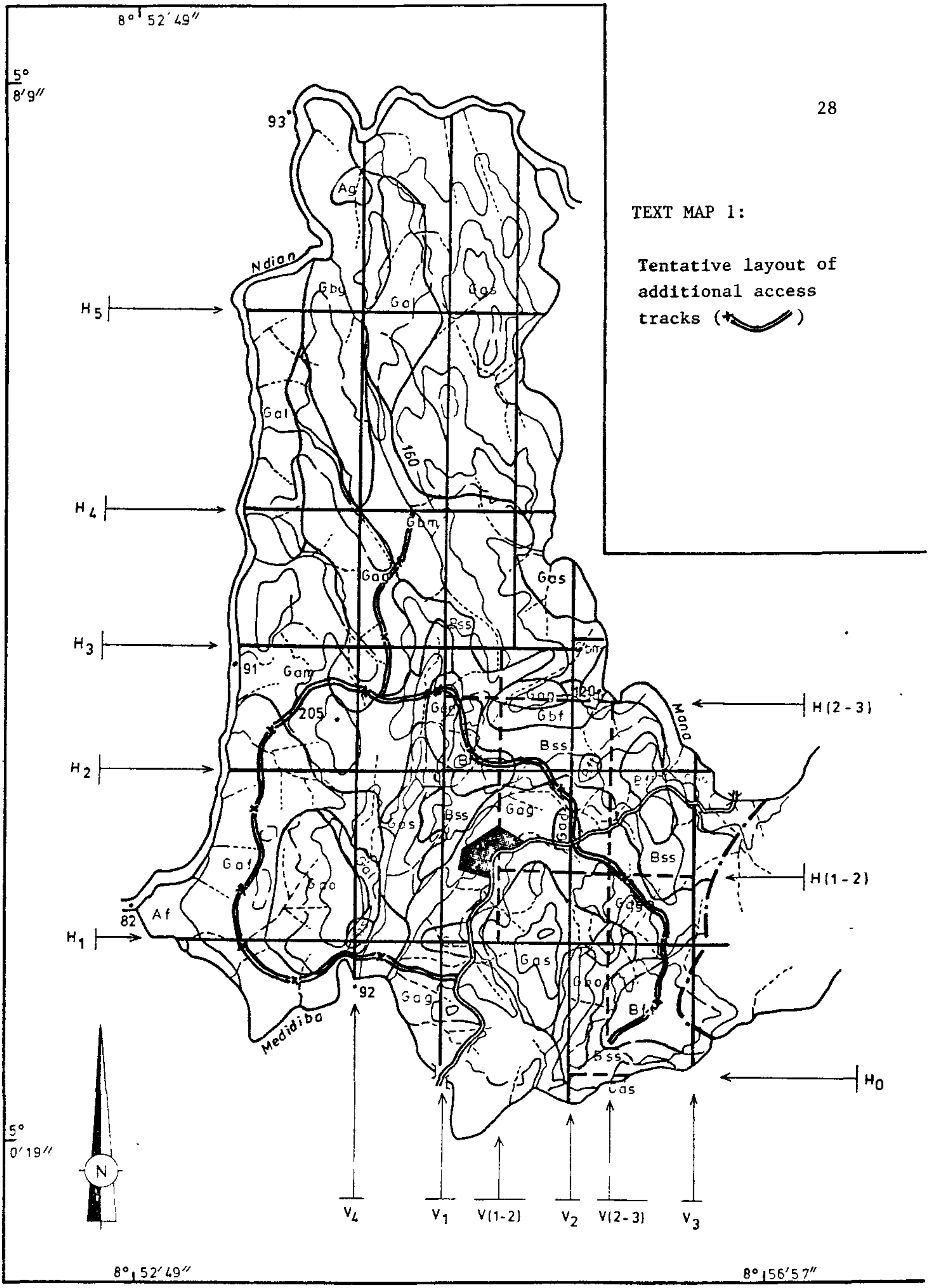
- 625 ha for soils on basalt,
- 450 ha for sandy clay loam soils,
- 1637 ha for sandy loam to sandy clay soils.

Each family should be given a plot in each soil type, meaning that each family will have three plots. The size of the plots may vary from 9.5 ha (soils on basalt: mapping units Bft and Bss) to 7 ha (sandy clay loam soils: mapping units Gbf, Gbm and Gbo) and 10 ha (sandy loam to sandy clay soils along the road to Fabe; mapping unit Gag).

In order to avoid land conflict with time between settlers, demarcation of the various plots is indispensable. The remaining area about 1000 ha should be considered as communal land for the entire village.

TEXT MAP 1:

Tentative layout of additional access tracks



7.2 Size and Type of Farms

Perennial crops, especially palms, should be grown in monoculture along the road to Fabe while cocoa and coffee can be planted with various fruit trees. The best cropping system for food crops like cocoyam, plantains, bananas, etc... is mixed intercropping. Individual fields may be as large as 2 to 3 ha or more for food crops and 3 to 5 ha or more for perennial crops.

In addition to crops, poultry, sheep, goats and pigs can be kept around compounds as most of the lands suitable for food crops are at a distance of 3 to 6 km from proposed settlement sites.

7.3 Population Carrying Capacity

With the 2712 ha of potentially usable land for smallholder farming and seeing the size of the population, it is assumed that there will be no pressure on land. Moreover the current agricultural system in the area seems to be in balance with the environment and can be sustainable without overall soil degradation. This is certainly due to the low population density in all of Ndian Division and limited access to markets.

The term carrying or grazing capacity is mostly used in pasture and range survey. It is defined (FAO, 1976a) as the maximum possible stocking that a range can support without deterioration, or the number of hectares that can carry one mature stock unit (Barrett and Larkin, 1974). Similarly, although not really applicable to human settlement, it can be stated that the 65 families can be resettled within the area and farm the lands in a sustainable way, even if a little increase in the population is envisaged.

A soil conservation plan of measures to control erosion should be prepared with the cooperation of the farmers at an early stage of the resettlement scheme.

7.4 Soil Conservation Measures

Although little evidence of erosion was seen in the field due to the forest cover, most of the mapping units, because of the steepness of slopes and sandy nature of some topsoils will be very susceptible to erosion when the forest is cleared.

In deciding on the type of conservation measures to be employed in the area, attention should be paid mainly to agronomic systems that are less expensive and easy to apply. These systems are based on the role of plant cover in reducing erosion. They keep the soil up to 100% covered while disturbing it as little as possible. They are related directly to matters such as reducing rain drop impact, increasing infiltration, reducing run-off volume and decreasing its velocity. It is also easier to fit them into any farming systems than mechanical works (terraces).

The following types of agronomic systems, i.e. cover crops, strip cropping, rotation and mulching are considered helpful for the implementation of erosion control in most of the study area.

7.4.1 Cover crops

The main advantages of cover crops are to protect the soil from erosion or wind. They smoother weeds and can be incorporated in the soil as green manure.

It is recommended to sow the cover crop (*Pueraria*, etc..) when the main crops are established in most of the fields on mapping units with a high erodibility such as Bss, Gbo, Gag, Gbm and Gam. By the time the main crops are harvested, the cover crop will be established and protect the soil from erosion and later serve as green manure (FAO, 1976). This is known as controlled fallow. A green manure crop generally refers to one which is grown specifically to improve the soil structure and fertility. It is seldom economic to take up the land to grow a green manure crop just for this purpose, but the green manuring properties of crops may certainly be exploited by combining the added advantages of erosion control and nitrogen fixation in a planned crop **rotation.**

7.4.2 Contour strip cropping

Strip cropping is one of the most simple additional measures which may be employed to provide protection to the soil singly or in combination with one or more of the agronomic and tillage practices. Strip cropping means dividing land into alternate strips of close growing erosion resistant plant such as legume or leguminous trees and shrubs (agroforestry) with strips of wider spaced crops such as maize, root and tuber crops (FAO, 1976). Erosion is largely limited to the crop strip, and soil removed from there is trapped in the adjacent strip down slope which is under legume.

The layout of the approximate width slope ratio is shown in Table 16 below.

Slope steepness (%)	Strip width (m)
2-5	30-33
6-9	24
10-14	21
15-20	15

Source: FAO bulletin N° 30.

7.4.3 Mulching and Manuring

Mulching is the spreading of cleared vegetation including crop residues, banana and plantain leaves, etc. over a cultivated piece of land. It protects the soil particularly from splash erosion by reducing the impact of rain-drops thus decreasing the danger of surface sealing.

A mulch should cover 70 to 75% of the soil surface with time, decomposition of mulch (manuring) provides organic matter and nutrients.

7.4.4 Mechanical Protection Works

Apart from contouring, other mechanical works like construction of terraces should not be envisaged. They are expensive to build and to maintain.

Contouring amounts to ploughing, planting and cultivation along the contour lines. The effectiveness of contour farming varies with slope steepness and length. The permissible slope length varies inversely with slope steepness (30 m at 12%, 20 m at 19%). It is recommended to supplement contouring with strip cropping in most of the fields on mapping units with steep slopes.

APPENDICES

APPENDIX 1: Description of soil profile No. KRP 1

Location: on line V_2 900 m. south of V_2H_1
Altitude: 180 m.
Slope : 10 - 20 %
Parent material: Tertiary basalt

A1 -- 0 to 2 cm: Strong brown (7.5YR 3/4), moist; clay loam; crumby structure; slightly sticky, slightly plastic; friable; many fine coarse interstitial pores; many fine, few medium; few coarse roots; few (2%) fine gravel-sized laterite fragments; few 5% basalt fragments; clear smooth boundary.

A2 -- 4 to 18 cm: Strong brown (7.5YR 3/4), moist, clay loam; crumby structure; sticky, slightly plastic; friable, many fine coarse interstitial pores, few medium tubular; many fine, common medium and coarse roots; 5% coarse fragments as above. 10% basalt fragments.

Bt -- 18 to 46 cm: Dark yellowish brown (10YR 3/4), moist, clay, crumby and weak fine sub-angular blocky structure; sticky, slightly plastic, friable; many fine coarse interstitial pores, common medium, tabular; few fine, common medium; few coarse roots; 35% coarse fragments as above, 20% stone- and boulder-sized unweathered basalt fragments, protruding into the pit.

Bt/R -- 46 to 88 cm: Dark yellowish brown (10YR 3/4), moist; clay, same as above but with 40% basalt fragments.

Classification

USDA Keys to Soil Taxonomy: Typic Haplohumults, fine clayey skeletal, Kaolinitic, isohyperthermic.
FAO-UNESCO Soil Map of the World: Umbric Alisols.

Physical and Chemical characteristics of Profile N° KRP1

Horizon	A1	A2	Bt	Bt/R
Depth (cm)	00-4	4-18	18-46	46-88
T 2μ (clay) %	48.14	54.54	54.17	57.57
E 2-20μ (fine silt) %	12.81	15.39	13.44	13.27
X 20-50μ (coarse silt) %	5.33	4.21	4.83	3.23
T 50-100μ (sand) %	2.84	2.00	2.54	1.57
U 100-250μ (sand) %	5.70	2.47	2.64	2.63
R 250-500μ (sand) %	7.53	3.67	3.68	3.43
E 500-2000μ (sand) %	17.65	17.72	18.69	18.31
Moisture (105°C) %	12.80	12.38	14.19	12.43
Organic carbon %	6.68	1.61	1.98	3.04
Total N %	.49	.14	.11	.26
C/N	14	12	18	12
Av. P. (Bray-2) ppm	3	0	0	2
pH H_2O 1:2.5	4.0	4.0	4.1	4.4
pH KCl 1:2.5	3.5	3.7	3.9	3.8
Na^+ *	.06	.03	.05	.03
K^+ *	.44	.05	.13	.20
Mg^{++} *	.77	.18	.07	.05
Ca^{++} *	2.34	.52	.53	.78
TEB *	3.61	.78	.78	1.16
$Al3^+$ (KCl) *	2.11	0.88	1.15	2.45
H^+ (KCl) *	2.29	0.92	1.36	1.48
ECEC *	8.01	2.58	3.29	5.09
CEC *	34.00	23.83	25.28	24.89
Base Saturation %	11	3	3	5
Al Saturation %	26	34	35	48

* cmol (+)/kg soil, results based on oven dry (105°C) weight

APPENDIX 2: Description of soil profile No. KRP 2

Location: on V_3, 1400 m from V_3H_1 (North direction)
Altitude: 270 m.
Slope : 7 - 15 %
Surface stoniness: Basalt stones and boulders.
Parent material: Tertiary basalt.

A1 -- 0 to 8 cm: Dark brown (7.5YR 3/2), moist; clay loam; crumby structure. friable, sticky, slightly plastic; abundant interstitial pores; 50% fine gravel-sized laterite fragments, many fine few medium and coarse roots, Clear smooth boundary.

Bt1 -- 8 to 18 cm: Strong brown (7.5YR 3/4), moist; clay; weak fine subangular blocky and crumby structure; friable sticky and plastic; many fine and medium tubular pores; abundant fine interstitial pores; many fine common medium and coarse roots; coarse fragments as above; gradual smooth boundary.

Bt2 -- 18 to 52 cm: Strong brown (7.5YR 3/4), moist; clay, friable, sticky and plastic; weak medium and fine subangular blocky and crumby structure; many fine and medium tubular pores and interstitial; common coarse, medium and many fine roots; 5% stone-sized superficially weathered basalt fragments. 50% gravel as above; clear smooth boundary.

Bt3 -- 52 to 105 cm: Brown to dark brown (7.5YR 4/4), moist; clay; friable; sticky ad plastic; weak medium subangular blocky and also breaking into fine strong subangular blocky and crumby structure; many fine and medium tubular pores; many fine interstitial pores; few medium roots; 75% gravel-sized laterite fragments, especially in south part of pit; 20% basalt fragments as above; clear smooth boundary.

Bt/Cr -- 105 to 140 cm: Strong brown (7.5YR 4/5), moist; clay; friable; sticky and plastic; moderate medium and fine subangular blocky many fine and medium tubular pores; many fine interstitial, few medium roots; 50% brittle, highly weathered gravel and basalt fragments. 10% superficially weathered stone-sized basalt fragments.

Deep gravelly, clayey soil developed in intrusive basalt.

<u>Classification</u>

USDA Keys to Soil Taxonomy: Typic Palehumults, fine clayey - skeletal, kaolinitic, isohyperthermic.
FAO-UNESCO Soil Map of the World: Umbric Alisols.

Physical and Chemical characteristics of Profile N° KRP2

Horizon	A	Bt1	Bt2	Bt3	Bt/Cr
Depth (cm)	0-8	8-18	18-52	52-105	105-140
T 2μ (clay) %	21.10	46.96	51.61	56.41	60.44
E 2-20μ (fine silt) %	8.22	11.56	10.85	16.10	12.48
X 20-50μ (coarse silt) %	5.06	4.76	5.39	4.77	4.50
T 50-100μ (sand) %	1.92	2.36	2.14	2.14	1.59
U 100-250μ (sand) %	5.66	5.29	3.20	3.47	2.88
R 250-500μ (sand) %	9.82	6.04	4.89	3.84	4.20
E 500-2000μ (sand) %	48.21	23.04	21.92	13.27	13.89
Moisture 105°C %	9.28	10.40	11.97	10.73	10.32
Organic Carbon %	6.63	3.10	1.71	1.47	1.35
Total N %	.53	.25	.15	.14	.14
C/N	13	12	11	11	10
Av. P. (Bray-2) ppm	4	2	1	2	7
pH H20 1:2.5	4.0	4.3	4.2	4.4	4.2
pH KCl 1:2.5	3.8	3.9	3.5	4.0	4.0
Na^+ *	.07	.03	.05	.04	.03
K^+ *	.39	.27	.11	.11	.08
Mg^{++} *	.74	.21	.18	.07	.00
Ca^{++} *	2.01	1.27	.52	.76	.76
TEB *	3.21	1.78	.86	0.98	0.87
$Al3^+$ KCl *	0.94	2.02	1.13	1.04	0.68
H^+ KCl *	1.03	1.84	0.99	0.73	0.75
ECEC *	5.18	5.64	2.98	2.75	2.30
CEC *	24.71	22.36	21.89	18.78	22.86
Base Saturation %	13	8	4	5	4
Al Saturation %	18	36	38	38	30
* cmol(+)/kg soil, Results based on oven dry (105°C) weight					

APPENDIX 3: Description of soil profile No. KRP 3

Location: On V_2 100 m South of H_2V_3 junction and 400 m North of road to Fabe.
Altitude: 195 m
Slope : 5 %
Parent material: Gneiss (>50% Ferro-magnesium minerals).

A -- 0 to 8 cm: Dark yellowish brown (10YR 3/4), moist; sandy clay loam; weak fine subangular blocky structure; friable; slightly sticky; slightly plastic; many fine, few medium, few coarse roots; many fine interstitial and tubular pores; clear smooth boundary.

Bt_1 -- 8 to 30 cm: Dark yellowish brown to brown (10YR 4/5 - 7.5YR 4/4), moist, sandy clay; weak medium subangular blocky structure; slightly sticky; slightly plastic; few fine, common medium, common coarse roots; many fine and medium few coarse, tubular pores; gradual smooth boundary.

Bt_2 -- 30 to 54 cm: Strong brown (7.5YR 4/6), moist; sandy clay; weak, fine and medium subangular blocky structure; friable; slightly sticky; slightly plastic; ; few fine, medium, and coarse roots; many fine and medium few coarse tubular pores; sand is coarse sand Some mica flakes, few partially weathered coarse gravel-sized rock fragments (Gneiss). Abrupt smooth boundary.

CR/Bt -- 54 to 68 cm: Strong brown (7.5YR 4/6), moist; sandy clay; slightly sticky; slightly plastic, weak fine subangular and angular blocky structure; many fine; medium and common coarse tubular pores; few medium roots; 60% gravel and fine stone-sized, partly weathered and highly weathered gneiss fragments few gravel and stone-sized quartz fragments (stone line); clear smooth boundary.

Bt_3 -- 68 to 107 cm: Strong brown to brown (7.5YR 4/5), moist; sandy clay loam; weak medium and coarse subangular blocky structure, slightly sticky; slightly plastic; many fine, medium and few coarse tubular pores; few medium and coarse roots. 10% fine gravel-sized laterite fragments, 10% rock fragments as above; boundary clear wavy.

Cr/Bc -- 107 to 152 cm: Strong brown (7.5YR 5/6), moist; sandy clay loam; weak coarse angular blocky structure breaking into weak fine and medium subangular and angular blocky structure; friable slightly sticky; slightly plastic; many fine and medium tubular pores; few medium roots; 75% partly weathered; stone and boulder-sized, gneiss fragments; some protruding.

Deep strong brown coarse sandy clay soil with gneiss fragments in the subsoil.

<u>Classification</u> *USDA Keys to Soil Taxonomy*: Typic Palehumults fine loamy, mixed, isohyperthermic.
FAO-UNESCO Soil Map of the World: Haplic Alisols.

Physical and Chemical characteristics of Profile N° KRP3

Horizon	A	Bt1	Bt2	Cr/Bt	Bt3	Cr/Bc
Depth (cm)	0-8	8-30	30-54	54-68	68-107	107-152
T 2μ (clay) %	9.15	18.90	20.68	20.88	22.21	25.61
E 2-20μ (fine silt) %	5.43	7.81	7.89	7.60	7.98	8.40
X 20-50μ (coarse silt) %	4.40	6.00	4.13	3.61	3.93	8.12
T 50-100μ (sand) %	8.32	6.96	6.83	7.00	6.60	8.85
U 100-250μ (sand) %	27.21	19.08	17.46	16.62	15.88	17.39
R 250-500μ (sand) %	29.89	34.67	36.06	31.55	25.76	17.64
E 500-2000μ (sand) %	15.58	6.57	6.95	12.72	17.63	13.99
Moisture 105°C %	2.54	2.75	2.98	2.52	3.07	3.61
Organic carbon %	2.51	1.00	.95	.64	.53	.63
Total N %	.17	.08	0.8	.05	.05	.05
C/N	15	13	12	13	11	13
Av. P. ppm	2	1	0	0	1	1
pH (H20) 1:2.5	4.0	4.2	4.1	4.3	4.0	4.1
pH (KCl) 1:2.5	3.8	3.9	3.7	3.9	3.5	3.6
Na^+ *	.07	.05	.03	.03	.03	.04
K^+ *	.42	.20	.13	.13	.18	.15
Mg^{++} *	.23	.06	.10	.14	.06	.14
Ca^{++} *	2.12	.71	.47	.73	.47	.72
TEB *	2.84	1.02	0.73	1.03	0.74	1.05
$Al3^+$ KCl *	1.10	1.37	1.41	1.12	1.21	1.34
H^+ KCl *	1.16	1.14	0.94	0.85	0.74	0.88
ECEC *	5.10	3.53	3.08	3.00	2.74	3.27
CEC *	11.59	14.52	12.62	12.64	13.11	15.61
Base saturation %	25	7	6	8	6	7
Al Saturation %	22	39	46	37	44	41
* cmol(+)/kg soil, results based on oven dry (105°C) weight						

APPENDIX 4: Description of soil profile No. KRP 11

Location:1600 m from road to Fabe along V(1-2) going to the north.
Slope : 0-2 %
Parent material: Colluvium derived from fine grained leucocratic gneiss
Drainage: imperfectly drained.

A -- 0 to 20 cm: Dark brown (10YR 3/3) moist, sandy loam; weak medium and coarse subangular blocky structure; friable, non sticky, non plastic; few coarse and medium tubular, many fine interstitial pores; few coarse, common medium, many fine roots; clear smooth boundary.

BA -- 20 to 87 cm: Yellowish brown (10YR 5/8) moist; sandy loam; weak medium and coarse subangular blocky structure; friable, non sticky, non plastic; common medium tubular, many fine interstitial pores; 10% fine gravel mainly quartz fragments and iron oxides; few medium and fine roots; clear smooth boundary.

Bg -- 87 to 150 cm: white to light grey (10YR 7.5/2) moist, loamy sand, weak medium and coarse sub-angular blocky structure; friable, non sticky, non plastic; few medium tubular; many fine interstitial pores. 10% gravel mainly quartz fragments and iron oxides; faint grey mottles; few medium roots; at the bottom of the pit there is C material consisting of partly to strongly weathered gneiss.

Classification

USDA Keys to Soil Taxonomy: Fluventic Humitropepts, sandy, mixed, isohyperthermic.
FAO-UNESCO Soil Map of the World: Dystric Cambisols.

Physical and Chemical characteristics of Profile N° KRP11

Horizon	A	B	Bg
Depth (cm)	0-20	20-87	87-150
T 2μ (clay) %	8.87	10.13	12.39
E 2-20μ (fine silt) %	2.59	4.56	2.59
X 20-50μ (coarse silt) %	5.38	6.38	6.47
T 50-100μ (sand) %	4.27	1.87	6.16
U 100-250μ (sand) %	22.14	13.01	20.28
R 250-500μ (sand) %	36.06	33.48	25.43
E 500-2000μ (sand) %	20.68	30.56	26.68
Moisture 105°C %	1.15	1.94	1.38
Organic carbon %	.72	.10	.42
Total N %	.08	.02	.05
C/N	9	5	8
Av. P. (Bray-2) ppm	6	40	8
pH H20 1:2.5	4.4	4.5	4.4
pH KCl 1:2.5	3.9	4.0	4.2
Na^+ *	.01	.02	.01
K^+ *	.05	.08	.06
Mg^{++} *	.00	.06	.00
Ca^{++} *	.23	.47	.47
TEB *	0.29	0.63	0.54
$Al3^+$ KCl *	1.04	0.40	0.66
H^+ KCl *	0.67	0.20	0.49
ECEC *	2.00	1.23	1.69
CEC *	11.43	6.72	8.12
Base saturation %	3	9	7
Al Saturation %	52	33	39
* cmol(+)/kg soil, results based on oven dry (105°C) weight			

APPENDIX 5: Description of soil profile No. KRP 15

Location: on H_4, 200 m East of H_4V_4 junction
Altitude: 115 m
Slope : 7 %
Parent material: Gneiss (>50% Ferro-magnesium minerals)

A -- 0 to 6 cm: Dark yellowish brown (10YR 4/4), moist; coarse sandy loam; weak fine subangular blocky structure, many fine, common medium and coarse roots, many fine tubular pores, slightly sticky non plastic; many small pockets filled with dark coloured materials; clear smooth boundary.

BA -- 6 to 21 cm: Strong brown (7.5YR 5/6), moist; coarse sandy clay loam; weak fine and medium subangular and angular blocky structure; slightly sticky slightly plastic, few fine common medium; common coarse roots; few channels; many fine many medium, few coarse tubular pores; many fine interstitial pores; many small pockets filled with dark coloured materials; clear smooth boundary.

Bt_1 -- 21 to 40 cm: Strong brown (7.5YR 5/6), moist; sandy clay loam to coarse sandy clay; moderate medium and coarse angular and subangular block structure; common fine; common medium few coarse roots, many fine tubular and interstitial pores; few channels; gradual smooth boundary.

Bt_2 -- 40 to 59 cm: Strong brown (7.5YR 5/7), moist; coarse sandy clay loam to sandy clay; moderate medium and coarse subangular and angular blocky structure; slightly sticky; slightly plastic; common fine, common medium tubular pores; few fine medium and coarse roots; 10% fine gravel-sized quartz fragments; many small pockets filled with dark coloured materials; abrupt wavy boundary.

Bcs -- 59 to 130 cm: Strong brown (7.5YR 5/8), moist; coarse sandy clay loam; moderate fine and medium subangular blocky structure; slightly sticky; slightly plastic; many fine; few medium and coarse tubular pores; few fine and medium roots; 30-40%; partly and highly weathered subgravel-sized feldspar fragments; few pockets with coarse gravel-sized quartz fragments; 20% fine gravel-sized quartz and highly weathered rock fragments;

deep, strong brown, sandy clay loam; well drained soil developed in gneiss.

Classification

USDA Keys to Soil Taxonomy: Typic Palehumults, coarse loamy, mixed, isohyperthermic.
FAO-UNESCO Soil Map of the World: Haplic Alisols.

Physical and Chemical characteristics of Profile N° KRP15

Horizon	A	BA	Bt1	Bt2	BCr
Depth (cm)	0-6	6-21	21-40	40-59	59-130
T 2μ (clay) %	10.88	17.71	18.13	22.55	24.07
E 2-20μ (fine silt) %	1.11	6.06	6.11	5.72	7.93
X 20-50μ (coarse silt) %	5.95	5.22	7.05	6.18	4.35
T 50-100μ (sand) %	7.67	8.32	6.87	6.28	6.67
U 100-250μ (sand) %	25.80	21.48	18.49	18.53	15.57
R 250-500μ (sand) %	27.45	22.33	21.71	18.59	17.96
E 500-2000μ (sand) %	21.15	18.88	21.64	22.14	23.46
Moisture 105°C %	1.50	2.11	1.86	2.45	3.37
Organic carbon %	1.35	.67	.62	.52	.48
Total N %	.11	.06	.06	.06	.05
C/N	12	11	10	9	10
Av. P. (Bray-2) ppm	7	1	1	1	0
pH H20 1:2.5	4.1	4.2	4.4	4.5	4.2
pH KCl 1:2.5	3.3	3.6	3.9	3.9	3.6
Na^+ *	.04	.03	.03	.04	.04
K^+ *	.19	.14	.11	.12	.10
Mg^{++} *	.06	.10	.00	.03	.20
Ca^{++} *	.70	.71	.47	.47	.24
TEB *	0.99	0.98	0.61	0.66	0.58
$Al3^+$ KCl *	0.96	1.23	0.97	1.01	1.06
H^+ KCl *	0.90	1.19	1.27	0.91	0.94
ECEC *	2.85	3.40	2.85	2.58	2.58
CEC *	8.61	8.18	7.68	8.92	7.55
Base saturation %	12	12	8	7	8
Al Saturation %	34	36	34	39	41
* cmol(+)/kg soil, results based on oven dry (105°C) weight					

LITERATURE CONSULTED

Awah, E.T., 1984. Soil Survey and Land Evaluation of Pamol Ndian Estate. National Soils Centre Tech. Report No. 23, IRA Ekona Buea. 30pp.

Barrett M.A., Larkin P.J., 1974. Milk and Beef production in the Tropics. Oxford University Press, Great Britain.

De Geus J.G., 1973. Fertilizer Guide for the Tropics and Subtropics. Centre d'Etude de l'Azote, Zurich. Cit. in Booker Tropical Soil Manual, ed. by J.R. Landon.

FAO, 1976. A Framework for Land Evaluation. FAO Soils Bulletin No. 32, Soil Resources Development and Conservation Service Land and Water Development Division, Rome.

FAO., 1983. Guidelines: Land Evaluation for Rainfed Agriculture. FAO Soils Bulletin 52. Soil Resources Management and Conservation Service. Land and Water Development Division, Rome.

FAO., 1984. Improved Production Systems as an Alternative to Shifting Cultivation, FAO Soils Bulletin No. 53. Soils Resources, Management and Conservation Service, Land and Water Development Division, Rome.

FAO., 1987. Guidelines: Land Devaluation for Extensive Grazing, Third draft, Rome.

FAO/UNDP/IRAF-ONAREST., 1977. Soil Surveys and Land Evaluations for the Second Development Programme of the Cameroon Development Corporation (CDC). Technical Report No. 7. Ekona (Cameroon).

FAO/UNEP., 1983. Guidelines for the Control of Soil Degradation, Rome.

FAO/UNESCO., 1985. Soil Map of the World, 1:5.000.000. Revised legend, Rome.

Kochhar S.L., 1986. Tropical Crops, a textbook of economic botany, Hong Kong.

Landon J.R. (ed.), 1984. Booker Tropical Soil Manual.

Ministry of Plan and Regional Development, 1989. Plan for developing the Korup National Park and its support zone, World Wide Fund for Nature, Commission of European Communities, Overseas Development National Resources.

Norman M.J.T., C.J. Pearson and P.G.E. Searle, 1984. The ecology of tropical food crops, Cambridge University Press, Great Britain.

Simmonds N.W., 1966. Bananas. Second Edition. Longman, London. Cit. in Booker Tropical Soil Manual, ed. by J.R. Landon.

USDA. 1994. Keys to Soil Taxonomy, 6th Ed. 1994. USDA Soil Conservation Service. Washington, D.C. USA.