

SOILS  
OF THE AGRICULTURAL ZONE IN THE CENTRAL AND NORTHERN PART  
OF THE

DENG DENG FOREST  
(EASTERN PROVINCE - CAMEROON)

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FAO Soil Resources Project  
Soil Science Department - ONAREST  
Ekona Research - Cameroon

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## INTRODUCTION

In response to a request of the Wageningen State Agricultural University, the Netherlands, I worked from January to November 1978 with the FAO Soil Resources Project and the Soil Science Department of ONAREST at Ekona, Cameroon, as part of my study Tropical Soil Science.

During my stay, I participated in a reconnaissance soil study of the Deng Deng Forest in the Eastern Province.

This report presents the results of my work. The report concerns a reconnaissance soil survey (1:50.000) of one of the agricultural zones planned along the existing road in the central and northern part of the Deng Deng forest and two detailed surveys (1:25.000) of sample areas.

Field work was done from February to the end of March 1978 and was completed with a final correlation tour and additional field work in May 1978. The following technicians participated in the survey: Messrs Ntamack, Nyobe, Akwar, Verwey, van Barneveld and undersigned.

## ACKNOWLEDGEMENTS

The completion of the survey and report would have been impossible without the help of many people. In particular I would like to thank the following individuals and institutions:

- The Chief of Centre of the Ekona Research Centre of the Institute of Agricultural and Forestry Research - Dr. J.M. Menyonga and his staff; in particular Mr. E.M.T. Awa, Head of the Soil Science Department and Mr. J.N. Efite, Head of the Laboratory.
- The Project Manager of the FAO Soil Resources Project, Mr. G.W. van Barneveld and Associated Experts Messrs H.E. Verwey and M.E.F. van Mensvoort.
- My colleagues Messrs H. Tukker, H. Waayenberg and H.C. van den Burg, working in the same area on a study of the system of shifting cultivation.
- The Organization of Netherlands Volunteers (S.N.V.) in the Eastern Province of Cameroon.
- The Delegate of Agriculture in the Eastern Province and his staff.
- Organizations including the ZAPI-EST, S.C.T. and the National Meteorological Service in Bertoua.

Ekona, November 1978

J. Floor,  
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# *P*ART I

## THE ENVIRONMENT

- 1.1. LOCATION AND EXTENT
- 1.2. GEOLOGY AND GEOMORPHOLOGY
- 1.3. CLIMATE
- 1.4. VEGETATION
- 1.5. TERMITE ACTIVITY
- 1.6. POPULATION
- 1.7. LAND UTILISATION TYPES



LOCATION MAP OF DENG DENG FOREST

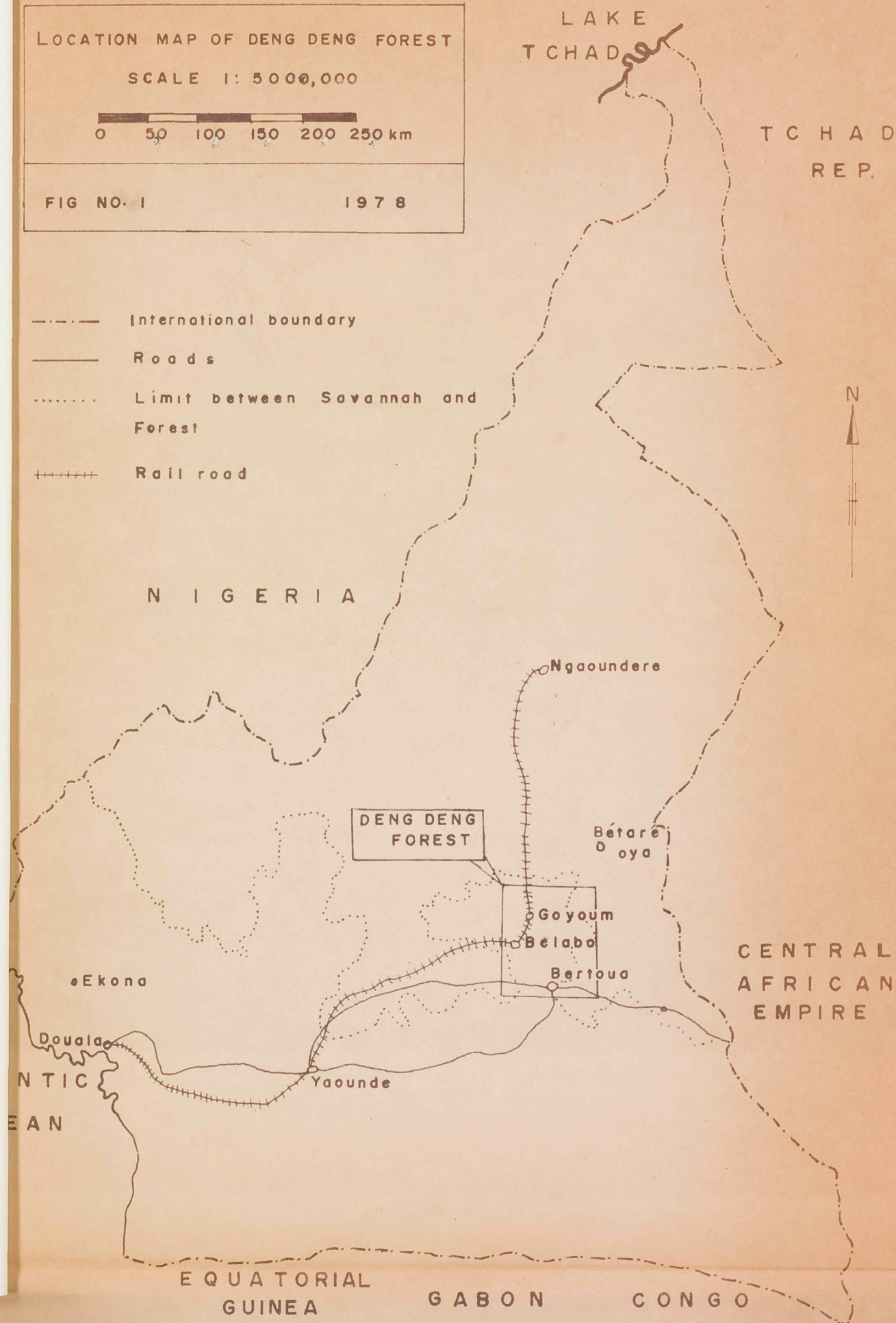
SCALE 1: 5000,000

0 50 100 150 200 250 km

FIG NO. 1

1978

- International boundary
- Roads
- ..... Limit between Savannah and Forest
- + + + + Rail road





DENG DEN  
SAMPLE A



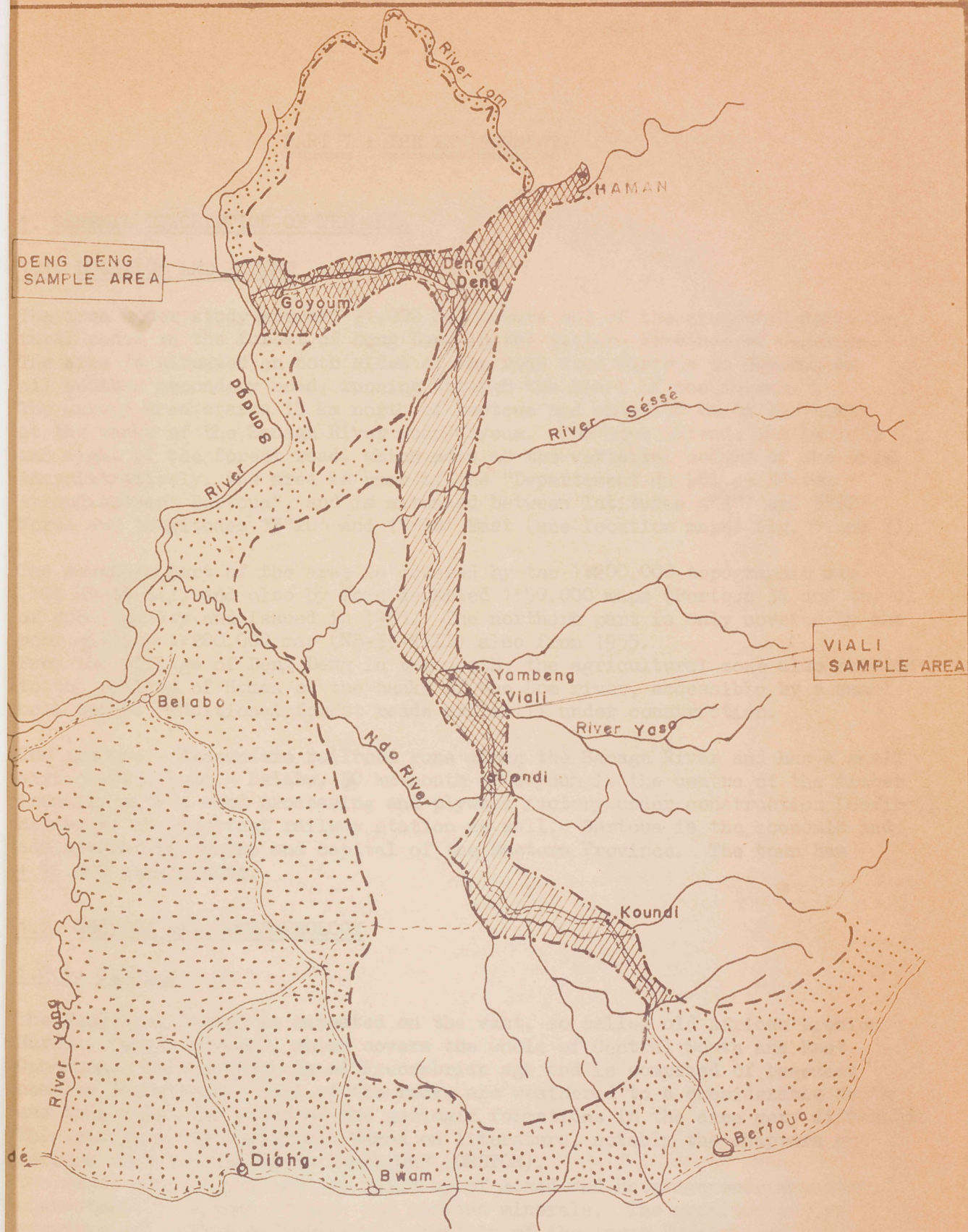
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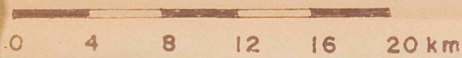
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LOCATION MAP OF SURVEYED AREA






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G. NO. 2

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LEGEND

-  Sample Areas (detailed survey-1:25,000)
-  Reconnaissance Survey (1:50,000)
-  Agricultural Zones
-  Roads
-  Rivers



## PART I : THE ENVIRONMENT

### 1. GENERAL DESCRIPTION OF THE AREA

#### 1.1. LOCATION AND EXTENT

The area under study (approx. 21.000 ha) covers one of the projected agricultural zones in the forest of Deng Deng in the Eastern Province of Cameroon. The area is situated on both sides of the road from Bertoua to Goyoum; an all weather secondary road, running through the heart of the forest. The survey area starts 18 km north of Bertoua and ends 100 km to the north at the banks of the Sanaga River near Goyoum. The area extends 1-4 km left and right of the forest road, which acts as the vertebral column of the area. Administratively, the area is part of the "Departement du Lom et Djerem - Arrondissement Bertoua", and is situated between latitudes 4°40' and 5°22' North and longitudes 13°20' and 13°38' East (see location maps: fig. 1 and 2).

The southern part of the area is covered by the 1:200.000 topographic map (IGN NB-33-II), and also by more detailed 1:50.000 maps (Bertoua 3d and 4a, c) of good quality and issued in 1955. The northern part is only covered by the poor quality 1:200.000 map (NB-33-VIII) also from 1955. From the village of Deng Deng in the north, the agricultural zone also extends to the village of Haman on the banks of the Lom river, accessible by a small bush track. Additional forest roads are still under construction.

The Yaounde - Ngaoundere railroad runs along the Sanaga River and has a small station at Goyoum. Belabo, 30 km south of Goyoum is the centre of the timber industry with a wood processing and plywood factory under construction (Sofibel). Belabo is an important railway station as well. Bertoua is the economic and administrative centre and capital of the Eastern Province. The town has ± 20.000 inhabitants.

#### 1.2. GEOLOGY AND GEOMORPHOLOGY

##### 1.2.1. Geology

The Deng Deng Forest is situated on the vast, so called old African Erosion Surface (socle ancien), which covers the whole of Central South and East Cameroon. This surface is of Precambrian age and is composed of basement complex formations. Most of the rocks are weathered to a considerable depth and this makes the study of the geologic formations in the area very difficult. This paragraph is therefore, based on literature, notably the chapters on geology from the "Atlas du Cameroun" (ORSTOM).

The major part of the area is build up of mixed and heterogeneous granites, characterized by some biotite and related minerals. The granites are an eruptive and intrusive formation, probably of the lower Precambrian. Near Bertoua, East of Viali, North and East of the Deng Deng village, the granites are more porphyritic.



In the North-East and the West the granites are bordering other basement complex formations of metamorphic rocks, including embrechites, gneisses and schists.

Most of the soils formed on these old acid rocks have many characteristics in common and are therefore referred to as "ferrallitic basement complex soils."

### 1.2.2. Geomorphology

Peneplanation of the old shield is an important process which started at the end of the Cretaceous and continued to modern times. It is likely that this process has not been a continuous one, but a process in which geogenetic and pedogenetic cycles succeeded each other under influence of changing climatic conditions. The present peneplain is deeply dissected, particularly in the forest zone. The area is situated in two major watersheds: the Sanaga River watershed, aggressive and relatively young and the Congo River watershed, less aggressive and probably younger. The erosion base of the Sanaga watershed is situated at approx. 600 m. while the erosion base of the Congo watershed is found at approx. 750 m.

Due to these differences, several peneplain subtypes can be distinguished, situated at different levels, as follows:

- 1) a deeply dissected peneplain at 700-740 m in the central, north and north-west, covering approx. 90 % of the area under study.
- 2) a moderately dissected landscape at 720-740 m in the north east (8.5 %).
- 3) the complex slopes to the Lom and Sanaga Rivers (1 %)
- 4) the floodplains of the Lom and Sanaga River (0.5 %)

ad1) This peneplain is situated at 700-740 m above sealevel and is strongly dissected and deeply incised. The plateaus are small and rectangular in form (6-60 ha). Ferruginous gravel can be found several meters below the surface, but on the (steep) slopes gravels can be found at or close to the surface (see fig. 4).

Slopes are mostly convex throughout, however, in some cases the lower slopes are concave (S-slopes). Slope percentages vary from 3 to 16 %, locally over 20 %, particularly on lower slopes. The length of the slopes ranges from approx. 400 m to 2000 meters.

The incision depth of the main valleys is 40 to 70 meters. Generally, the drainage pattern is semi dendritic, showing evidence of some geologic control. The main streams have roughly a SE-NW direction. The drainage density is high, 3,0-3,5 km per km<sup>2</sup>.

The valley bottoms of the main streams are mostly wide (60-500 m), hydromorphic and U-shaped. The valley bottoms of the smaller streams and tributary streams are V or U-shaped and generally they are less than 60 meters wide.



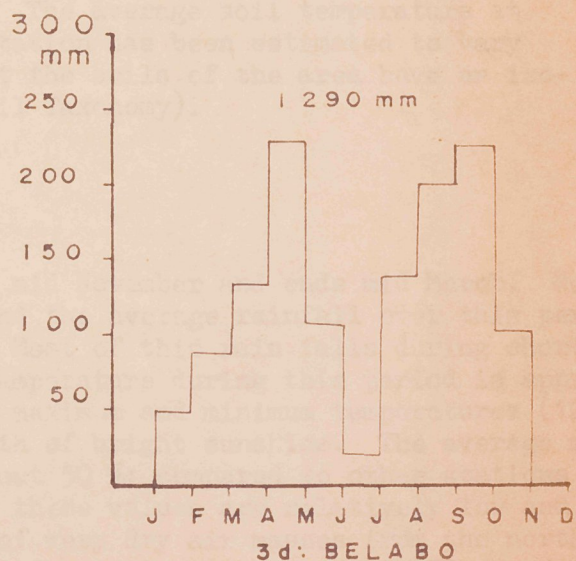
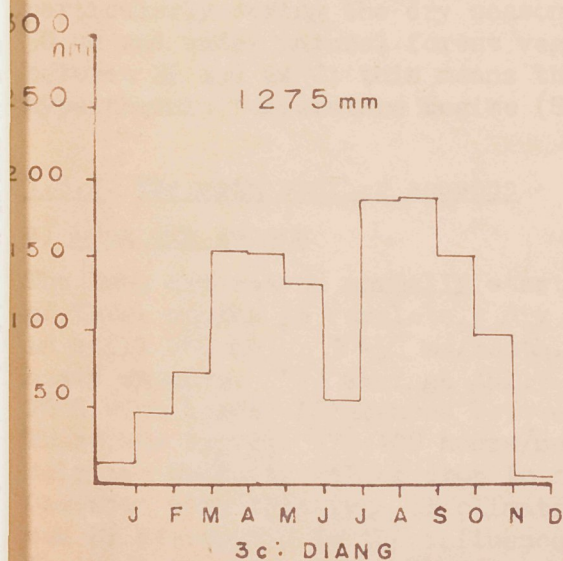
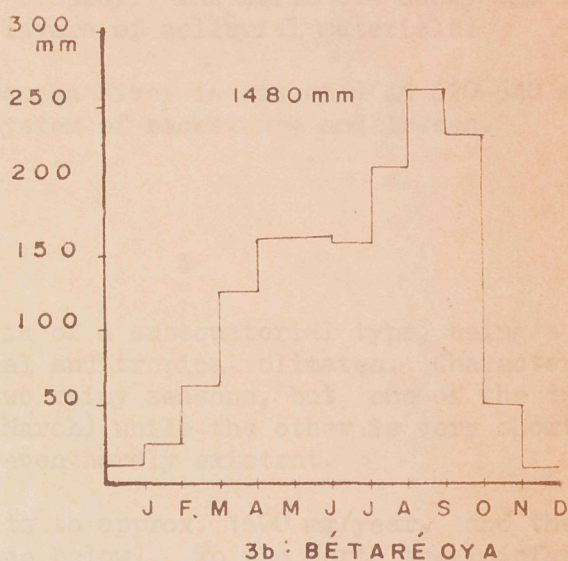
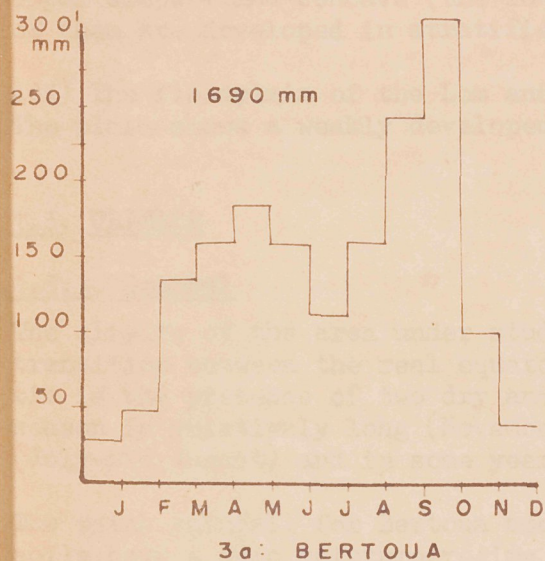
FIG 3: Rainfall histograms of four weather stations

3a BERTOUA : Observations over 30 years

3b BÉTARÉ OYA : 165 km NNE of Bertoua; observations over 31 years

3c DIANG : 42 km W- of Bertoua; observations over 5 years

3d BELABO : 80 km N.W. of Bertoua; observations over 5 years





ad2) The peneplain of the north eastern part is situated at a level of 720-740m and is covered by a resistant laterite (ironstone) cap. This plain is also strongly dissected but less deeply. Plateaus are very small or almost absent. Slopes are convex and vary between 3 and 16 %, while the valleys are mostly V-shaped.

ad3) The complex slopes to the Lom and Sanaga Rivers (640-680 m) are characterized by erosional and colluvial processes. Slopes are mostly convex (the upper slopes) and concave (the lower slopes). The soils are sandy and many of them are developed in stratified layers of colluvial materials.

ad4) The floodplain of the Lom and Sanaga River is situated at 620-640 m. The plain shows a weakly developed system of backswamps and levees.

### 1.3. CLIMATE

#### 1.3.1. General

The climate of the area under study is of a subequatorial type, being a transition between the real equatorial and tropical climates. Characteristic is the presence of two dry and two rainy seasons, but one of the dry season is relatively long (November-March) while the other is very short (July-mid August) and in some years even hardly existent.

The total rainfall for Bertoua amounts to approx. 1600 mm/year, and the soils have a udic moisture regime (see below). To the North the rainfall is slightly decreasing (1400-1500 mm).

The average temperature shows very small variations over the months (23 - 25°C) but the daily temperature variation can be considerable, particularly during the dry season. The average soil temperature at 50 cm and under natural forest vegetation has been estimated to vary between 22 and 24°C; this means that the soils of the area have an iso-hyperthermic temperature regime (Soil Taxonomy).

#### 1.3.2. The main weather seasons

##### a) Long dry season

The long dry season normally starts mid November and ends mid March. None of these months is completely dry and the average rainfall over this period is still 200 mm or 30-50 mm/month. Most of this rain falls during short but heavy showers. The average daily temperature during this period is approx. 25°C with large differences between maximum and minimum temperatures (12-14°C). There are approx. 170-180 hours/month of bright sunshine. The average minimum relative humidity values drop to about 50 %; compared to other stations in Cameroon with this type of climate, these values are relatively low and this can be attributed to the influence of very dry air masses from the north. In the beginning of the dry season, most soils will have 100-150 mm of accumulated soil water in the first 100 cm of the solum and during the dry season a few rain storms will replenish part of the losses. Calculating the waterbalance, the soils will not be completely dry for more than 90 cumulative days and in terms of Soil Taxonomy, the soils have a Udic moisture regime.



b) The small rainy season

The small rainy season starts mid March and ends in the beginning of July. Total rainfall during this period is about 625 mm, or roughly 160 mm/month. The weather is characterized by squalls and showers with a high rainfall intensity (April), which may cause erosion and can do quite some damage to crops (maize). Sunshine during this period is limited but still approximates 150 hours/month.

c) The small dry season

The small dry season (July and August) is only relatively dry: 250 mm rainfall is recorded in Bertoua for these two months. The sky is always cloudy and sunshine very limited: 80-90 hours/month. Infact, these are the months with the highest minimum humidity values ( $\pm 70\%$ ) and the lowest average temperatures. In some years this small dry season is absent with only a small dent in the monthly rainfall histogram.

d) The big rainy season

During the big rainy season, from September till November, the total amount of rain is approx. the same as during the small rainy season but the period is much shorter. For Bertoua:  $\pm 600$  mm or 250 mm/month. Persistent rains are characteristic but the rains are sometimes accompanied by strong winds. October is the wettest month with over 300 mm rainfall. Sunshine is limited (100-150 hours), and the temperatures are relatively low as well.

#### 1.4. VEGETATION

The Deng Deng forest is the most northern "offshoot" of the tropical rain forest zone, covering the South of Cameroon. The forest is bordered by savannas at three sides, the transition to the savannas being not sharp and influenced by human activity (man-made savannas). The equilibrium between the savanna and the forest is a precarious one. Under influences of man, agricultural activities in general, but burnings in particular the savanna is encroaching rapidly on the forest, particularly along the roads. On the other hand, we observe that in some places the forest is gaining lost territory on the savanna. This occurs probably only on gravel-free soils and where burning is restricted. The soils of these later areas have a rather thick A1 horizon, characteristic for savanna soils but they are covered with (secondary) forest. Expansion of the savannas can be expected particularly in the area between Bertoua and Koundi Village, i.e. where gravelly soils predominate.

According to the UNESCO classification the forest is of a "tropical ombrophilous type". According to R. Letouzy (1958), the forest belongs to the hemiombrophilous forest, a dense, humid semi-deciduous forest of medium altitude (600-800m) and characterized by species of the Sterculiaceae. Characteristic species are Triplochiton scleroxylon, Sterculia oblonga and other Sterculiaceae, Pterygota kamerunensis and various Cola species. Of the other families, the presence of Celtis, Chlorophora excelsa, Ficus and Terminalia superba has to be mentioned.



TABLE 1: SUMMARY OF CLIMATICAL DATA

	JAN.	FEB.	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPT.	OCT.	NOV.	DEC.	AV.
MAXIMUM TEMP. (°C) <sup>xx</sup>	29,8	31,1	30,9	30,5	29,8	28,5	27,1	27,2	28,3	28,8	29,8	29,7	29,3
MINIMUM TEMP. (°C) <sup>xx</sup>	16,4	17,2	18,7	19,1	19,0	18,6	17,9	18,7	18,7	18,6	17,9	16,5	18,1
T MAX - T MIN. (°C) <sup>xx</sup>	13,4	13,9	12,2	11,4	10,8	9,9	9,2	8,5	9,6	10,2	11,9	13,2	11,2
RAINFALL BERTOUA (mm) <sup>xx</sup>	28,2	48,6	135,8	159,9	185,5	158,5	112,2	161,3	242,5	309,9	99,0	38,5	1690
" DIANG (mm) <sup>xxx</sup>	13,6	48,7	74,7	154,8	153,3	135,1	56,0	189,2	192,5	153,5	100,3	4,5	1276
" BELABO (mm) <sup>xxx</sup>	0,5	49,0	87,3	136,5	228,3	107,5	18,8	138,4	199,0	225,0	102,9	0,0	1292
MAX. HUMIDITY (%) <sup>xx</sup>	97	96	97	97	97	98	97	97	97	98	97	98	
MIN. HUMIDITY (%) <sup>xx</sup>	52	50	57	60	62	68	71	70	66	66	57	55	
WIND (m/s) <sup>xx</sup>	E/18	E/20	E/25	E/25	SE/20	NW/16	Var/20	NE/16	E/16	E/20	SE/20	E/20	

xx Data from Meteorological Station Bertoua : Observations over 30 years

xxx " " other Meteorological Stations : Observations over 5 years only



The vegetation of the hydromorphic valley bottoms is very conspicuous and varies according to the local hydrological conditions. Often it is characterised by the presence of *Raphia* palms. Exact observations are not done. Then very poorly to poorly drained, grasses and scrubs are the dominant vegetation type, while better drained valley bottoms have a hydromorphic forest cover.

Concessions exist for 13 exploitable tree species; these species are *Entandophragma cylindrium*, *Entandophragma utile*, *Khaya anthoteca*, *Eribroma oblonga*, *Pyenantrus angolensis*, *Gossweilodendron balsamiferum*, *Entandophragma angolense*, *Entandophragma candoleii*, *Chlorofora excelsa*, *Mensoria altissima*, *Guarea cedrate*, *Lovoa trichilioides* and *Tryplochyton scleroxylon*.

### 1.5. TERMITE ACTIVITY

An important characteristic of the area is the presence of large quantities of termite mounds, both in the savanna and the forest.

The mounds vary between 2-12 meter in diameter, have a height up to 3.5 m or more and cover 20-50% (!) of the surface. Most of the large mounds are presently abandoned and they are probably very old. This can be observed when we compare soil profiles on the mounds with non affected profiles. Morphological characteristics (e.g. structure, colour, and horizon differentiation) are very similar in both profiles. However, the abundant mounds give the surface a very pronounced and conspicuous micro-relief and are the origin of a high micro-variability of the chemical and physico-chemical (water retention) properties.

The actual termite activity is also high but active mounds are generally small. Other spp. of *Macrotermes* often build their mounds on the fossile mounds. The influence of the microvariability on the growth and performance of crops is generally very pronounced; stands are uneven over short distances, this being particularly marked under a low level of management, without or with very low levels of purchased inputs, such as fertilizers, pest and disease control.

In general, the termites are believed to use fine textured soil material from the subsoil for their mound building and are hence enriching the topsoil with clay. Another aspect is the concentration of certain plant nutrients in the topsoil, in particular Ca and Mg. Calcium, as shown in profile DD 45 of the Dondi Series, is often irregularly distributed over the profile. Present day termite activity also influences the structure of the topsoil. Termites form large round structural aggregates, with large voids in it. The holes are often filled with excrements of other soil animals (worms, etc.). These aggregates cannot be described properly with the existing system and the introduction of additional structural classes may be necessary. Termites can also harden the topsoil, reducing the infiltration rates and other physical properties of the soil. An additional aspect is the erosion of the termite mounds.

The distribution of the mounds is related to the type of soil and their geographic position.



The undulating plateaus with the deep Dondi soils are covered for 20-50% with mounds. On the gravelly soils and on the steeper slopes mounds are less abundant (5-20%). From these observations it becomes clear that termites do not like to build their mounds in humid areas (lower slopes) and prefer areas without any obstruction for mounds building (i.e. deep, gravel free soils).

## 1.6. POPULATION

### 1.6.1. Population

According to data from the Sous-Prefecture (Bertoua, 1978), the total population of the studied area amounts to 5500 individuals, divided over the Maka, Pol and Kepéré tribal groups. The first two occupy the southern part of the area up to the village of Kano approx. 60 km north of Bertoua, the later group is found in the northern part of the forest.

### 1.6.2. Population density

Population densities can be calculated in different ways. For the Department Lom and Djerem, the density is approx. 2.6 inhabitants per square kilometer. For the Arrondissement Bertoua this value is 4.2. Both figures indicate low densities indeed.

In former times, however, the people were encouraged to resettle along the existing roads and presently only very few people are living right in the forest. When we calculate the "real" population density for the major part of the studied area (the agricultural zone from Kombité to Deng-Deng village), the density amounts to 20 inhabitants/km<sup>2</sup>. Realizing that 1/3 of the area is unsuitable for agriculture and housing, the actual density comes about 30 inh./km<sup>2</sup> of available land. This is a high value and reflects more or less the potential of the soil resources and the very special land utilization system of the area (see next chapter).

## 1.7. LAND UTILISATION SYSTEMS

### 1.7.1. General

The overall agricultural land use pattern can be split into two land utilization systems.

The first is the cultivation of foodcrops, mostly for own consumption in a shifting cultivation system; the second the cultivation of cashcrops for the market economy, in a permanent system.

In general, cashcrops are grown in small plantations just around the villages or along the existing roads, while foodcrops are grown on lands behind the plantations, up to 3-6 km from the villages. In a few cases, foodcrops are mixed with cashcrops, e.g. young cacao, coffee or banana plantations with macabo as an intercrop.

.../...



### 1.7.2. The shifting cultivation system

Foodcrops are grown in a shifting cultivation system. The basic principle of this system is the cultivation of an area of land for a few years, after which the land is abandoned temporarily. During this fallow period the land has the opportunity to recover. After many years, the farmer returns to the land and starts cultivation again.

For the forest area of the Deng Deng Forest the length of occupation varies between 3 and 7 years and the fallow period between 11 and 14 years, the later period becoming shorter due to the increasing population. Calculating the land Use Factor (L) of Allan, which is the ratio of the sum of the length of the cropping period plus the fallow period to the length of the cropping period, this factor varies from 2.5 to 4.5, corresponding to a "short term recurrent cultivation" of the land and an almost semi-permanent land use system.

### 1.7.3. Rotation pattern

After clearing and burning of the forest (mostly regrowth, sometimes primary forest) in February - March, the opening crop in the agricultural calendar is maize. This is planted after the first rains (mid March) or a little earlier in case of the valley bottoms. The plant density is about 7000-7500 plantholes per hectare, and 4-6 maize seeds are put into one hole. During the growing period, various other crops are planted in between the young maize plants, including cucumber, macabo, sweet potato, sugar cane and some vegetables. Before harvesting (from the end of July to August) the space between the maize plants is already cleared for the next groundnut crop. Approx. 50% (25-75%) of the area planted with maize is used in the second rainy season for groundnuts. Groundnuts are planted from mid-July till September and harvested from the middle of November to the end of December. Groundnuts are not only used for consumption and a large part is sold out. Consequently, groundnuts are actually a cashcrop grown in a self subsistence system. Fields which are not used for groundnut cultivation are fallowed after the maize has been harvested and are only used during the second year. Regrowth of weeds etc. is very fast and cultivation during the second year starts with clearing and burning, adding again nutrients to the soil. The groundnut fields are fallowed after harvesting the groundnuts in November - December. Sometimes Yams are planted on some ridges in the old groundnut fields.

The first crop of the second year is again maize. Infact, the cultivation of maize crop continues for four to five years, each time preceded by clearing and burning. The maize crop is generally followed again by groundnuts, but during the 3rd, 4th and 5th year maize is generally planted together with cassava, plantains and macabo, giving very little space for groundnuts. Sometimes cassava is already planted in the first 1-2 years, to spread the risks of failure or to bridge the period to the new maize harvest.



#### 1.7.4. The soils under the system of shifting cultivation

The actions of the system of shifting cultivation on the physico-chemical properties of the soils are threefold: - burning

- occupation
- fallow

The effects of clearing and burning are complex. In general, plant nutrients stored in the vegetation are returned to the soil. In particular Ca, Mg and P. will be returned, resulting in higher base saturation values. We also observed a slight rise of the pH values. It is difficult to give exact data as the high microvariability of the soils often marks the effects of burning. In addition, observations of this kind require a special study.

According to literature, S and N are lost by burning in the form of SO<sub>2</sub> and NO<sub>2</sub>. An important factor is the intensity of the burning (temperature). High temperatures (at the end of the dry season) may cause a total destruction of the exchange capacity, through a process of "baking". Low temperature burning is therefore recommended.

During cultivation, the soils will be particularly exposed to the effects of sunlight and rainwater. Soil temperatures will raise, causing a rapid oxidation of the organic matter and a reduction of the soil microbiological activity. Raindrops will change the structure of the topsoil (ceiling), leach plant nutrients, cause erosion of the valuable topsoil and reduce the water retention capacity. Plant nutrients are removed from the field through the harvest.

During the fallow period organic matter and plant nutrient levels as well as the structure of the topsoil will be gradually restored. During the complete regeneration of the forest, the soil may even restore the original balance.

#### 1.7.5. Yields

To give an idea of the yield levels of the main crops and the total areas planted, a few data are given below. However, one should realize that yield data are very difficult to obtain from a mixed cropping system as most products are used for consumption.

The presented data of the next table are from the Ministry of Agriculture and concern the entire Department Lom et Djerem.

Table 2: Yield levels of maize, groundnuts and cocoyam and their extension

Product	Surface in ha		Yields in kg/ha	
	1975/76	1976/77	1975/76	1976/77
Maize	6800	7150	1220	1180
Groundnuts	5325	6000	850	1070
Cocoyam (Xantosoma)	415	605	4200	4300



With the arrival of the Europeans, cashcrops like cocoa and coffee made their entry in the agricultural system and during the years their importance increased. Nowadays also tobacco, plantains, bananas and rice are grown more or less in a permanent and monoculture system. The cashcrop plantations are invariably found near the roads and close to the villages and are mainly attended by men. In the studied area the management and yields levels are low. Some new tobacco and banana plantations have been started recently.

The table below gives a few data on total planted area and yield levels within the Department Lom and Djerem and are derived from data from the Ministry of Agriculture.

Table 3: Yield levels of cashcrops

CASHCROP	SUBJECT	YEARS					
		1971/72	1972/73	1973/74	1974/75	1975/76	1976/77
Cacao	Surface (ha)	2576	2689	2823	3246	3410	4000
	Yield (Kg/ha)	140	77	101	123	40	35
Coffee (Robusta)	Surface (ha)	3015	3080	3063	3083	3106	3670
	Yield (Kg/ha)	51	78	136	136	107	123
Tobacco	Surface (ha)			785	791	679	619
	Yield Cappe	-	-	450	470	472	529
	Yield Cappe + Coupe (Kg/ha)				662	656	823
Plantains	Surface (ha)					2007	3015
	Yield (Kg/ha)	-	-	-	-	6833	4270
Bananas	Surface (ha)					532	544
	Yield (Kg/ha)	-	-	-	-	8458	12132



## P A R T II

### A). THE SOILS

#### 2.1. SOIL SURVEY AND ANALYTICAL METHODS

#### 2.2. SOIL FORMING PROCESSES

#### 2.3. THE CLASSIFICATION OF THE SOILS OF THE STUDIED AREAS

### 3. SOILS AND SOIL CONDITIONS OF THE STUDIED LANDS

#### 4. INTERPRETATION OF SOIL SURVEY DATA

##### 4.1. INTRODUCTION

##### 4.2. THE LAND SUITABILITY CLASSIFICATION

##### 4.3. SUITABILITY OF THE STUDIED LANDS FOR ROBUSTA COFFEE

##### 4.4. SUITABILITY OF THE STUDIED LANDS FOR FOODCROPS IN A SHIFTING CULTIVATION SYSTEM



## PART II - THE SOILS

### 2.1. SOIL SURVEY AND ANALYTICAL METHODS

Due to the poor accessibility of the area, heavy emphasis had to be placed on the use of the aerial photographs. Used in this study were 1:25.000 aerial photographs of an aerial survey of January 1970, carried out on behalf of the "FAO PROJECT FORESTIER". Unfortunately, the photographs are of a very poor quality due to the use of poor quality photographic materials and the lack of enough overlap between the individual photographs. Extrapolation had to be done sometimes with topographic maps.

As field maps for the study, were used the 1:50.000 topographic maps (sheets NB-33-II Bertoua, 4a, 4c, 3d). Unfortunately, for the northern part north of 5°00' only a 1:200.000 scale top-map was available (IGN, 1:200.000 Deng-Deng, sheet NB-33 VIII).

The survey was organized in the following way: First soils were studied in detail (1:25.000) in carefully selected sample areas, sample strips and toposquences. The collected data provided a technical base for detailed reconnaissance survey of the rest of the agricultural zone. The results of both, the detailed surveys of the sample areas and the detailed reconnaissance survey, are presented in this report (including maps).

Most of the field observations were made close to the existing roads or tracks. A total of about 200 observations were made using auger and spade. A soil observation includes the study of the topsoil (up to  $\pm$  50 cm) in a small pit and the subsoil (up to  $\pm$  120 cm) using an auger. In gravelly soils, it was not always possible to reach this depth. Descriptions were made according to the FAO Guidelines for Soil Description and the U.S. Soil Survey Manual Handbook 18; for the topsoil, the study includes the nature and depth of the surface horizons, their colour, texture, structure, consistency, presence of concretions, mottles, porosity and rootability, while for the subsoil only texture, colour, consistency, concretions and gravels were observed in disturbed (auger) samples. For each observation, the environmental characteristics are noted as well, including relief and microrelief, position on slope, vegetation and land use, soil drainage and permeability, erosion and parent material (see attached observation sheet, page 15).

are

Representative profiles of most of the taxonomic units/described in detail and sampled. The selection of these profiles was based on the auger and spade observations. The samples were analyzed in the Soil and Plant laboratory at Ekona.

In the area Bertoua - Deng Deng in total 15 pits were described of which 12 were sampled. In the area Goyoum - Deng Deng - Haman 7 pits were described and sampled.

Being unfamiliar with the existing relationships between landscape and soils in the area, it was necessary to start with field work first, to obtain a sound base for photo interpretation.

.../...



In forest areas photointerpretation is not an easy task; the aerial photos do not permit to observe the soil itself, nor the soil surface, but only gives a view of the canopy of the tropical forest. The interpretation of aerial photography in these areas consists therefore of the study of "related elements", such as relief, vegetation, and differences in tone, in order to find the correlation between photo-image and soil conditions.

The amount of detail and the accuracy of the interpretation depends on the photo-scale and the quality of the photos. The poor quality photos and the conditions of the area (dense tropical rainforest) only permitted the delineation of easy detectable physiographic units, including plateaus, upper and middle slopes, valley sides and valley bottoms. Different forest types (based on differences in canopy density and "tone") made it sometimes possible to separate areas with gravelly soils from non gravelly areas. However, in areas with secondary forest this element is unreliable and could not be used. From all this, it will be clear that the final soil maps are largely based on physiographic units, the resulting maps being therefore, physiographic soil maps.

Aerial photo mosaics 1:25.000 were used as base maps. These mosaics have been prepared with unrectified photos. The resulting maps are therefore uncontrolled and they should not be used for precise measurement of distances or surfaces.

The preliminary soil maps were checked and improved during a field conclusion tour in the final 1:25.000 maps of the sample areas and a 1:50.000 map of the entire agricultural zone.

The methods used for the analytical analyses are basically those of current use in most international laboratories. Only some methods have been adapted to the available instrumentation of the Ekona Soils Laboratory and the tropical soil conditions.

Air dried samples are crushed with a rolling pin to pass a 2 mm round hole sieve. Determinations are performed on the less than 2 mm fractions and results are reported on that basis. The following analytical determinations were done:

- a) Particles Size Analysis: USDA standard sieves and pipet method, with sodium hexametaphosphate as dispersing agent and end over end shaking.
- b) Organic Carbon: Walkley-Black, wet combustion and colorimetric determination of  $\text{Cr}^{3+}$ ,  $\text{NH}_4$  using Na-phenate and hypochlorite (Auto-Analyser).
- c) Total Nitrogen: Kjeldahl digestion, and colorimetric determination of  $\text{NH}_4$  using Na-phenate and hypochlorite (Auto-Analyser).
- d) pH: Potentiometrically using glass electrode in a 1:2.5 soil/water and soil/1N KCl solution.
- e) Cation Exchange Capacity:  $\text{NH}_4$  saturation with  $\text{NH}_4\text{OAc}$  at pH 7, leaching with  $\text{NH}_4\text{OAc}$ , methylated spirit and KCl. Colorimetric determination of  $\text{NH}_4$  using Na-phenate and hypochlorite (Auto-Analyser).
- f) Exchangeable Cations: Displacement with 1N  $\text{NH}_4\text{OAc}$  at pH 7. Calcium, Potassium and Sodium are determined by flame photometer; Magnesium colorimetrically with titan yellow (Auto-Analyser).
- g) Available Phosphorus: Kurz-Bray II (0.03 N  $\text{NH}_4\text{F}$  and 0.025 N KCl).

.../...



E K O N A

AREA:	AERIAL PHOTO:	PROFILE NO.:
DATE:	DESCRIBED BY:	
SOIL SERIES:	PHASE:	
GEOMORPHY. SURFACE:		ELEVATION:
PARENT MATERIAL:		
LAND USE:		
NATURAL VEGETATION:		GROUND COVER: %

RELIEF:	concave		flat		subnormal		normal		excessive		
POSITION:	top	upper		middle		lower		foothill		bottom	
SLOPE: (%)	0-1	1-3	3-8	8-16	16	LENGTH:					
EROSION:	sheet	rill	gully		CLASS:	0	1	2	3	4	x
ERODIBILITY	none	slight	moderate		high	very high		deposition			
RUNOFF:	ponded	very slow		slow	medium	rapid		very rapid			
PERMEABILITY:	none	very slow	slow	moderate		rapid		very rapid			
DRAINAGE:	very poor	poor	imperfect		mod.well		well	somewh.exces.		excessive	
FLOODING:	none	rare	unusual		regular		frequent				
GROUNDWATER:	depth:		cm			fluctuation:					
ROCK/STONINESS:	0	1	2	3	4	5			pH:		
ALKALINITY/SALIN:	0	1	2	3	4			code:			

REMARKS:

[illegible]



## 2.2. SOIL FORMING PROCESSES

The soils of the Deng Deng Forest are developed under influence of several soil forming processes.

In the studied area the chemical weathering is a very intense process because of the climatic conditions (high temperatures and high rainfall). Due to this and to the old age, the poor parent materials (granites) are weathered to a considerable depth resulting in deep soils, strongly weathered and with low contents of silt, weatherable minerals and plant nutrients, except for potassium (the granites have some K bearing minerals). The physical properties of these soils are good. The soils are very clayey, with over 65 % clay. Their clay fraction is dominated by 1:1 kaolinitic clays and sesquioxides.

Relief appears to be an important factor to explain the differences in the recognised soils. On the flat to undulating surfaces the soils are generally deep, free of gravel and rocks within the rooting zone. (Dondi Series). On the steep slopes, however, the soils are often less deep and contain over 30 % (vol) ferruginous gravels in their subsoils (gravelly phase). The (deep) slope soils differ slightly in texture with their counterparts on the plateaus. They have in general a somewhat sandier topsoil, while the subsoil contains often a little bit more clay. The argillic-B horizon (see next chapter) is also a bit more pronounced in these soils (slope phase). Due to erosion the sloping lands can be rather heterogeneous in their distribution, reason to map these soils as Soil Associations.

The colour of the soils is, through the drainage conditions, indirectly related to the relief. The red (hematite) soils (Dondi Series) occur on the plateaus and upper slopes, while yellowish (goethite) soils (Yambeng Series) are found on the middle and lower slopes, where drainage conditions are somewhat less favourable.

The soils of the valley bottoms are very heterogeneous and are grouped in the Akidi Complex. Most of them are poorly drained. Due to reduction and oxidation most soils have a gley horizon.

Gravelly soils, with over 30 % (vol) gravel starting within the first 20 to 50 cm are found on all positions and are the result of weathering of hardened plinthite.

The real hardened plinthite (or ironstone) is found at greater depth; at 40-60 cm below the surface in case of the Déolé Series and over 100 cm for the gravelly phases of the Dondi and Yambeng Series.

The hardened plinthite is the result of exposure to repeat drying and wetting of soft plinthite, which has been formed in earlier days, probably in a wetter climate, on places with less favorable drainage conditions.



### 2.3. THE CLASSIFICATION OF THE SOILS OF THE STUDIED AREAS

The soils of the area have been classified according to the three, most widely used systems in Africa: the U.S. Soil Taxonomy, the French CPCS system and the FAO/UNESCO legend of the soil map of the world.

Classification of most of the soils of the studied lands is not easy and shows obviously that taxonomic systems are man-made constructions, while nature is often more complex.

The soils of the peneplain have all in common that they are old, strongly weathered soils with a low Cation Exchange Capacity, low base saturation and low pH.

These soils have been classified by Martin et al of ORSTOM as Sols Ferrallitiques typiques, rouges sur roches acides and some as Sols Indurés sur roches acidés (ORSTOM reports, 1966). Based on these reports, these soils have been classified as Orthic Ferralsols in the FAO/UNESCO system and are mapped as such on the Soil Map of the World. Correlating this with the US Soil Taxonomy, they probably would belong to the Oxisols.

However, except for the soils developed in relatively recent colluvial and alluvial sediments, old soils have properties and characteristics indicating the presence of a weak argillic horizon.

- a) the ratio % clay B2/% clay A1 is between 1.2 - 1.4. In only very few cases we find ratios of 1.15 - 1.20 but this may be due to termite activity.
- b) most soils lack the very typical oxisol structure in the B-horizons. The soil structure is angular blocky and there is a fairly good tendency to form weak prisms. A few cutans are always observed but we do not know whether these are really argillous. Certainly many are destroyed by biological activity.
- c) the landscape is relatively young and rejuvenated; although old, this is not the typical oxisol landscape.

The clay distribution is such that the percentage of clay does not decrease from its maximum amount by over 20 % of that maximum within 150 cm from the surface.

As a result of this all the soils have been classified in this report as Paleudults (US Soil Taxonomy), Nitosols (FAO/UNESCO legend) or Sols ferrallitiques fortement désaturés, appauvris.

The deep soils of the slopes show more pronounced features of clay illuviation, compared to the plateau soils; the ratio % clay B2/% A1 amounts to 1.4 or more. However, this and other differences (e.g. more yellowish colours, sandier topsoils and somewhat clayier subsoils) are too small to classify the soils in other taxonomy at subgroup level and the differences generally occur at family level. The plateau soils are very fine clayey, while the slope soils are often fine clayey.

The gravelly soils are also Paleudults, but they have a clayey skeletal texture and are shallow (gravels between 18 and 50 cm). In this report a Petroferric subgroup is introduced for soils having a petroferric contact within 100 cm of the surface.

.../...



Soils formed in recent colluvial material show less profile development. Diagnostic horizons are an ochric epipedon and cambic horizon. Due to their Low Base Saturation and low CEC many of these soils are members of the Oxic Dystropepts (Soil Taxonomy), Sols d'apport colluvial (French) and Dystic Rogesols (FAO/UNESCO legend). Others are more developed and have an argillic horizon. These soils would be Orthoxic Tropudults (Soil Taxonomy) or Orthic Acrisols (FAO/UNESCO).

Most soils of the hydromorphic valley bottoms and the poorly drained floodplains are young alluvial soils with distinct features characteristic for excess water and without many profile development. The organic matter content is moderately high for these soils and generally decreases regularly with depth. They are developed in layers of contrasting textures. Most of them belong to the Tropic Fluvaquents (US Soil Taxonomy), Sols hydromorphes peu humifères a gley de surface ou gley de profondeur (French) or Dystic Gley Sols (FAO/UNESCO).



LEGEND SOIL MAP			
MAPPING UNITS	U.S. SOIL TAXONOMY	FRENCH	FAO
<u>IA. SOILS OF THE PLATEAUS</u>			
Do.u. Dondi Series, gently undulating	Oxic Paleudult, very fine clayey.	Sols ferrallitique fortement désaturés en (B) appauvris	Mostly Dystric Nitosols
De.u Déole Series, gently undulating	Petroferric Paleudult, clayey skeletal.		
<u>IB. SOILS OF THE UPPER/MIDDLE SLOPES</u>			
Ya. Yambeng Association	Oxic Paleudult; 75% very fine and fine clayey; 25% clayey skeletal.	"	"
Do.s Dondi Series, sloping	Oxic Paleudult, mostly fine clayey.	"	"
Do.gr Dondi Series, gravelly	Oxic Paleudult, clayey skeletal	"	"
De.s Déole Series, sloping	Petroferric Paleudults	"	"
Go.s Goyoum Series, sloping	Oxic Paleudult, fine clayey	"	"
Go.l Goyoum Series, lateritic	Petroferric Paleudult, clayey skeletal	"	"
<u>IC. SOILS OF THE INCISED VALLEY SYSTEM</u>			
Mi. Mianbab Association	Oxic Paleudults, 25% fine clayey, 65% clayey skeletal, 10% Oxic Dystropepts.	"	"
Di. Dido Association	75% Oxic Paleudults clayey skeletal and very fine clayey, 10% Petroferric Paleudults, 15% Oxic Dystropepts.	"	"
Ng. Ngolo Association	80% Petroferric Paleudults, 20% Oxic Dystropepts.	"	"
Mb. Mbalò Association	80% Oxic Paleudult, clayey skeletal 20% Oxic Dystropept.	"	"
Ba. Badanga Series	Oxic Paleudult, loamy	"	"
<u>ID. SOILS OF THE VALLEY BOTTOMS + FLOODPLAINS</u>			
Ak. Akidi Complex	60% Tropic Fluvaquent; 40% Tropoflu- vents and Tropaquepts.	Sols hydromorphes peu humifères à gley	Dystric Gleysol
Sa.p. Sanaga Ass., poorly drained	Mostly Tropic Fluvaquent	"	"
Sa.m.w. Sanaga Ass., mod. well drained	Mostly Tropofluvents, Tropoquepts and Dystropepts	Sols peu évolués d'apport.	Dystric Fluvisol



# VIALI SAMPLE AREA- SCHEMATIC CROSS SECTION

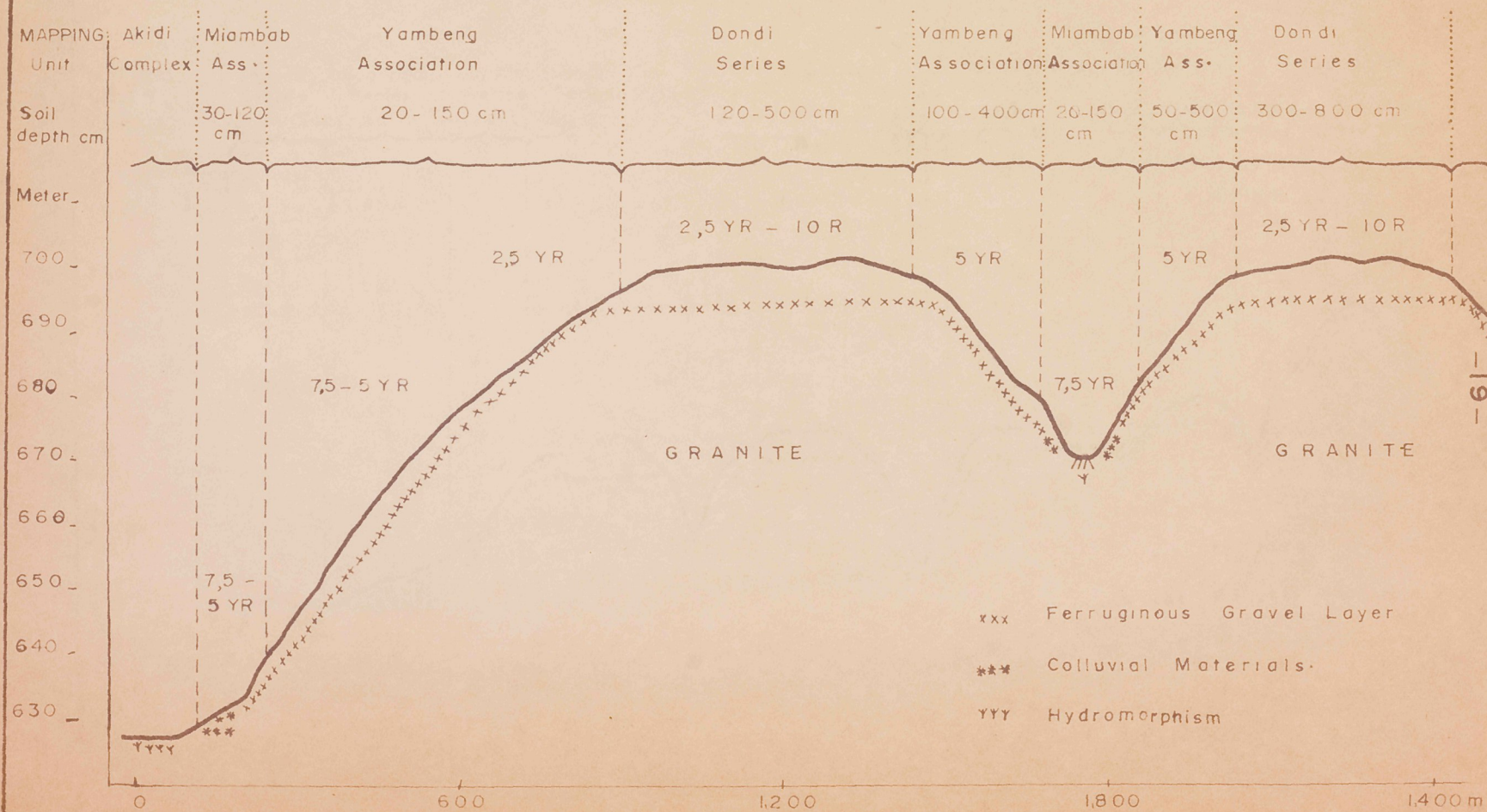


FIG. 4



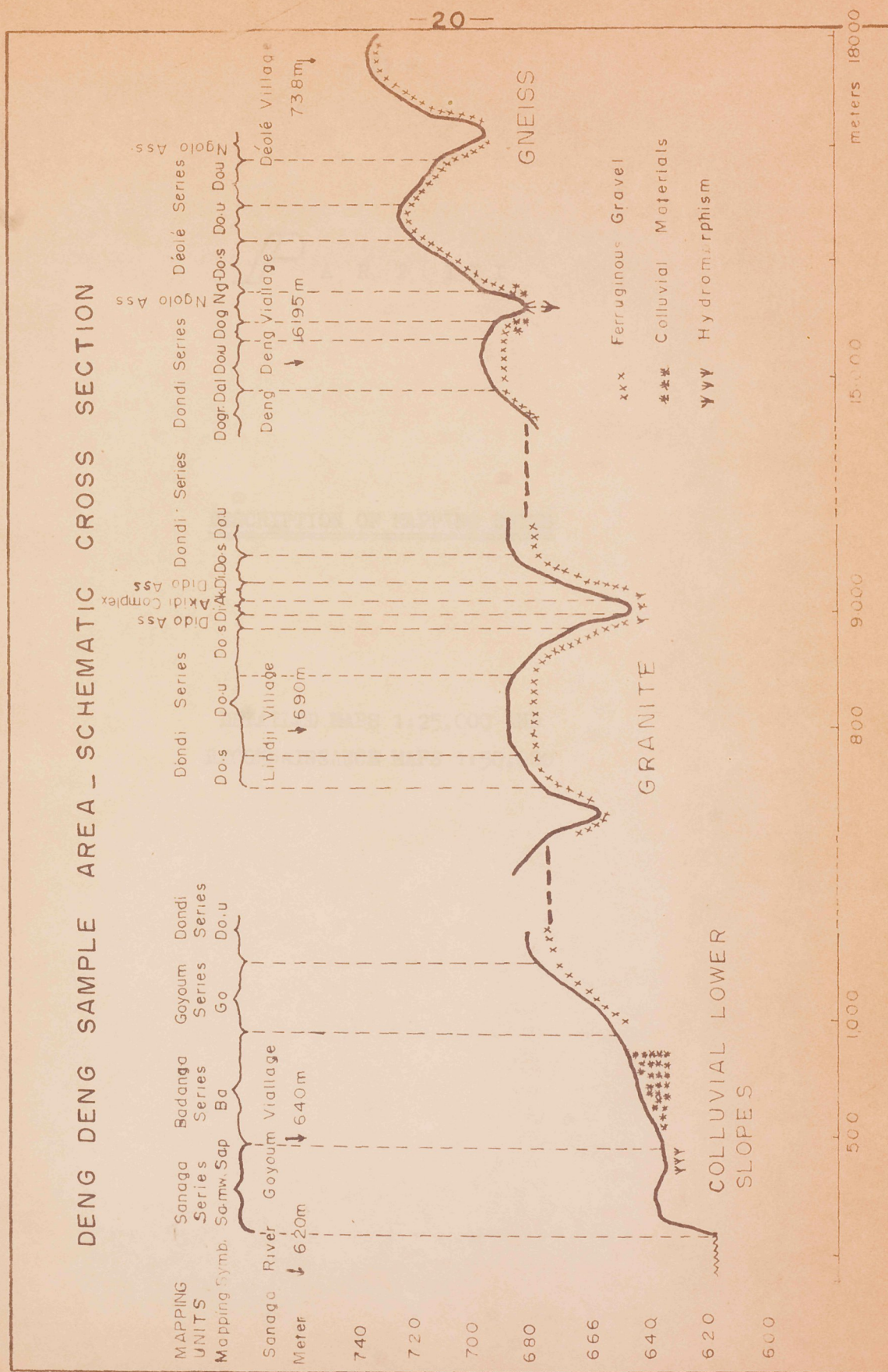


FIG. 5



# *P* A R T I I I

## DESCRIPTION OF MAPPING UNITS

### DETAILED MAPS 1:25,000 AND RECONNAISSANCE MAPS 1:50,000

The soil is a light brown, sandy, loamy, slightly acid, with a high water table. It is a typical coastal soil, formed from sand and silt, with a high water table. The soil is very fertile, and is well suited for the cultivation of a wide range of crops. The soil is very fertile, and is well suited for the cultivation of a wide range of crops. The soil is very fertile, and is well suited for the cultivation of a wide range of crops.

The soil is a light brown, sandy, loamy, slightly acid, with a high water table. It is a typical coastal soil, formed from sand and silt, with a high water table. The soil is very fertile, and is well suited for the cultivation of a wide range of crops. The soil is very fertile, and is well suited for the cultivation of a wide range of crops. The soil is very fertile, and is well suited for the cultivation of a wide range of crops.

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#### 1.1.2. Sand Dunes, showing mapping symbol: Dune

These dunes are found on the upper and middle slopes of the coastal dunes. They are formed from sand and silt, and are very fertile. The soil is very fertile, and is well suited for the cultivation of a wide range of crops. The soil is very fertile, and is well suited for the cultivation of a wide range of crops. The soil is very fertile, and is well suited for the cultivation of a wide range of crops.



### 3.1. DONDI SERIES

#### 3.1.1. Dondi Series, very gently undulating (mapping symbol Do.u)

The Dondi soils are very deep, well drained, red ferrallitic soils, derived from granitic parent materials. Dondi soils are free of ferruginous gravel, except on some edges of the plateaus and on some of the steeper slopes (gravelly phase). They are found on the undulating plateaus (680-720m above sealevel with 0-3 % slopes) in the central and northern part of the Deng Deng Forest. The unit covers approx. 9 % of this part of the forest. The plateaus are sometimes very small and on the 1:50.000 map, the plateaus <25 ha could not be mapped as individual units. These very small units are indicated on the map with a special symbol.

The surface shows a very characteristic microrelief of hinge old termite mounds covering over 20-50 % of the surface.

The Dondi soils are forest soils with a thin topsoil (A1 of 3-8 cm, and a B1 of 10-20 cm), darkbrown to reddish brown and with sandy clay to clayey textures (50-60 % clay). The structure is granular to subangular blocky. The subsoils are very clayey (over 65 % clay) and are yellowish red to red. The upper part (B21) has a moderate irregular angular blocky structure with a tendency to prisms. The lower part (B22) has a moderate to weak angular blocky structure.

#### Physical properties:

Dondi soils have good physical properties. The soils are well drained and have a moderate permeability and water retention capacity (120-150 mm in the first 100 cm by estimate). The soils are presently not eroded, but when cultivated they are slightly susceptible to sheet erosion.

#### Chemical properties:

Dondi soils have a low fertility status. Fertility is largely depending on the organic matter in the thin topsoils. Under a dense forest cover the organic matter content in the first 20 cm is roughly 2.5 % and is regularly but rapidly decreasing with increasing depth. At 1m the levels vary between 0.6 and 0.9 %.

Dondi soils have low levels of available plant nutrients, except Potassium; extremely low are Magnesium and Sodium. The distribution of calcium is irregular within the profile, due to termite activity.

Dondi soils are acid soils with pH values ranging from 4.5 to 5.5. Under the system of shifting cultivation the topsoils are temporarily enriched by the ash of the burned vegetation.

For data and more details see Annex page 2.

Dondi soils are the most suitable soils for most crops of the area, but the low fertility status is a main constraint for high yields.

#### 3.1.2. Dondi Series, sloping (mapping symbol: Do.s)

These soils are found on the upper and sometimes middle convex slopes in the central and northern part of the Deng Deng Forest. Slope percentage ranges from 3 to 8 %, and in some cases from 8-20 %, and length is between 400 and 200 m. This unit covers approx. 20 % of the central part and approx. 30 % of the northern part of the area.



The physical and chemical properties are similar to the soils of the flatter plateaus (the Dondi soils very gently undulating), although the topsoil may be slightly more sandy. In addition, termite mounds are less abundant. Under forest cover these soils are not eroded, but when the forest is cleared the soils are slightly to moderate susceptible to sheet(gully) erosion. In the north and northwest the gently sloping Dondi soils are mapped as individual units, but in other areas these soils are grouped with the Yambeng soils in the Yambeng Association (mapping symbol: Ya.).

### 3.1.3. Dondi Series, gravelly (mapping symbol Do.gr.)

In the northern part of the forest, in the transition zone to the Déolé Series, gravelly Dondi soils are mapped as individual units, but in other areas they are mapped as an association with the Yambeng soils (Miambab and Yambeng associations, see paragraph 3.3 and 3.4) or with colluvial and sloping Dondi soils (Dido Association, see paragraph 3.5). The individual units cover approx. 7 % of the surface in the northern part. Gravel starts generally within 20-50 cm of the surface and the gravel content is rapidly increasing with depth. The properties of the gravelly Dondi soils are similar to the ones without gravel except for the limited water retention capacity, and the low absolute quantity of nutrients.

These soils have low potentials for most crops.

## 3.2. DEOLE SERIES

### 3.2.1. Déolé Series, very gently undulating (mapping symbol: De.u)

The Déolé Series are found in the North-Eastern part of the Deng-Deng Forest on the undulating upper plateaus (720-760m) with slopes between 1 to 3 %.

The soils are well drained, ferrallitic soils with a limited soil depth, due to the presence of a continuous indurated plinthite (ironstone) layer.

This mapping unit covers a limited area, northeast of Deng Deng village.

The ironstone layer starts between 20 and 40 cm from the surface and the upper part is generally weathered giving the topsoils a gravelly character.

On some places the soils contain less gravel or are even free of gravel in the topsoils as a result of some colluvial enrichments. Due to local variation, it is impossible to map the gravelly soils individually on a 1:25.000 map.

Déolé soils have a thin (3-8cm) A1 horizon with a sandy clay texture.

The colours are ranging from dark yellowish brown to (dark) brown (10 YR 5/4, 4/4 - 7.5 YR 4/4, 5/4). This topsoil contains 0-40 % (vol) ferruginous gravel, with a diameter up to 3 cm.

This horizon is followed by a transitional B1 horizon of 8-16 cm with a sandy clay to clayey texture. It contains up to 70 % (vol) ferruginous gravel (up to 5 cm). Below this horizon, the amount of gravels and their size is increasing rapidly with increasing depth and forms a continuous indurated plinthite (ironstone) layer, generally between 40 and 50 cm from the surface. The B2 horizon (where existent) has strong brown to yellowish red colours (7.5 YR 5/8, 5 YR 5/6, 5/8) or is sometimes red (2.5 YR 5/6) and has a clayey texture.



The vegetation is a poor semi-deciduous tropical forest but in places where the soils are very shallow a bushy savana prevails. Once cleared, it is likely that the forest will not return on these soils. Under the natural vegetation the soils are not to slightly eroded, but they are moderately susceptible to erosion when the vegetation is cleared. The chemical and physical properties are similar to the gravelly Dondi soils. The fertility status and the water retention capacity are low. Due to the limited extension and their very limited development possibilities, no samples have been analyzed.

### 3.2.2. Déolé Series, sloping (mapping symbol De.s)

The sloping phase groups the Déolé soils on 3-16 % slopes (locally up to 25 %). Generally, the topsoils are rather sandy (sandy clay loam) and are more susceptible to erosion. On the reconnaissance 1:50.000 map a few very gently undulating Déolé soils are included in this unit as well. The unit covers 20 % of the northern part of the agricultural zone.

### 3.3. YAMBENG ASSOCIATION (Mapping symbol: Ya)

The Yambeng Association is an association of soils found on the gentle middle and lower slopes to the main streams in the central part of the Deng Deng forest. Most of the slopes are of an S-type, with convex 3-8 % (locally up to 16 %) upper slopes and concave 3-8 % lower slopes. The mapping unit covers approx. 45 % of the central portion of the area.

The soils are derived from granitic parent materials. Most are deep to moderately deep and many are eroded, particularly on the steeper slopes and under cultivation. Steep relief and erosion problems are the main constraints for their development.

The association includes the following soils:

#### a) Sloping Dondi Soils (25 % of the association)

These soils occur on the gently sloping and sloping upper slopes (3-8 % slopes). The Dondi soils are deep soils with thin, sandy clay, dark brown to reddish brown topsoils and clayey, reddish subsoils. For details see paragraph 3.1.2.

#### b) Gravelly Dondi Soils (10 % of the association)

The gravelly Dondi soils are generally found on slope breaks and steeper upper slopes (8-16 % slopes). Gravel generally starts within the first 50 cm of the profile, but many are gravelly right from the surface. The chemical properties are similar to the Dondi soils without gravel, but the water retention capacity is limited, giving the soils a rather droughty character.

In a few cases, the gravel forms an almost continuous indurated ironstone layer, very difficult to penetrate.

#### c) Yambeng Soils (50 % of the association)

The Yambeng Series are found on the gentle middle and lower slopes (3-8 % slopes). The soils are deep to moderately deep, with rather thin, sandy clay to sandy clay loam surface horizons, dark yellowish brown to dark brown in colour. The subsoils are clayey and have strong brown to yellowish red colours. They differ from the Dondi soils in their texture (more sand, particularly in the topsoil) and colour (yellowish). A description of a typical Yambeng soil is given in the Appendix page 6.



The Yambeng soils have a limited suitability for most crops due to the low nutrient levels, limited waterholding capacity and erosion hazard.

d) Gravelly Yambeng Soils (15 % of the association)

The gravelly Yambeng soils are mostly found on slope breaks and steeper parts of middle slopes (8-10 % slopes). Gravel is generally found within the first 20-50 cm, and increases (% size) with depth. The soils are hardly suitable for any successful agriculture.

3.4. MIAMBAB ASSOCIATION (Mapping Symbol: Mi.)

The Miambab Association groups the soils of the deeply incised and steep valley systems in the central part of the Deng Deng Forest. The association includes the soils of the steep slopes of the very small U-shaped and the V-shaped valleys. The Miambab Association covers approx. 40 % of the central portion of the Deng Deng Forest.

The association includes the following soil types:

Gravelly Dondi Soils (15 % of the association)

These soils are found on the moderately steep upper and sometimes middle slopes (3-16 % locally up to 20 %). Gravels generally start within 50 cm from the soil surface. The soils have a thin sandy clay, dark brown to reddish brown topsoil and clayey, reddish and gravelly subsoils. A detailed description is given in paragraph 3.1.3. The soils have low potential for most crops; the presence of gravel (limited water retention capacity) and the rather steep relief (erosion) being major limitations.

Gravelly Yambeng Soils (50 % of the association)

The gravelly Yambeng soils are found on the steep middle and lower slopes (8-16 %, locally up to 40 %). Gravel starts generally within 20-50 cm from the soil surface. Generally speaking, the soils have yellowish sandy loam to sandy clay topsoils and gravelly, clayey, strong brown to yellowish red subsoils (see annex page 6).

The steep relief and the presence of gravel are serious limitations for any type of agriculture.

Yambeng Soils (25 % of the association)

These soils occur on the moderately steep lower slopes. The soils are gravel free or gravel occurs only in the deeper subsoil. They have the same textures and colours as the gravelly Yambeng soils. The steep slopes are a major limitation for agriculture. A detailed description is given in annex, page

Other soils of the steep lower slopes (10 % of the association)

On some places, some colluvial material is accumulated at the footslopes. The soils are rather young, and fairly well supplied with nutrients (Dystropepts). They have sandy clay loam to sandy clay profiles with yellowish colours. They cover only a very small part of the area (less than 1 %).

On some other places these soils are very shallow (0-30 cm) because of the presence of the granitic parent material, close to the surface.



### 3.5. DIDO ASSOCIATION (Mapping Symbol: Di.)

The Dido Association groups the soils of the incised valley systems in the northern and northwestern part of the Deng Deng Forest. Approx. 60 % of the soils are gravelly and very gravelly.

The Dido Association covers approx. 25 % of the northern portion of the agricultural zone.

Description of the composing soils of the Dido Association:

#### Gravelly Dondi soils (50 % of the Association)

These soils occur on the steep valley sides (8-16 % slopes, locally 16-40 %). They have clayey, yellowish red profiles with over 30 % (vol) ferruginous gravel, which starts between 20 and 50 cm from the surface. These soils have low potentials for agriculture, due to the presence of gravel and the steep relief.

#### Petroferric Dondi soils (10 % of the Association)

On some places the ferruginous gravel layer is very close to the surface and is indurated at shallow depth. These soils are unsuitable for agriculture.

#### Sloping Dondi soils (25 % of the Association)

The sloping Dondi soils occur mostly on the moderately steep middle and upper slopes of the valley system (8-16 % slopes). The soils are moderately deep; gravel content increases with depth after the first 100 cm of the surface. The profile shows a sandy clay, dark brown to reddish brown topsoil and clayey, yellowish red subsoils. Due to the limited extension and the steep relief these soils have low to moderate suitabilities for most crops.

#### Colluvial soils (15 % of the Association)

On a few places the footslopes are concave and on these spots colluvial material accumulates. The soils are rather young and have stratified sandy profiles (Dystropepts). Due to their sandy character they have low water retention capacities which is a major limitation for their use.

### 3.6. NGOLO ASSOCIATION (Mapping Symbol: Ng)

The Ngolo Association groups the soils of the incised valley systems in the north-eastern part of the Deng Deng Forest. The soils of this association are gravelly to very gravelly, and due to this and the steep slopes, the development potential of this unit are very limited.

The composing units of the Ngolo Association are:

#### Sloping Déolé soils (+ 80 % of the association)

These soils are found on the steep slopes (8-16 %, slopes locally up to 40 %) of the valley sides. The sloping Déolé soils are characterized by high amounts of gravel in the upper part of the profiles and an indurated plinthite (iron-stone) layer at shallow depth (20-60 cm).

The soils have very low potentials for most crops.



Other valley side soils ( $\pm 20\%$  of the association)

On some places, due to erosional processes, soils are moderately deep (Dystropepts). In general, they are developed in stratified colluvial materials of different age and have sandy clay loam topsoils and sandy clay subsoils. Most of these soils are gravelly in the subsoil. Due to their small extension and steep slopes and sandy profiles, they have low development potentials.

3.7. GOYOUN SERIES

3.7.1. Goyoum Series, gently sloping and gravelly (mapping symbol: Go.s)

The Goyoum soils are well drained, yellow ferrallitic soils, found on the upper and middle slopes to the Sanaga and Lom River and its immediate tributaries. The soils are derived from acid parent materials, including gneisses in the northeast and granites in the northwest. This unit cover approx 8 % of the northern part of the agricultural zone. Slope percentages range from 3 to 16 %. On the gentle slopes ( $\pm 85\%$ ), the soils are free of ferruginous gravel within the first 80 cm but on the steep slopes ( $\pm 15\%$ ) the soils are gravelly almost from the surface. Individual mapping of the gravelly Goyoum soils proved to be impossible, even at the 1:25.000 scale and this mapping unit is therefore basically a soil association.

Goyoum soils have a sandy clay loam to sandy clay topsoil (0-25 cm) with dark yellowish brown, or strong brown colours. The organic matter content in the topsoil amounts to 2.2 - 2.7 % under natural forest. The subsoils have sandy clay to clayey textures and strong brown to yellowish red colours. The upper part of the subsoil shows few evidences of clay illuviation, including a few fine clay skins on ped faces and weak prismatic structure. The ratio clay B2/clay A1 ranges from 1.4 to 1.5. (see annex page 13)

Physical and chemical properties:

Goyoum series have good physical properties. The soils are well drained and have a moderate permeability. Runoff is medium. The water retention is estimated to be 125 mm for the first 100 cm. The soils are not to slightly eroded under natural forest but they are rather susceptible to erosion when cleared. The fertility status of the Goyoum soils is low, in particular the ones derived from granite in the northwest. In the northeast they appear to be slightly more fertile (derived from gneisses) but this difference is not enough to separate them.

Goyoum soils are acid soils, pH values range from 4.0 to 6.0.

These soils are moderately suitable for the cultivation of most crops. The relatively low water retention capacities, low fertility status, and erosion hazards are the main constraints.

3.7.2. Goyoum Series, petroferric (mapping symbol: Go.l)

These soils have an indurated plinthite (ironstone) layer near the surface (within 20 to 40 cm) and are found on the middle slopes of the complex slopes to the Sanaga floodplain. In general, they occupy positions downslope the sloping and gravelly Goyoum soils and upslope the Badanga soils. The unit covers a limited area in the northwestern part of the agricultural zone (0.6%). The soils are covered by a savanna vegetation and have low potentials.



### 3.8. BADANGA SERIES, slope (mapping Symbol: Ba.s)

Badanga Series are colluvial soils found on the footslopes and lower complex slopes (1-8 %) to the Sanaga and Lom floodplains. The mapping unit covers approx. 1.5 % of the northwestern part of the agricultural zone.

Generally, the Badanga soils have some (<30 % vol) ferruginous gravel in the first 100 cm. They have a 7-15 cm thick A1 horizon, which often can be divided into an A11 and A12 horizon. The texture is sandy clay loam (20-35 % clay) and colours are dark brown to brown to yellowish brown. The organic matter content is between 1 and 3 % and is slowly decreasing in the subsoil. The transitional B1 horizon (13-22 cm) has a sandy clay loam texture and is rather compact.

The B2 horizon is composed of different layers of colluvial material. The texture is sandy clay to clay (50-65 % clay) and has strong brown colours.

#### Physical characteristics:

Badanga soils are well drained and permeability is estimated to be moderate. Due to their sandy clay loam topsoils and their low content of organic material, the water retention capacity is limited (approx. 80 mm) in the first meter. The Badanga soils are slightly to moderately susceptible to erosion, depending on position and slope.

#### Chemical properties

Badanga soils have a low fertility status and are rather acid (pH: 5-5.5). Like all the soils in the Deng Deng Forest, they are particularly poor in Magnesium and sodium and have relatively good levels of Potassium. For more details see Annex page 17.

The Badanga soils are moderately suitable for most crops, the major constraints being the sandy textures which make the soils rather droughty.

### 3.9. MBALO ASSOCIATION (Mapping symbol: Mb)

The Mbalo Association includes the soils of the incised and steep valley sides in the area of the complex slopes to the Sanaga and Lom River.

The soils are rather sandy in the topsoils and many are gravelly.

The soils are derived from acid parent materials, including granites in the west and gneisses in the east. Most are moderately deep or shallow, with low potentials for most crops.

The Association is composed of the following soils:

#### Gravelly Goyoum soils (70 % of the association)

These soils occur on the steep lower slopes (8-20 %). Gravel generally starts between 20 and 50 cm from the surface, and increases with depth.

These soils have a 5-10 cm thick A1 horizon, with sandy clay loam to sandy clay textures and yellowish brown colours. This horizon is followed by a sandy clay B1 horizon of 15-20 cm. The underlying B2 horizon has over 75 % ferruginous gravels. The soils are well drained and surface runoff is moderate to rapid. Permeability is estimated to be medium.

#### Badanga soils (20 % of the association)

On the concave footslopes some soils are developed in older colluvial material. The soils have a sandy clay loam topsoil and a sandy clay to clayey subsoil (see paragraph 3.8).



Young colluvial soils (10 % of the association)

On some convex footslopes young colluvial soils are found (Dystropepts). The soils have sandy clay loam and sandy clay textures throughout.

3.10. AKIDI COMPLEX (Mapping symbol: Ak)

**The Akidi Complex groups the alluvial and alluvio-colluvial soils of the hydromorphic U-shaped valley bottoms, found throughout the area.**

On the 1:25.000 maps these valley bottoms are mapped individually only where they are wide enough (generally over 65 m). Smaller valleys are indicated by special symbols. On the 1:50.000 scale maps only the valley bottoms over 130 m are mapped. Akidi Complex covers approx. 10 % of the surface in the central part and approx. 6 % in the northern part of the Deng Deng Forest.

The Akidi soils have one characteristic in common: they all show more or less distinct features of excess water including Fe Mn mottles and gley. During the dry season groundwater tables are found between 1.50-2 m and close to the surface, depending on the position. During the rainy season many are flooded. Most soils (70 %) are poorly to imperfectly drained Tropic Fluvaquents and Tropofluvents, while others (15 %) are very poorly drained Fluvaquents or, on the somewhat higher places (15 %), moderately well drained Tropofluvents and Tropaquepts.

The distribution of the soils is largely depending on differences in local drainage conditions and sedimentation patterns. Generally speaking, the profiles are developed in stratified layers of sandy clay loam to clayey materials, with one or more bands (of 10-20 cm), composed of more sandy materials, in between. Their thin (5-10 cm) dark coloured A1-horizons are rich in poorly decomposed organic matter (5-10 %) and are followed by an AC (or B1) horizon. The underlying C (or gley B) horizons are characterized by gley colours or profuse mottling throughout.

The fertility status of the Akidi soils vary greatly, but generally the soils are poor and acid. Except for Potassium, the soils have a low content of nutrients (Na and Mg); pH-values range from 4.0-5.5. Due to the high amount of organic matter in the topsoil, the fertility status of the topsoil is moderate. Some of the lands are suitable for rice cultivation and the better drained lands also for early maize.

Poor accessibility, heterogeneity and poor drainage conditions are the major constraints for the large scale development of these lands.

A typical valley bottom soil is described in the Annex on page

3.11. SANAGA ASSOCIATION

The Sanaga Association includes the soils of the floodplains of the Lom and Sanaga Rivers. Both rivers have build up a system of weakly developed levees and backswamps with the following soils:

- moderately well drained levee soils
- poorly to imperfectly drained backswamp soils.

The floodplains cover approx. 5 % of the northern part of the agricultural zone, with 60 % levee and 40 % backswamp soils.



### 3.11.1. Levee Soils (Mapping symbol: Sa. m.w.)

The levee soils are moderately well drained, the groundwater table fluctuating between 150-250 cm below the surface during the dry season and 100-200 cm during the rainy season. Flooding is rare and when it occurs it is only for short periods.

The soils are formed in relatively recent alluvial deposits of medium textures. The A1 horizon (8-12 cm thick) has dark brown to brown colours (10 YR 4/3, 5/3) under natural conditions. Under cultivation, leading to a decrease of organic matter content, the colours become lighter and vary from dark grayish brown to grayish brown (10 YR 4/2, 5/2). The textures of this horizon are mostly sandy loam to sandy clay loam (16-25 % clay). The organic matter content under natural vegetation is relatively high (5-10 %), under cultivation this content drops to 1.5-3.0 %.

This horizon is followed by a AC horizon or a weakly developed B1 horizon of 20-25 cm mostly sandy clay loam (20-25 % clay).

The subsoil (C, or weakly developed B2 horizon) has faint gley colours ranging from lightgrey to grey with moderate mottling. The range in textures is rather wide but sandy clay loam and sandy clay textures prevail.

In some cases the subsoil has some actual plinthite (soft) while other soils are slightly buried by one or more thin colluvial layers.

### 3.11.2. Backswamp Soils (Mapping symbol: Sa.p)

The soils of the backswamps are poorly to imperfectly drained, and show moderate to strong features of excess water. The poorly drained soils are saturated the greater part of the year, the imperfectly drained only during the rainy season. Very often they receive water from streams coming from the adjacent slopes. Generally, the soils have sandy clay textures but this depends on the local sedimentation pattern and position. Due to poor accessibility, these soils are not studied in detail. The backswamp soils have a grass vegetation. This conspicuous vegetation pattern made it possible to map the backswamp soils individually.



#### 4. INTERPRETATION OF SOIL SURVEY DATA

##### 4.1. INTRODUCTION

This part of the report concerns the interpretation of the collected land and soil resources survey data into terms of suitability for the two main land systems: the cultivation of coffee and the cultivation of foodcrops in a shifting cultivation system.

The land evaluations presented here are physical evaluations and have an ecological approach. Economics did not enter the evaluations, as no reliable data on crop production and yield levels could be obtained.

##### 4.2. THE LAND SUITABILITY CLASSIFICATION

The structure of the interpretative grouping of lands is a system adopted in all studies and surveys carried out by the Soil Science Department and the FAO Soil Resources Project at Ekona.

According to this system, the suitability of a certain land unit is indicated following a classification consisting of four levels of detail:

Land Suitability Orders  
    Land Suitability Class  
        Land Suitability Subclass  
            Land Suitability Unit

##### a) Land Suitability Orders

Order S: SUITABLE LAND. Lands on which sustained use for the defined land utilization type is expected to yield benefits that will justify its use, without unacceptable risks of land degradation.

Order N: UNSUITABLE LAND. Lands having characteristics which appear to preclude its sustained use for the defined land utilization type, or which would create production, upkeep or conservation problems unacceptable at the time of the survey.

##### b) Land Suitability Classes

Land suitability classes indicate the relative degree of suitability for the particular land utilization type. The classes are numbered in order of decreasing suitability (increasing limitations).

Class S1: HIGHLY SUITABLE LAND. Lands without limitations or only one very slight limitation. Major improvements are not necessary, and management practices required to ensure sustained use without hazard to the land resources are normal and simple. Lands giving high yields at relatively low costs. There are no lands of this class in the studied area.

Class S2: SUITABLE LAND. Lands with usually a few minor limitations. Major improvements, where necessary, are relatively simple or apply to all the lands in the area considered. Apart from the normal management practices, some special practices may be required where necessary but they can be implemented easily and at readily acceptable cost. Lands giving high yields at moderate costs or good yields at relatively low costs.



Class S3: MODERATELY SUITABLE LAND. Lands suited with usually a few moderate limitations that will significantly reduce production levels or that require correction at significant cost. Major improvements, where necessary, are more difficult or expensive than in the case of class S2, but their cost is acceptable. Special management practices may be required to ensure sustained use without hazard to the land, but they may be fairly difficult or expensive to apply. Land giving either significant lower yields, or high yields at relatively high costs.

Class S4: marginally suitable land. Lands marginally suited with limitations which together are severe and that will seriously reduce production levels or cause erratic variations in production, or that require corrections at high cost. Major improvements, where necessary, are still feasible but difficult and expensive. Special management practices, where required to ensure sustained use without hazard to the land, may be difficult and expensive to apply. Land giving marginal yields in relation to the cost.

Class N1: PRESENTLY UNSUITABLE LAND. Lands having limitations which cannot be corrected with existing knowledge at presently acceptable cost and which preclude the successful sustained use of the land. (There are no lands of this class in the studied areas).

Class N2: PERMANENT UNSUITABLE LAND. Lands having limitations which cannot be corrected and which are so severe as to preclude any possibility of successful sustained use of the land.

#### c) Land Suitability Subclasses

Land suitability subclasses are divisions within classes, distinguished by the nature of the diagnostic criteria that are not optimal (limitations). The subclasses are indicated by lower case letters following the class symbol. Only one or rarely two lower-case letters are used; this means that subclasses do not provide information on the nature of all the limitations.

The following subclass symbols are used:

- c: climatic limitations (length of dry season, excessive rainfall, temperature, altitude, low radiation, etc.)
- d: adverse drainage conditions (excess soil water groundwater levels, ponding, etc.)
- f: flooding.
- l: limitation in the free layout of large blocks, limited accessibility, etc.
- n: low nutrient levels with or without extreme soil acidity.
- s: adverse physical soil conditions (texture, structure, soil depth, stoniness, rockiness, etc.)
- t: adverse topography (slope, erosion).

Subclasses are not used for class S1 (no limitations).

#### d) Land Suitability Units

Land suitability units are divisions within subclasses distinguished by detailed aspects of their management requirements (often detailed differences of their limitations). Land suitability units are only used in detailed surveys at farm management level. They are not used in this report.



#### 4.3. SUITABILITY OF THE STUDIED LANDS FOR ROBUSTA COFFEE

This chapter describes the fitness of the mapping units for Robusta coffee by smallholders. For the evaluation of the suitability, the following factors are important to consider: climate, physical and chemical soil conditions, soil drainage and topography. Freedom of layout and accessibility are of minor importance because of the type of cultivation (smallholders) and the fact that only the agricultural zone is considered, i.e. the lands immediately along existing roads.

According to literature,<sup>\*</sup> the requirements of Robusta coffee can be summarized as follows:

##### Climate:

Although the ecology of Robusta is not yet very well known, the following can be said: Robusta, an ever green plant, prefers a climate with an udic moisture regime with approx. 2000 - 2500 mm of rainfall for optimal growth. More rain or very wet rainy seasons decrease yields, probably due to a major incidence of diseases.

Some authors stated that an equatorial climate would be ideal because the life cycles of the coffee plant (vegetative growth - flowering - fruit setting - rest period) is following the annual rainfall distribution pattern.

Robusta has, compared to Arabica, a rooting system which is largely confined to the upper soil layers. As a result of this the plants are rather susceptible to drought and a long dry season can seriously affect the growth and production. Optimum temperatures for Robusta are between 24 and 25°C, with small variations during the year. In the tropics these temperatures often occur in soils, found between 200 and 700 m above sealevel.

Robusta grows well under full sunshine, provided there are no other limitations; shade only seems to be necessary in areas with over 3000 hours of sunshine a year, or with very low levels of management and/or soil fertility levels.

In the area of Deng Deng the total amount of rainfall is approx. 1600 mm/yr., occurring mainly in two rainy seasons with 600 mm of rain each. Only during January and February the soils are completely dry for 3 to 7 weeks, depending on soil texture and gravel content. During this long dry season (Dec., Jan., Feb.) rainfall amounts to 200 mm only, mostly irregularly distributed and only partly replenishing lost soil-water. As a result of this, this dry period can be a more or less serious limitation for coffee cultivation. Sunshine ( $\pm$  1600-1700 hrs/yr.) can be considered probably as a slight limitation, while the temperatures can be considered as optimal.

##### Physical and Chemical soil conditions and Drainage

Good physical soil conditions are very important for coffee. Fairly deep, friable and permeable soils are preferable as well as soils with a good and friable structure.

The nutrient requirements of coffee are high; although the amount of nutrients, removed from the field with the coffee berries are relatively low and crop residus can easily be returned and maintain the soil fertility levels.

Coffee requires particularly high amounts of K, Ca and optimum pH values for Robusta, are approx. 5.0 to 6.5. Due to the rather superficial rooting system, the topsoil is very important for the coffee plant. Organic matter, concentrated in the topsoil, plays an important role in structure stability and storage of plant nutrients and water.

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<sup>\*</sup> Technical Report no. 8 of the Soil Science Department of ONAREST and FAO Soil Science Project at Ekona, Cameroon.



Decrease of the organic matter (particularly fresh) can easily lead to a decay of the soil structure. Management, therefore, should be aimed at keeping good organic matter levels in the topsoils, (e.g. mulching). This is particularly important for coffee cultivation without shade.

The soils of the Deng Deng Forest have all in common their good internal drainage system and stable, friable structures. However, the fertility status is low. Except for potassium, the other available nutrients, including nitrogen, phosphorus and calcium are low, while magnesium and sodium are very low. To obtain good yields, the use of fertilizers is considered therefore to be necessary.

Table no. 5 summarizes the diagnostic soil and land characteristics of the studied lands, while table no. 6 compares these data with the requirements of Robusta leading to the suitability of the different mapping units for this cashcrop.



TABLE 5: SUMMARY OF DIAGNOSTIC SOIL AND LAND CHARACTERISTICS OF THE MAPPING UNITS

MAPPING UNITS	CLIMATE					CONDITION FOR ROOT DEVELOPMENT							TOPOGRAPHY	
	(TEMPERATURE) ALTITUDE M.	HOURS OF SUNSHINE (APPROX.)	RAINFALL (MM)	LENGTH DRY SEASON (MONTH)	LENGTH PERIOD (WEEKS) DRY SOIL	SOIL DEPTH (CM)			TEXTURE		DRAINAGE		SLOPE %	ERO- SION
						TO GRAVEL CM	TO IRON- STONE CM	TO GROUND WATER CM	% CLAY		CLASS	FLOOD- ING		
DONDI SERIES	680-720	1600	1600	3-4	4-5	300	400	-	47-60	60-70	4	-	0-3	L
DEOLE SERIES	720-760	1600	1500	3-4	7-8	10-40	40-100	-	45-55	60-70	4	-	0-3	L
DONDI SLOPING	660-700	1600	1600	3-4	4-6	200	300	-	45-60	60-70	4	-	3-8	L/M
DONDI GRAVELLY	660-700	1600	1500	3-4	5-7	20-50	100	-	45-60	60-70	4	-	3-16	L/M
YAMBENG ASS.	660-680	1600	1600	3-4	4-7	20-300	100	-	40-55	60-80	4	-	3-16	L/M
DEOLE SLOPING	700-740	1600	1500	3-4	7-8	10-40	40-100	-	40-55	60-70	4	-	3-16	L/M
MIAMBAB ASS.	640-680	1600	1600	3-4	5-7	20-150	100	150	40-55	60-80	4/3	-	8-16	M
DIDO ASS.	640-680	1600	1600	3-4	5-7	20-200	100	150	40-55	60-80	4/3	-	8-16	M
NGOLO ASS.	640-680	1600	1600	3-4	5-7	20-200	100	150	40-55	60-80	4/3	-	8-16	M
GOYOUUM SLOPPING	640-680	1600	1500	3-4	5-6	50-200	150	-	40-50	55-65	4	-	3-8	L/M
GOYOUUM, LATERITIC	640-660	1600	1500	3-4	7-8	10-40	40-100	-	-	-	4	-	3-8	L/M
BADANGA SERIES	620-640	1600	1500	3-4	+6	75	100	150	30-35	35-55	4/3	-	1-8	L
MBALO ASS.	620-640	1600	1500	3-4	5-7	20-150	100	150	20-50	35-65	4/3	-	8-16	M
AKIDI COMPLEX	620-660	1600	1600	3-4	1	-	-	0-150	50-65	VAR	1/2	REGULAR	-	-
SANAGA, LEVEE	610-620	1600	1500	3-4	1-3	-	-	100	15-25	35-40	2/3	RARE	0-3	L
SANAGA, BACKSWAMP	600-610	1600	1500	3-4	1	-	-	0-150	40-60	VAR	1/2	REGULAR	-	-



TABLE 5 (CONTINUED)

MAPPING UNIT	CHEMICAL PROPERTIES						HETEROGENEOU- SITY	MICRO- RELIEF (% TER- MITE MOUNDS)	FERTILIZER REQUIREMENT	
	pH		CEC		TEB					KG ORGANIC MATTER 0-75cm
	0-20 cm	50 cm	meq/100 0-20 cm	grs 50 cm	meq/100 0-20 cm	grs 50 cm				
DONDI SERIES	4.5-6.0	4.8-5.5	4-8	4-6	1.5-2.0	0.5-2.0	12-15	0	20-50	HIGH
DEOLE SERIES	-	-	-	-	-	-	6-10	2	10-15	HIGH
DONDI SLOPING	4.5-6.0	4.8-5.5	4-8	4-6	1.5-5.0	0.5-2.0	12-15	1	20-40	HIGH
DONDI GRAVELLY	4.5-6.0	4.8-5.5	4-8	4-6	1.5-5.0	0.5-2.0	8-12	1	5-15	HIGH
YAMBENG ASS.	4.0-6.0	4.6-5.5	4-9	4-7	1.5-7.0	0.5-2.0	8-17	3	10-30	HIGH
DEOLE SLOPING	4.5-6.5	-	5-10	-	2.0-1.0	-	5-9	2	5-10	HIGH
MIAMBAB ASS.	4.0-6.0	4.6-5.5	4-9	4-7	1.5-7.0	0.5-2.0	6-17	3	5-15	HIGH
DIDO ASS.	4.0-6.0	4.6-5.5	4-8	4-6	1.5-5.0	0.5-2.0	6-15	3	5-15	HIGH
NGOLO ASS.	-	-	-	-	-	-	-	3	5-15	HIGH
GOYOUM SLOPING	5.0-6.5	5.0-6.0	6-10	5-7	4-10	4-6.5	12-15	2	10-20	MOD/HIGH
GOYOUM LATERITIC	5.0-6.5	5.0-6.0	6-10	5-7	4-10	4-6.5	6-10	1	5-15	HIGH
BADANGA SERIES	5.0-6.0	5.0-6.0	4-8	5-7	1.0-5.0	1.5-2.0	10-14	1	5-20	HIGH
MBALO ASS.	-	-	-	-	-	-	-	3	5-15	
AKIDI COMPLEX	4.5-6.5	4.5-6.5	10-30	4-20	3-15	1-10	12-25	3	-	MOD/HIGH
SANAGA LEVEE	5.0-6.0	5.0-5.5	3-8	3-6	1.5-2.5	1.0-2.0	10-15	1	5-15	HIGH
SANAGA BACKSWAMP	4.5-5.5	4.5-5.5	10-20	6-10	3-10	1.0-5.0	15-25	2/3	-	MOD/HIGH



TABLE 6: NATURE AND DEGREE OF LIMITATIONS AND SUITABILITY OF THE MAPPING UNITS FOR ROBUSTA COFFEE

MAPPING UNIT	CLIMATE	TOPOGRAPHY	EXCESS WATER	AV. WATER	PHYSICAL SOIL CONDITIONS	SOIL FERTILITY	LAYOUT	SUITABILITY	
								SUBCLASS	
c	t	d	d	s	n	l			
<u>PLATEAU SOILS</u>									
DONDI SERIES	1	0	0	1	0	2	0	Suitable	S2.n
DEOLE SERIES	1	0	0	3	3	2	1	Unsuitable	N2.s
<u>UPPER SLOPE SOILS</u>									
DONDI SLOPING	1	1(-2)	0	1-2	0	2	0	Suitable	S2.n
DONDI GRAVELLY	1	1(-2)	0	2	2-3	2	0	Marginally suitable	S4.sn
YAMBENG ASSOCIATION	1	1(-2)	0	1-2	1-3	2	1	Moderately suitable	S3.sn
DEOLE SLOPING	1	1(-2)	0	3	3	3	1	Unsuitable	N2.s
<u>LOWER SLOPE SOILS</u>									
MIAMBAB ASSOCIATION	1	2(-3)	0	2-3	2-3	2-3	1-2	Unsuitable	N2.ts
DIDO ASSOCIATION	1	2(-3)	0	2-3	2	2-3	1-2	Marginally suitable	S4.ts
NGOLO ASSOCIATION	1	2(-3)	0	2-3	2-3	2-3	1-2	Unsuitable	N2.ts
<u>UPPER/LOWER SLOPE SOILS</u>									
GOYOUN SLOPING	1	1	0	2	1-2	2	1	Suitable	S2.sn
GOYOUN LATERITIC	1	1	0	3	3	3	1	Unsuitable	N2.s
BADANGA SERIES	1	1	0	2	1	2-3	1	Moderately suitable	S3.sn
MBALO ASSOCIATION	1	2(-3)	0	3	2-3	3	1-2	Unsuitable	N2.ts
<u>VALLEY BOTTOM SOILS</u>									
AKIDI	1	0	3(-2)	0	2	1-2	3	Unsuitable	N2.d
<u>FLOODPLAIN SOILS</u>									
SANAGA LEVEE	1	0	1	1	1-2	2	1	Moderately suitable	S3.sn
SANAGA BACKSWAMP	1	0	2-3	0	2	1-2	2	Unsuitable	N1.ds

0 : no limitations

1 : slight

2 : moderate

3 : severe

1-2 means : slight to moderate limitations

1(-2) means : in general slight but locally moderate limitations



#### 4.3. THE SUITABILITY OF THE STUDIED LANDS FOR FOODCROPS IN A SHIFTING CULTIVATION SYSTEM

The evaluation of the lands for its use for foodcrops is not an easy task. Each crop within the rotation pattern has his own, specific requirement and the rating of them together will have a very large range. Infact, all soils used for the system of shifting cultivation are suitable in the sense, that farmers will adapt the system a bit. There are many adaptions to the system not reflected and difficult to assess.

Another problem is that the ecology of most crops (foodcrops) is not yet very well studied and results of research are often difficult to transfer to our area. Also, relating yield levels to limiting (soil) factors proved to be extremely difficult, as data on yields are not known or difficult to obtain. As a result of this, this chapter necessarily is quite theoritical.

Table 7 gives some requirements of the most frequently cultivated crops, of which maize and groundnuts are the most important. Table 8 compares these requirements with the land qualities of the mapping units (given in Table no.5), leading to a qualitative land suitability classification.

Discussed below are the climatic and soil conditions of the area in relation to their suitability for various crops.

##### Climate.

The total growing period of the area under study amounts to approx. 270-290 days. Growing season starts with the beginning of the first rains, about 15 March and ends at the end of the second rainy season (15 November).

The first crop in the rotation pattern is maize. Temperatures during the growing season (110-130 days) are optimal. Early planting, in order to have most benefit of sonar energy, is often risky because of the irregular starts of the first rain. Sunshine during the growing period is a slight limitation. The total amount of rainfall ( $\pm$  600 mm) is sufficient for maize cultivation. Infact, two maize crop would be possible, but yields are rather low, particularly of the second crop.

Groundnuts are the crop of the second rainy season. The average temperatures during the growing period (130-180 days) are a slight limitation for optimal growth as well as the hours of sunshine. Rainfall during this period is no limitation. Groundnuts are harvested during the beginning of the long dry season.

For these annual crops the long dry season (3-4 month) causes no problem. The farmers escape from this period by not using the soils for the main crops. However, most perennial and root crops are affected by drought during this period.

Yams and cocoyam can really suffer during this dry period as well as plantains. Infact, soils with over 4 weeks dry have already moderate limitations for plantains. Also the total sunshine is limited for optimal growth. In the rotation pattern, cassava is the crop which resist drought best. It can survive dry periods of 2-3 months very well.



### Soil conditions.

The deep ferrallitic soils of the Deng Deng Forest have good physical properties and from the physical point of view there are no limitations for root development. On the other hand soils with over 50% gravel starting between 20 and 50 cm of the topsoil have poor conditions for root development, particularly for rootcrops, mainly because of the lack of available water and penetration difficulties to lower depth. Soils with 30-50% (vol) gravel have probably only slight limitations.

The friable and stable structures of the top soils is a result of the type of clay minerals and the organic matter, (non-humified!!), which is concentrated in this topsoil. Organic matter is also a main source of plant nutrients including nitrogen and phosphorus and provides the soil with the capacity to retain or release cations (Approx. 75% to 85% of the CEC and TEB in the A1 and 60% in the B1). The organic matter contents of the soils are moderate to low. From this all, it should be clear that the maintenance of the organic matter levels is very important and management practices, including the use of additional mulch, crop residues etc, are important. Minimum tillage is done by a hoe or cutlass and seems to be right. In order to prevent a fast nitrification of the organic matter, followed by leaching of nitrogen during the first rains.

The amounts of available nutrients are respectively low for phosphorus, nitrogen and calcium, very low for sodium and magnesium and moderately high for potassium. The latter seems to be important because most crops in the system require high to moderately high amounts of potassium (plantain, yam, cassava and to a lesser content Maize). The irregular distribution and often low quantities of calcium can be a considerable constraint for root development at lower depth. The strong weathered soils are fairly acid (pH: 4.5 - 5.5).

Alluminium toxicity is not observed with maize, in the field.



TABLE 7 : REQUIREMENTS OF SOME INDIVIDUAL CROPS WITHIN THE SHIFTING CULTIVATION SYSTEM

CROPS	CLIMATE			CONDITIONS FOR ROOT DEVELOPMENT								TOPOGRAPHY	
	TEMPERATURE (°C)		GROWING SEASON (days)	RAINFALL DURING GROW SEASON	EFFECTIVE SOIL DEPTH (cm)			TEXTURES		SOIL DRAINAGE		SLOPE %	
	opt	range <sup>±</sup>			opt	slight limit.	mod/sev	opt	slight limit.	opt	slight limit.	opt	slight limit.
MAIZE	18-30°	20-30°	110-130	480-800mm	50	20-50	20	sil-cl	sl-cl	MW-W	I-SE	0-8	8-12
PLANTAIN	25°	20-30°	365-420	>2000mm	100	60-100	60	cll	cl	W	MW- SE	0-6	6-12
GROUNDNUT	28°	24-33°	130-180	500-750mm	50	30-50	30	cll	cl	W	MW	0-6	6-12
CASSAVA	25-29°	-	420-540	1000-2000mm	100	75-100	75	sil-cl	sl-ke	W	MW-SE	0-8	8-12
OVERALL SHIFTING CULTIVATION	25°	20-30°	110	1300-2000mm	50	20-50	20	cl.l	cl	W	MW-SE	0-8	8-12

sil : silt loam

cll : clay loam

cl : clay

kc : kaolinitic clay

sl : sandy loam

MW : Moderately Well

W : Well

I : Imperfectly

SE : Somewhat excessive

± the degree of limitations is not known



TABLE 7 : CONTINUED

CROPS	CHEMICAL REQUIREMENTS				
	pH		NUTRIENTS		SPECIAL DEMANDS
	OPT	SLIGHT LIMIT.	REQUIREMENTS	UPTAKE N: P <sub>2</sub> O <sub>5</sub> : K <sub>2</sub> O	
MAIZE	5.5-8.0	4.5-5.5- 8.0	HIGH	1: 0.4: 0.8	
PLANTAIN	6.0-7.0	5.0-6.0	MODERATELY/HIGH	1: 0.1: 4	Ca + Mg
GROUNDNUT	6.0-7.0	5.0-6.0	MODERATE	-	P + Ca + S
CASSAVA	5.2-7.0	4.5-5.5 7.0-8.0	LOW/MODERATE	1 : 1 : 2	
SHIFTING CULTIVATION	6.0-7.0	4.5-6.0 7.0	MODERATE	1 : 1 : 2	Ca + Mg



TABLE 8 : SUITABILITY OF THE MAPPING UNITS FOR SHIFTING CULTIVATION

MAPPING UNITS	c	t	d	s	s	n	1	SUITABILITY FOR SHIFTING CULTIVATION	S2.n N2.sn S3.n S4.ts S3.sn N2.ts S4.ts S4.ts S3.n N2.sn S3.sn N2.ts N2.d S3.n N2.d
Dondi Series	1	0	0	0-1	0	2-3	1	suitable	S2.n
Déolé Series	1	0	0	3	3	2-3	1	unsuitable	N2.sn
Dondi Sloping	1	1	0	1	0	2-3	0	moderately suitable	S3.n
Dondi Gravelly	1	1-(2)	0	2	2	2-3	0	marginally suitable	S4.ts
Yambeng Association	1	1	0	1-2	1-2	2-3	1	moderately suitable	S3.sn
Déolé Sloping	1	1-(2)	0	3	3	2-3	1	unsuitable	N2.ts
Miambab Association	1	2-(3)	0	2	2	2-3	1	marginally suitable	S4.ts
Dido Association	1	2-(3)	0	2	2	2-3	1	marginally suitable	S4.ts
Ngolo Association	1	2-(3)	0	2	2	2-3	1	marginally suitable	S4.ts
Goyoum Sloping	1	1	0	1	1-2	2-3	1	moderately suitable	S3.n
Goyoum Lateritic	1	1	0	3	3	2-3	0	unsuitable	N2.sn
Badanga Series	1	0-1	0	1-2	1	2-3	1	moderately suitable	S3.sn
Mbalo Series	1	2-(3)	0	2-3	2	2-3	1	unsuitable	N2.ts
Akidi Complex	1	0	2-3	0	2-3	1-2	3	unsuitable	N2.d
Sanaga Levee	1	0-1	0-1	1	1	2-3	1-2	moderately suitable	S3.n
Sanaga Backswamp	1	0	2-3	0	2-3	1-2	3	unsuitable	N2.d

1-2 means slight to moderate limitations

1-(2) means generally slight but locally moderate limitations

0 = no limitations  
1 = slight limitations  
2 = moderate



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DNEX

## DESCRIPTIONS OF TAXONOMIC UNITS



DONDI SERIES

The Dondi Series is a member of the clayey, kaolinitic family of the Oxic Paleudults. Typically, Dondi soils have deep, well drained, red clayey profiles, and are generally free of ferruginous gravel. They occur on the flat to undulating plateaus in the central and northern part of the Deng Deng Forest. The Dondi soils are derived from granitic parent materials.

Mapping Symbol: Do

Description of Typifying Pedon:

Profile no. DD 45 2000 m north of Nola Mbéten, ± 25 km NNW of Bertoua, along the road Bertoua-Deng Deng in recently cleared forest.

Aerial photo 14-10 (FAO Aerial Survey 1970, 1:25,000)

Described by: M.M. Ntamack and J. Floor 20.2.78

Soil was dry when described.

- A1 : Dark reddish brown to reddish brown (2.5 YR 3.5/4) when dry and  
00-06 cm reddish brown (2.5 YR 4/4) when moist; sandy clay; medium, moderate, subangular blocky and granular structures; slightly hard, friable, sticky and plastic; common roots; many very fine, many fine and few medium pores; termite influences; clear, smooth boundary.
- B1 : Dark red (2.5 YR 3/6) when dry, dark red to red (2.5 YR 3.5/6)  
06-24 cm when moist; clay; medium, moderate, irregular angular blocky structure; slightly hard, friable, sticky and plastic; few roots; many very fine, common fine and few medium pores; gradual and smooth boundary.
- B21 : Dark red to red (2.5 YR 3.5/6) when dry, red (2.5 YR 4/6) when  
24-59 cm moist; clay; medium, moderate, irregular angular blocky structure; slightly hard, friable sticky and plastic; few roots; many very fine and few fine pores; few fine cutans and few fine quartz particles; gradual, smooth boundary.
- B22 : Red (2.5YR 10 R 4/6) when dry and moist (2.5 YR - 10 YR 4/6); clay;  
59-80 cm medium, weak to moderate, irregular angular blocky structure slightly hard to weak, friable, sticky and plastic; few, fine discontinuous cutans on ped faces; few roots; many very fine and few fine roots; few quartz particles; diffuse and smooth boundary.
- B23 : Red (2.5 YR - 10 YR 4/7) dry and moist; clay; medium, moderate  
80-150 cm to weak irregular angular blocky structure; slightly hard to soft, friable, sticky and plastic; few fine pores.



### Range in characteristics

The thickness of the solum is not known, but exceeds probably 4 meters.

The greater part of the Dondi soils are free of ferruginous gravel within the first 1.50 m of the solum, but on the slope breaks and on steeper slopes the soils are generally gravelly with over 30 % (vol) ferruginous gravel, starting within 30-60 cm from the surface (gravelly phase or petroferric phase). Approx. 20-50 % of the soil surface is covered by (fossile) termite mounds of 4-12 m in diameter and 1.5-3.5 m. high, being the origin of a strong microvariability in the properties of the soils.

The A1 horizon varies from 3-8 cm, and has a sandy clay to clayey texture with 45-60 % clay and 3-4 % organic matter. The colours are ranging from dark brown, brown to reddish brown (7.5 YR 4/2, 4/4 - 5 YR 4/3 4/4). The structure is for a greater large part influenced by termites (see termite activity page ) and other soil animals. A transitional B1 horizon is underlying the A-horizon. This horizon (10-20 cm) has a clayey to sandy clay texture (50-65 % clay) and yellowish red to red colours (5 YR 4/6 - 2.5 YR 4/6). Organic matter content is roughly 1.6 % and fast decreasing in the subsoil.

The B2 horizon has yellowish red (5 YR 5/6, 5/8) or red colours (2.5 YR 5/6, 5/8 - 10 R 5/6, 5/8) and a clayey texture (60-75 % clay). The clay content increases slightly with depth B21: 65-70 %, B22: 70-75 % clay. A weak prismatic structure and few clay skins on the red faces in the B21 and B22 are observed. On the slopes, the soils show more features of clay illuviation. The lower part of the B2 horizon shows a real "oxisol structure". Typically, all horizons contain very little silt due to intense weathering.

### Phase and variants:

Gravelly phase: Dondi soils with more than 30 % gravel starting within 50 cm from the surface.

Petroferric phase: Dondi soils with an indurated hardened plinthite layer starting within 20-50 cm from the surface.

Gently sloping phase: Dondi soils on 3-8 % slopes. The A1 horizon generally has a sandy clay texture. These soils are less deep (approx. 2 m) and more susceptible to erosion.

### Competing series and their differences:

In the same positions are found the soils in the Déolé Series. Déolé Series are shallow soils with an indurated plinthite layer starting within 20-50 cm of the surface.

Competing with the slope and gravelly phase are the Yambeng and Goyoum soils. Yambeng soils are more sandy in their topsoils and have yellower colours, while Goyoum soils are only more sandier in their topsoils.

### Drainage and Erosion:

The Dondi soils are well drained; surface run-off is slow to medium and permeability is estimated to be moderate. Available water is about 150 mm (00-100 cm).

The soils are not eroded under natural conditions, but are slightly to moderate susceptible to erosion, depending on slope, their position and landuse.



Setting:

Dondi Series are found on the undulating peneplain in the central and northern part of the Deng Deng Forest, 680-720 m above sea level.

Climate: isohyperthermic, udic moisture regime.

Land Use and Vegetation:

Native vegetation is a semi-deciduous tropical forest. The lands around the villages are locally used for foodcrops and cashcrops.

Classification:

Oxic Paleudult, very fine clayey, kaolinitic, isohyperthermic family (U.S. Soil Taxonomy).

: Sols ferrallitiques fortement desaturés en (B) approuvis (French).

: Dystic Nitosols (FAO).



Dondi Series

Profile no. DD 45

Lab. no.	349	350	351	352	353
Horizon	A1	B1	B21	B22	B23
Depth (cm)	00-06	06-24	24-59	59-80	120-144

T	2	u	51.3	62.3	68.1	69.9	71.8
E	2-20	u	2.3	5.1	3.6	4.0	0.7
X	20-50	u	0.4	2.0	1.6	0.7	1.2
T	50-100	u	3.3	3.1	2.7	2.8	2.9
U	100-250	u	14.0	9.7	7.8	7.4	7.5
R	250-500	u	19.7	12.2	9.8	8.9	8.9
E	500-1000	u	8.3	5.5	5.8	5.6	6.2
	1000-2000	u	0.6	0.3	0.6	0.7	0.8

Org. Carbon %	1.96	0.91	0.59	0.44	0.33
Org. Matter %	3.37	1.57	1.01	0.76	0.57
Total N %	0.27	0.16	0.10	0.09	0.07
C/N	7.3	5.7	5.9	4.9	4.7

pH-H <sub>2</sub> O	4.5	4.5	5.0	5.1	5.3
pH-KCl	3.6	3.7	3.9	4.1	4.5
CEC meq/100 gr.	8.4	4.8	4.2	3.4	3.2
e K <sup>+</sup> (NH <sub>4</sub> OAc) meq	0.60	0.26	0.20	0.19	0.30
x Na <sup>+</sup> " "	0.02	0.02	0.03	0.04	0.05
h Ca <sup>++</sup> " "	1.6	0.6	0.4	0.8	0.8
a Mg <sup>++</sup> " "	0.7	0.0	0.0	0.0	0.0
TEB (sum)	2.92	0.88	0.63	1.03	1.15
% Base Sat.	34.76	18.33	15.00	30.29	35.93
Av. P. (Kurtz-Bray 2)	30	11	6	6	3



### YAMBENG SERIES

The Yambeng Series is a member of the clayey, kaolinitic family of the Oxic Paleudult. Typically, Yambeng soils have deep, well drained, yellow, sandy clay to clayey profiles. They occur on the middle and lower slopes in the central part of the Deng Deng Forest. Yambeng soils are derived from granitic parent materials.

#### Mapping symbol:

The Yambeng soils are found in an association with other soils: the Yambeng Association (with 65 % Yambeng soils) and the Miambab Association (75 % Yambeng soils).

#### Description of typifying pedon:

Profile no. DD 34, near Viali,  $\pm$  53 km NNW of Bertoua, along the road Bertoua - Deng Deng,  $\pm$  23m of the road in secondary forest.

Aerial photo: 13-10 (FAO 1970 Aerial Survey 1:25.000).

Described by: Messrs Ntamack, Nyobe, Floor and Verwey. 8.02.1978.

Top soil was dry and sub soil moist when described.

- A1 : Dark brown (10 YR 4/3) when dry, dark yellowish brown when moist  
00-7 cm (10 YR 4/4); sandy clay; medium, moderate granular and sub angular blocky structures; slightly hard, friable, slightly sticky and slightly plastic; common roots; many very fine, many fine pores; few fine quartz particles; some charcoal; few fine ferruginous gravels (vol 10 %); abrupt, smooth boundary.
- B1 : Yellowish brown (10 YR 5/8) when dry and moist; sandy clay;  
7-21 cm medium moderate subangular blocky and angular blocky structures; slightly hard, friable, sticky and slightly plastic; few roots; few fine and few medium pores; gradual, smooth boundary.
- B21 : Brownish yellow to yellowish brown (10 YR 5.5/8) when dry and  
21-36 cm moist; sandy clay; medium, moderate irregular angular blocky structure with tendency to prisms; slightly hard, friable, sticky and plastic; very few roots; few fine pores; few, fine quartz and fine ferruginous gravels (vol 10 %); few charcoal and crotovinas; few, patchy to broken thin cutans on ped surfaces (probably clay skins); gradual, smooth boundary.
- B22 : Reddish yellow to brownish yellow, moist and dry (8.75 YR 6/8);  
36-80 cm clay; medium, moderate, angular blocky with a slight tendency to prisms; slightly hard, friable, sticky and slightly plastic; very few fine roots; few very fine, few medium and few fine pores; quartz particles and fine ferruginous gravels (vol 15 %); few patchy, thin cutans on ped surfaces (probably clay skins); diffuse, smooth boundary.



- B23 : Strong brown (7.5 YR 5/8) when moist, reddish yellow (7.5 YR 6/8) when dry; clay; weak irregular angular blocky, with tendency to weak prisms; friable, sticky and slightly plastic, very few fine roots; few very fine, few fine and few medium pores; quartz and ferruginous gravel (30 % vol); gradual and smooth boundary.
- B3 : Strong brown (7.5 YR 5/8) when moist; clay; weak irregular angular blocky structure; friable; sticky and slightly plastic; few very fine and few fine pores; over 50 % (vol) ferruginous gravel and quartz particles.

#### Range in characteristics:

The depth of the solum ranges from 20-30 cm to several meters. Generally, the Yambeng soils are almost free of gravel on the long, gentle convex and concave slopes to the wide hydromorphic valley bottoms. However, on steep slopes (8-20 %) the soils contain often over 30 % gravel starting within the first 50 cm of the profile. The soils are often more or less enriched with colluvial material; if this is the case the organic matter contents are somewhat higher and the profiles show an irregular distribution of the clay content.

Yambeng soils have a 3-8 cm thick A1 horizon with a sandy clay texture (45-54 % clay), in some cases sandy clay loam. Colours are ranging from dark yellowish brown to dark brown to brown (10 YR 3/3, 3/4, 4/3, 4/4 - 7.5 YR 4/3, 4/4). Organic matter content ranges from 3 to 6 % and soil structure is mostly granular to subangular blocky. This horizon is followed by a sandy clay to clayey transitional B1 horizon of 8-16 cm.

The argillic B2 horizon can be divided into several subhorizons with diffuse boundaries. The texture is always clay (60-80 %) and colours are strong brown to yellowish red (7.5 YR 5/8, 5 YR 5/8). This horizon shows features of clay illuviation in the B21 and B22 (30-70 cm), including some clay skins on ped faces and a weak prismatic structure. The ratio clay A1/clay B2 is over 1.4. Often the B2 horizon is followed by a B3 horizon with more than 30 % ferruginous gravel.

The Yambeng soils contain some fine ferruginous gravels and fine quartz particles (less than 10 % (vol) and with a diameter less than 5 mm) throughout the profile.

#### Phases and Variants:

The gravelly phase includes soils with over 30 % gravel within 50 cm of the surface.

#### Competing Series and their differences:

Related soils are the sloping and gravelly phase of the Dondi Series, the sloping phase of the Déolé Series, the Goyoum Series and the Badanga Series. Dondi soils are found on the upper slopes only, have redder subsoils and less sand. Déolé series have very gravelly topsoils and an indurated plinthite layer at shallow depth, while Badanga Series are more sandier in the topsoil.



Goyoum Series occur only on the middle slopes to the Lom and Sanaga Rivers. They have more sandy top soils.

Badanga Series are found on the lower slopes and footslopes to the Lom and Sanaga Rivers. They are developed in stratified, rather sandy, colluvial deposits.

Drainage and Erosion:

Yambeng Series are well drained and have a moderate permeability. Runoff is estimated to be medium to fast. The soils are not or slightly eroded but they are moderately susceptible to sheet erosion, depending on the position and slope and land use.

Setting:

Yambeng soils are found on the middle and lower slopes to the river valleys of the deeply dissected peneplain in the central part of the Deng Deng forest. Climate: Isohyperthermic, Udic moisture regime.

Land Use and Vegetation:

Native vegetation is a semi-deciduous tropical rainforest. Some lands around the villages are cleared and used for agriculture.

Classification:

Oxic Paleudult; very fine and fine clayey, Kaolinitic, Isohyperthermic family (USA, 7th Approximation, 1967 ed).

: Sols ferralitiques fortement désaturés en (B) appauvris (French)

: Dystric Nitosols (FAO).



Yambeng Series

Profile no. DD 34

Lab. no.	306	307	308	309	310	311
Horizon	A1	B1	B21	B22	B23	B3
Depth (cm)	00-07	07-21	21-36	55-69	100-115	135-139

T	2	u	47.4	52.2	53.2	63.6	67.4	67.1
E	2-20	u	2.3	0.4	0.0	0.3	1.1	3.8
X	20-50	u	1.1	1.5	1.2	0.5	0.5	0.3
T	50-100	u	11.6	10.8	7.0	6.8	8.2	7.9
U	100-250	u	8.1	5.6	5.1	3.8	3.9	5.0
R	250-500	u	15.5	11.8	8.7	6.6	4.8	5.3
E	500-1000	u	11.9	10.6	15.4	13.0	7.5	6.9
	1000-2000	u	2.3	6.9	9.4	5.5	6.5	12.8
<hr/>								
Org. Carbon %			2.30	1.01	0.76	0.48	0.37	0.37
Org. Matter %			3.96	1.74	1.31	0.83	0.64	0.64
Total N %			0.29	0.14	0.14	0.09	-	0.07
C/N			7.9	7.2	5.4	5.3	-	5.3
<hr/>								
pH-H <sub>2</sub> O			5.0	4.4	4.4	4.7	5.0	5.1
pH-KCl			4.0	3.5	3.5	3.6	3.8	3.9
CEC meq/100 gr.			10.4	4.6	6.6	5.6	5.6	6.0
<sup>e</sup> <sub>x</sub> K <sup>+</sup> (NH <sub>4</sub> OAc) meq			0.72	0.21	0.17	0.10	0.27	0.10
<sup>c</sup> <sub>h</sub> Na <sup>+</sup> " "			0.0	0.0	0.0	0.0	0.0	0.0
<sup>c</sup> <sub>r</sub> Ca <sup>++</sup> " "			3.2	0.8	0.8	1.2	0.6	0.5
<sup>t</sup> Mg <sup>++</sup> " "			3.3	0.7	0.7	0.7	0.7	0.7
<hr/>								
TEB (sum)			7.22	1.71	1.67	2.00	1.57	1.30
% Base Sat.			69.42	37.17	25.70	35.71	28.04	21.67
Av. P (Kurtz-Bray 2)			9	4	3	3	3	3



AKIDI COMPLEX

(mapping symbol Ak)

The Akidi Complex refers to the soils of the hydromorphic valley bottoms in the forest of Deng Deng. They are members of the Fluvaquents, Tropaquents and Tropofluvents. Approx. 60 % of them belong to the Tropic Fluvaquents and a description of this predominant soil is given below.

Tropic Fluvaquent:

Tropic Fluvaquents are young alluvial soils with distinct features of excess of water. Most of the soils are very poor to poorly drained and are unusually or regular flooded. The watertable fluctuates between 0 and 125 cm. The soils are developed in stratified layers of sandy clay loam to clayey materials, with small bands of sandy materials in between.

Description of Typifying Pedon:

Profile no. DD 36, near Viali + 52 km NNW of Bertoua, where road Bertoua - Deng Deng crosses the Yasso River.

Aerial photo: 11-10 (FAO Aerial Survey 1970; 1:25.000)

Described by: H.E. Verwey, Nyobe and J. Floor 7.02.1978.

Topsoil was humid when described, the subsoil wet (groundwatertable at  $\pm$  80 cm)

- A1 : Dark brown to brown (7.5 YR 4/2) when humid; clay; medium, weak  
00-07 cm sub angular blocky structure; friable, slightly sticky and slightly plastic; common roots; many very fine, many fine and common medium pores; clear and smooth boundary.
- II Ac : Grayish brown when humid (10 YR 5/2); sandy; medium weak to very  
06-16 cm weak subangular and angular blocky structures; friable, non sticky and slightly plastic; few roots; common very fine and common fine pores; some charcoal; few, fine, faint Fe Mn mottles; clear and smooth boundary.
- III C1g : Light grayish brown (10 YR 6/2) when humid; sandy clay loam;  
16-32 cm medium, very weak angular blocky structure; friable, slightly sticky and plastic; few roots; few very fine and common fine pores; medium, moderate, distinct Fe Mn mottles (7.5 YR 5/8); gradual and smooth boundary.
- C2g : Pale brown (10 YR 6/3) when wet; sandy clay; medium, very weak  
32-43 cm angular blocky structure; friable, sticky and plastic; many fine pores; few cemented Fe concretions; many, common, distinct Fe Mn mottles (7.5 YR 5/8); gradual and smooth boundary.
- C3g : Gray to light gray (7.5 YR 6/0) when wet; sandy clay; structure-  
43-62 cm less; friable, sticky and plastic; few fine pores; few cemented Fe concretions, profuse Fe Mn mottling; (7.5 YR 5/8); diffuse and smooth boundary.



C4 G : Gray to light gray (7.5 YR 6/0) when wet; sandy clay loam;  
62+ cm structureless; friable, slightly sticky and slightly plastic;  
some quartz; permanently reduced zone.

Range in characteristics:

The range in characteristics varies widely due to the local differences in sedimentation. The soils are saturated with water during a considerable time of the year. They are developed in stratified layers of clayey or loamy materials, generally with one or more bands of very sandy materials. Generally, they have a sandy clay to clayey topsoil (5-10 cm), dark coloured with a high content of organic matter (5-10 %). The organic matter is mostly poorly decomposed and decreasing with depth. Other bands of organic matter are sometimes found at greater depth.

The A1 horizon is followed by a 10-30 cm thick AC horizon. The textures vary from coarse sand to clay. Colours vary from grayish brown to dark grayish brown (10 YR 4/2, 5/2). In most cases this horizon is mottled.

The underlying C horizon has always gley colours; gray, light brownish gray to light gray (10 YR 5/1, 6/0, 6/2, 6/1, 7/1) and is mottled in its upper part (5 YR 5/7, 5/8). In some cases the subsoil has uniform textures, but very often contrasting layers of different materials are found. The lower part is always permanently reduced.

Drainage:

The Tropic Fluvaquents are very poor to poorly drained and unusually to frequently flooded. During the rainy seasons the watertable fluctuates between 0 and 50 cm, during the dry seasons between 75 and 125 cm.

Setting:

The Tropic Fluvaquents are found in all hydromorphic valley bottoms in the Deng Deng Forest. The soils are formed in relatively young alluvial sediments.

Land use and Vegetation:

Native vegetation is a swamp forest. Some of the somewhat better drained lands are used for early maize and rice cultivation.

Classification:

Tropic Fluvaquent (USA, 7th Approx. 1967 ed)

Sols hydromorphes peu humifères à gley (French)

Dystric Gleysol (FAO)



Akidi Complex (Tropic Fluvaquent)

Profile no. DD 36

Lab. no.	316	317	318	319	320	321
Horizon	A1	II AC	III C1,G	C2 G	C3 G	C4 G
Depth (cm)	00-06	06-16	16-30	32-40	55-60	70-80

T	2	u	62.1	6.3	26.5	38.5	39.3	33.4
E	0-20	u	0.5	0.0	11.2	7.6	3.7	0.0
X	20-50	u	4.5	2.8	2.1	6.3	4.0	2.6
T	50-100	u	4.9	12.0	13.9	13.5	11.7	7.5
U	100-250	u	5.6	37.5	16.4	12.1	15.4	23.9
R	250-500	u	11.8	35.7	14.1	10.3	12.0	19.3
E	500-100	u	9.0	5.2	12.8	9.6	11.3	9.6
	1000-2000	u	2.2	0.6	3.2	2.2	2.6	3.7
<hr/>								
Org. Carbon %			3.56	0.29	0.60	0.36	0.30	0.26
Org. Matter %			6.12	0.50	1.03	0.62	0.52	0.45
Total N %			0.35	0.05	0.09	0.08	0.06	0.09
C/N			10.2	5.8	6.7	4.5	5.0	2.9
<hr/>								
pH-H <sub>2</sub> O			6.4	4.8	5.1	5.3	5.1	4.7
pH-KCl			5.0	3.2	3.7	3.6	3.4	3.0
CEC meq/100 gr.			14.5	2.2	4.7	4.0	3.5	7.2
e	K <sup>+</sup>	(NH <sub>4</sub> OAc) meq	0.83	0.10	0.19	0.26	0.20	0.14
c	Na <sup>+</sup>	" "	0.0	0.0	0.0	0.0	0.0	0.0
c	Ca <sup>2+</sup>	(NH <sub>4</sub> OAc) meq	8.2	0.5	1.9	1.3	1.3	1.0
t	Mg <sup>++</sup>	" "	4.8	0.0	0.0	0.0	0.0	1.3
TEB (sum)			13.83	0.60	2.09	1.56	1.50	2.44
% Base Sat.			95.38	27.27	44.47	39.00	42.86	33.89
Av. P (Kurtz-Bray 2)			8	14	-	11	11	23

.../...



GOYOUM SERIES

Goyoum soils have a sandy clay loam to sandy clay, dark yellowish brown topsoil and a sandy clay to clayey, strong brown to yellowish red subsoil. Gravels are found at various depth. They are found on the complex slopes to the Sanaga and Lom rivers in the northern part of the Deng Deng Forest. Goyoum soils are derived from granites in the northwest and from gneisses in the northeast of the area.

Mapping symbol: Go

Description

Profile no: DD 53, 1800 m E of Goyoum.

Aerial photo: 5-02 (FAO Aerial Survey 1970, 1:25.000)

Described by : Ntamack, Akwar, Floor 04-03-1978

Profile was dry when described.

- A1 : Yellowish brown (10 YR 5/8) when dry, dark yellowish brown (10 YR 0-6 cm 4/4) when moist; sandy clay; medium, moderate, granular and subangular blocky structure; slightly hard to hard, friable, slightly sticky and slightly plastic; many roots; many pores; few fine cutans (organic matter); clear and smooth boundary.
- B1 : Strong brown (7.5 YR 5/6) when dry, brown (7.5 YR 5/4) when moist; 6-24 cm sandy clay; medium, moderate subangular blocky structures; hard, friable, slightly sticky and plastic; common roots; few fine and few medium pores; compact; gradual and smooth boundary.
- B21 : Strong brown to yellowish red (6.25 YR 5/8) when dry and moist 24-47 cm (6.25 YR 5/6); clay; medium, moderate angular blocky structure, slightly hard to hard, friable, sticky and plastic; common roots; common fine pores; traces of, probably clay skins on ped faces; few fine ferruginous gravel and quartz particles; gradual and smooth boundary.
- B22 : Yellowish red (5 YR 5/8) when dry and moist (5 YR 6/8); clay; medium, 47-77 cm moderate angular blocky structure with a tendency to prisms; slightly hard to hard, friable, sticky and plastic; few roots; common fine pores; few fine thin, probably clay skins on ped faces; few fine ferruginous gravel and quartz particles; few crotovinas; diffuse and smooth boundary.
- B23 : Yellowish red (5 YR 5/8) when dry and moist; clay; medium, weak 77-+ cm angular blocky structure; slightly hard, friable, sticky and plastic; trace of roots; common fine pores; few fine ferruginous gravel and quartz particles.



#### Range in Characteristics:

The depth of the soils is varying, due to the presence of a ferruginous gravel layer. Sometimes this layer is starting within 30 cm of the surface, in other cases at 1.50 meter depth or deep. Generally speaking the soils of the gentle slopes remain almost gravel free in the upper 80 cm while on the steeper slopes gravel is found at a shallower depth (gravelly phase).

The A1 horizon, of 5-10 cm, has a sandy clay loam to sandy clay texture. The colour is mostly dark yellowish brown (10 YR 4/4, 4/6), in some cases dark brown to brown (10 YR 4/3). The organic matter content in the A1 varies between 3.0-5.0 % and decreases with depth. Below a depth of 50 cm the amount is less than 1 %.

The structure of the A1 horizon is granular and subangular blocky. This horizon is followed by a 10-20 cm thick, sandy clayey B1 horizon. This dark yellowish brown to yellowish brown (10 YR 4/6, 5/4) or dark brown to brown (7.5 YR 4/4, 5/4) coloured horizon is a transitional horizon to the B2. The B2 horizon has in its upper part (B21 30-50 cm) a sandy clay to clayey texture and shows some evidences of clay illuviation, including few clay skins on ped faces. The colours are ranging from strong brown to yellowish red (7.5 YR 5/6 - 7.5-5 YR 5/6 - 5 YR 5/6). The lower part of the B2 horizon (B22) is always clayey (60-65 %). The ratio clay content B2/clay content A1 is over 1.4. All horizons have some ferruginous gravel and quartz particles, generally increasing with depth.

#### Phases and Variants:

Petroferric phase: Soils in which a continuous layer of undurated ferruginous materials occur within 40 cm of the surface.

Gravelly phase: Soils with over 30 % (vol) gravel starting in the first 50 cm of the profile.

#### Principally Associated Soils Series:

The Goyoum Series form a toposequence with the Dondi and Badanga Series. The Dondi series are more red and more clayey throughout their profiles. The Badanga Series have more sand and are developed in stratified layers of colluvial materials. In the toposequence the Dondi Series occupies positions upslope and the Badanga Series downslope of the Goyoum Series. In some cases the slope is incised by a steep valley system, described as the Mballo Association. This Association is composed of the steep and gravelly Goyoum soils and a few other soils.

#### Drainage and Erosion:

The Goyoum Series are well drained, surface runoff is medium to fast; permeability is estimated to be moderate. Available water is estimated to be approx. 100-130 mm (00-100 cm). The soils are generally not or slightly eroded but are moderately susceptible to erosion, depending on the position, slope and landuse.



Setting:

Goyoum Series are found on the long complex slopes to the Sanaga and Lom River Floodplain. The elevation is between 640 and 680 meter in the north-west and between 660 and 700 m in the northeast. They are derived from (mostly) acid parent material including granites and gneisses.

Climate: Isohyperthermic, Udic moisture regime.

Land use and Vegetation:

Native vegetation is a semi deciduous tropical forest. On the soils of the petroferic phase a savanna vegetation occurs. Some slopes near the road are cleared for agriculture. They are burned frequently and used for cultivation of foodcrops.

Classification:

Oxic Paleudult, fine and very fine clayey, kaolinitic, isohyperthermic family (US Soil Taxonomy)

: Sols ferrallitiques fortement désaturés en (B) appauvris (French)

: Dystic Nitosol (FAO).



Goyoum Series

Profile no. DD 53

Lab. no.	392	393	394	395	396
Horizon	A1	B1	B21	B22	B23
Depth (cm)	00-06	10-20	31-42	55-67	97-109

	2	u	44.4	45.9	64.0	64.1	64.1
T	2-20	u	3.7	8.2	2.5	4.5	2.5
E	20-50	u	1.1	0.7	2.0	0.5	2.3
X	50-100	u	9.0	9.1	6.8	6.2	6.2
T	100-250	u	20.3	18.6	12.0	11.9	11.8
U	250-500	u	13.5	11.4	7.0	7.4	7.0
R	500-100	u	7.2	5.4	4.6	4.4	4.8
E	1000-2000	u	1.0	0.7	1.3	1.0	1.2

Org. Carbon %	2.05	0.93	0.65	0.54	0.43
Org. Matter %	3.53	1.60	1.12	0.93	0.74
Total N %	0.28	0.15	0.10	0.09	0.07
C/N	7.3	6.2	6.5	6.0	6.1

pH - H <sub>2</sub> O	6.2	4.8	5.0	4.9	4.9
pH - KCl	5.3	3.9	3.9	3.9	4.0
CEC meq/100 gr.	9.3	5.1	4.5	4.9	4.4
<sup>e</sup> <sub>x</sub> K <sup>+</sup> (NH <sub>4</sub> OAc) meq	0.57	0.24	0.21	0.19	0.17
<sup>c</sup> <sub>h</sub> Na <sup>+</sup> " "	0.03	0.03	0.00	0.03	0.03
<sup>c</sup> <sub>a</sub> Ca <sup>2+</sup> (NH <sub>4</sub> OAc) meq	5.9	1.7	0.8	0.8	1.1
<sup>t</sup> Mg <sup>++</sup> " "	2.7	0.0	1.0	0.0	0.7
TEB (sum)	9.20	1.97	2.01	1.02	2.00
% Base sat.	98.20	38.62	44.67	20.82	45.45
Av. P (Kurtz-Bray 2)	13	2	1	0	0

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BADANGA SERIES

Badanga Series are well drained, deep soils on the lower slopes (1-8 %) and footslopes to the Lom and Sanaga floodplain. Badanga soils are developed in colluvial materials derived from granites (along the Sanaga) and gneisses (along Lom). They have sandy clay loam topsoils with dark brown to brown colours and clayey subsoils with strong brown colours.

Mapping symbol : Ba

Description Typifying pedon:

Profile no. : DD 52, 300 m E of Goyoum, along the road Goyoum-Deng Deng.

Aerial photo : 5-02, (FAO Aerial Survey 1970, 1:25.000)

Described by : Messrs Ntamack, Akwar and Floor

Soil was dry when described.

04.03.1978.

- A11 : Yellowish brown (10 YR 5/4) when dry and dark brown to brown  
00-05 cm (10 YR 4/3) when moist; sandy clay loam; medium, weak granular to subangular blocky structure; soft, slightly sticky and non plastic; many roots; very porous; termite activity; few fine ferruginous gravel; clear and smooth boundary.
- A12 : Yellowish brown (10 YR 5/4) when dry and moist; sandy clay loam;  
05-13 cm medium, moderate subangular and rectangular blocky structure; slightly hard, slightly sticky and slightly plastic; common roots; many very fine, few fine and common medium pores; few fine gravels; gradual and smooth boundary.
- B1 : Yellowish brown (10 YR 5/8) when dry and moist (10 YR 6/8);  
13-34 cm sandy clay loam; medium, moderate subangular and rectangular blocky; slightly hard, friable, slightly sticky and slightly plastic; few roots; common very fine and few fine pores; compact; 5 % (vol) gravel; gradual, smooth boundary.
- II B21 : Brownish yellow (10 YR 6/8) when dry and yellowish brown (10 YR  
34-64 cm 5/8) when moist; clay; medium, moderate rectangular blocky structure; hard, friable sticky and plastic; very few roots; few very fine and few fine pores; traces of clay skins on ped faces; 5 (vol) % gravel; compact; diffuse, smooth boundary.
- B22 : Reddish yellow (7.5 YR 6/8) when dry and strong brown (7.5 YR  
64-95 cm 5/8) when moist; clay; medium, moderate rectangular blocky structure with tendency to prisms; slightly hard to hard, friable, sticky and plastic; traces of roots; few very fine and few fine pores; less compact; traces of clay skins on ped faces; 10 % (vol) gravel; few fine, distinct Mn concretions; gradual and smooth boundary.



- B23 : Reddish yellow (7.5 YR 6.5/8) when dry and moist (7.5 YR 6/8);  
95-115 cm clay; medium, moderate rectangular blocky structure; slightly hard, friable, sticky and plastic; traces of roots; few fine pores; 15 % (vol) gravel; few fine, distinct Mn concretions; trace of clay skins on ped faces; clear and smooth boundary.
- B3 : Gravelly layer with over 75 % (vol) ferruginous gravels up to  
115± 4-5 cm in diameter.

Range in characteristics:

The Badanga soils are slightly enriched topsoils (colluvial influences). Only in a few cases the depth is limited by the presence of a ferruginous gravel layer, but in general soils contain up to 10 % ferruginous gravel in the first 100 cm of the solum.

The A horizon varies from 7-15 cm and has dark brown to brown to yellowish brown colours (10 YR 4/3, 5/3, 5/4). The texture is sandy clay loam (20-35% clay). Often this horizon can be subdivided into an A11 and A12 horizon. The horizon is followed by a rather compact B1 horizon of 13-22 cm with sandy clay loam textures.

The B2 horizon has brownish yellow to strong brown colours and clayey textures. The clay content is slightly increasing with depth ( $\pm$  60 % clay). The amount of gravel is increasing with depth. Traces of clay skins are observed in the upper part of the B2 horizon.

Competing Series and their differences:

Principal Associated Series:

The Badanga are found downslope of the Goyoum Series. Goyoum series have more clay and redder colours and miss the distinct colluvial influences which are characteristic for the Badanga Series.

Drainage and Erosion:

Badanga soils are well drained, surface runoff is slow to medium and permeability is rapid to moderate. The soils are not eroded, and slightly to moderately susceptible to erosion.

Setting:

Badanga Series are found on the footslopes to the Sanaga and Lom River floodplains, at an elevation of  $\pm$  640 m near Goyoum and 680 m near Haman. The soils are developed in colluvial materials.  
Climate: Udic, isohyperthermic.

Land use and Vegetation:

Native vegetation is a semi-deciduous forest. Some lands near the villages are used for agriculture.

Classification:

Oxic Paleudult; fine clayey, kaolinitic, isohyperthermic family (US Soil Taxonomy).



Badanga Series

Profile no. : DD 52

Lab. no.	385	386	387	388	389	390
Horizon	A11	A12	B1	II B21	B22	B23
Depth (cm)	00-05	05-13	16-30	45-63	74-85	97-109
T 2 u	24.9	27.3	27.5	58.2	59.3	60.3
E 2-20 u	2.2	4.4	1.1	0.3	4.9	2.2
X 20-50 u	1.4	0.2	0.3	1.5	0.7	0.2
T 50-100 u	14.9	12.5	14.3	9.3	6.6	6.7
U 100-250 u	27.5	24.9	26.0	13.9	9.9	9.0
R 250-500 u	16.6	16.8	16.7	8.5	7.7	7.1
E 500-1000 u	11.5	12.2	11.9	7.5	9.2	11.1
1000-2000 u	1.3	1.8	2.2	1.5	1.7	3.4
Org. Carbon %	0.86	0.60	0.64	0.56	0.55	0.52
Org. Matter %	1.48	1.03	1.10	0.96	0.95	0.89
Total N %	0.12	0.08	0.07	0.09	0.09	0.07
C/N	7.2	7.5	9.1	8.0	6.1	7.4
pH-H <sub>2</sub> O	5.3	5.0	4.9	5.0	5.3	5.2
pH-KCl	4.0	3.8	3.8	3.8	3.8	3.9
CEC meq/100 gr.	4.9	4.1	4.3	6.6	6.4	6.3
<sup>e</sup> <sub>x</sub> K <sup>+</sup> (NH <sub>4</sub> OAc) meq	0.31	0.23	0.22	0.26	0.26	0.24
<sup>c</sup> <sub>h</sub> Na <sup>+</sup> " "	0.03	0.01	0.03	0.02	0.02	0.01
<sup>c</sup> <sub>a</sub> Ca <sup>++</sup> " "	0.9	0.4	0.5	1.2	1.5	1.4
<sup>t Mg<sup>++</sup> " "</sup>	0.0	0.0	0.0	0.0	0.0	0.3
TEB (sum)	1.24	0.64	0.75	1.48	1.78	1.95
% Base Sat.	25.31	15.61	17.44	22.42	27.81	30.95
Av. P. (Kurtz-Bray 2)	7	3	2	1	1	0

.../...



