

TECHNICAL PAPER 23

**SOILS AND VEGETATION OF
BAMBA RIDGE FOREST RESERVE, MARAMBA DIVISION,
MUHEZA DISTRICT, TANGA**

Shaka J.M. and A. Msangi

Min. of Agriculture, National Soil Service
Agricultural Research Institute, Mlingano

1996

Detailed Soil Survey Report, 1996

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EAST USAMBARA CATCHMENT FOREST PROJECT

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SUMMARY

The East Usambara Catchment Forestry Project (EUCFP) requested the National Soil Service (NSS) to carry out soils and vegetation survey of Bamba Forest Reserve. The objectives of the study were to give general soils distribution, assess the fertility and to map out forest in terms of density and dominant tree species.

Bamba Forest Reserve covering an area of about 650 ha is located in Maramba division Muheza District. The climate is characterised by bi-modal rainfall pattern with long and short rain seasons from March to May and October to December respectively.

The forest is proposed by East Usambara Catchment Forest Project to be gazetted as a forest reserve. The study area is divided into three major physiographic units summit and upper slope, mid-slope and lower slopes. Slope gradient of the study area ranges from 8 to 50 % at an elevation between 250 to 700 m above sea level. The soils are formed from metamorphic rocks of the Usagaran system. The rocks are dominantly gneiss.

The soils in the study area are shallow to deep, moderately to well drained, sandy clay loam or clay loam to clay, dark reddish brown to dark red or red or yellowish red. In places the soils have rock outcrops or even rocky without surface stoniness. They have variable soil reaction that vary from neutral to strongly or very strongly acid. The soils in the study area have very high to high levels of the organic carbon. In places the levels are medium. Total nitrogen varies from low to medium while the available phosphorus is dominantly low. The C/N ratio generally show good quality organic matter.

The exchangeable calcium varies from high to very high while the exchangeable magnesium ranges from low to medium. Potassium levels are medium to low or very low. Cation exchange capacity (CEC) is generally medium.

Vegetation density varies from open forest mainly for the areas which have been under human influence to dense forest. In some of the plots one or two tree species are dominant while in others there is no tree dominance. The common tree species in the area include *Scorodophloeus fischeri*, *Manilkara sulcata*, *Lecaniodiscus fraxinifolius*, *Markhamia lutea*, *Cussonia zimmermanii*, *Pandanus rabaiensis*, *Julbernardia magnistipulata*, *Combretum schumannii*, *Diospyros kabuyeana*, *Diospyros natalensis*, *Vincentella passargei*, *Fernandoa magnifica*, *Antiaris toxicaria*, *Dombeya shupangae*, *Stereospermum kunthianum*, *Ricinodendron heudelotii*, *Xylopia parviflora*, *Millicia excelsa*, *Cynometra fischeri*, *Cynometra webberi*, *Dialium holtsii*, *Markhamia lutea*, and *Bombax rhodognaphalon*.

1. INTRODUCTION

This report presents the results of detailed soil and vegetation survey at a scale of 1:10,000 of Bamba Forest Reserve (650 ha) located at Maramba Division, Muheza District, in Tanga Region. It is found within coordinates 38°45'E and 38°50'E and 4°55' and 5°00'S about 10 km from Mtapwa village along Tanga-Maramba road. Bamba Forest Reserve is part of the East Usambara forests that is gazetted as a forest reserve and which is to be managed as a catchment forest.

The survey was carried out by the National Soil Service (NSS) at the request of East Usambara Catchment Forest Project (EUCFP) which is the project dealing with catchment forest within the region.

The objectives of the study were:

1. To give general soils distribution and assess the fertility status; and
2. To describe the survey area in terms of density and dominant tree species.

The fieldwork was carried out from 20th to 25th April 1996 by NSS Soil Surveyors. Vegetation classification is based on vegetation survey conducted by Mndolwa, a botanist from Amani botanical garden.

Soil samples collected during fieldwork were analyzed by the NSS Central Laboratory under supervision of Mr. C.T. Shawa.

2 THE ENVIRONMENT

2.1 Climate

Climate is one of the most important factor that affect a type of vegetation to be found in a given locality. It determines the type of tree species to be found in the given area. However, only rainfall data is available and relevant for Bamba Forest Reserve. Table 1 provides a summary of the rainfall data from Lugongo Sisal Estate, which is the nearest climatic recording station. Also temperature data are presented in this table as they are recorded at Mlingano Agricultural Research Station.

The rainfall pattern in the study area is bi-modal with long rains locally termed as "masika" and short rains locally known as "vuli" occur from March to May and October to December respectively. The main dry months are from June to September and January to February.

The data on temperature (Table 1) are those recorded at Mlingano Agricultural Research Institute located at Muheza District on the edge of East Usambara mountains. Air temperatures and relative humidity have small yearly variations. The coolest month is July with mean minimum temperatures of 27.6°C and the warmest one is February with mean maximum temperatures of 33.1°C.

Table 1. Mean monthly rainfall (mm) at Lugongo Sisal Estate and mean monthly temperatures (°C) at Mlingano Agricultural Research Institute (1949 - 1979)

Months	Mean monthly rainfall (mm)	Mean min. temp. (°C)	Mean max. temp. (°C)
Jan	64	21.6	32.5
Feb	59	21.7	33.1
Mar	156	21.9	33.0
Apr	159	21.9	30.6
may	161	21.7	29.2
Jun	46	19.5	28.2
Jul	51	18.6	27.6
Aug	50	18.4	28.1
Sep	66	18.8	28.6
Oct	125	19.7	29.8
Nov	156	20.7	30.7
Dec	147	21.6	32.1

2.2 Landform and Geology

Bamba Forest Reserve is situated on Bamba hills which are surrounded by wide valley bottom that are used for the cultivation of variety of crops including sisal. To the east of the area there is Mlungui Forest Reserve. The hill itself can be divided into units based mainly on the dominant slope gradient occurring in the study area.

Major physiographic units include summit and upper slopes, mid-slopes and lower slopes. The study area is situated at an elevation ranging from 150 to 700 m above sea level. Slope gradient is variable. It ranges from 3 to 30 %.

The East Usambara in general and Bamba forest reserve in particular is characterised by Metamorphic rocks of the Usagaran system (Precambian Basement). The rocks are dominantly gneiss with intermediate mineralogical composition. The rocks have approximately equal quantities of light minerals (quartz and feldspar) and dark minerals (pyroxene and hornblende). Locally amphibolites occur (Geological Survey of Tanzania, 1965).

2.3 Land-use and vegetation

A large part of Bamba Forest Reserve is natural forest. The forest in the area can be categorised according to density, and the degree of human involvements. 'Dense forest' include uneven aged more or less disturbed natural forest which has species composition characteristic to the original forest type and has an unbroken crown cover. This type of forest covers mainly the summits and upper slopes.

On the other hand 'poorly stocked forest' or open forest are those with variety of pioneer or secondary forest species which are poorly stocked because of various natural or manmade reasons. They are forest with low density, fairly open crown cover, modest volume and dominant height less than in dense forest belonging to the same forest type. This part of the forest shows some human influence especially logging or harvesting.

Some other parts of the forests are 'highly disturbed' such that often the natural vegetation types are absent. These are forests that are regenerated from the formerly cultivated lands. Or are the forests that have formally been encroached and in some plots are forests that are found at the forest edge. In such plots very few trees are present. The area is dominated mainly by short and dense grasses.

3 STUDY APPROACH

Prior to the commencement of the fieldwork, all relevant and available sources of information were studied. These include topographical and geological maps and all other relevant literatures for the study area.

A detailed soil study for the area included auger hole observations in each of the established sample plots. A total of 33 auger hole observations were made to a depth of 150 cm where possible. The augerings were described according to FAO (1977) guidelines for soil profile descriptions. Soil colours were named according to the Munsell notation (Munsell colour Charts Inc., 1973).

The augering and vegetation identification followed a grid approach, with observation sites spaced at standard intervals. The overall observation density was one observation point per 20 ha, corresponding to a nominal 450 m x 450 m grid system. In each grid square there was a 20 m x 50 m vegetation plot, in which samples were taken.

For vegetation identification and classification, in each of the sample plot all trees with Diameter at Breast Height (DBH) greater than 10 cm were counted followed by individual tree identification and botanical classification. Using information from aerial photography the forests were also categorised based on the density of the forests trees and the degree of the human involvement in the study area.

Soil samples for standard soil fertility analysis were collected from two depths 0-25 cm and 25-50 cm. The soils were then analyzed according to the Internationally accepted method in use at NSS. The parameters studied include texture by hydrometer, pH, total N, organic C, available P, cation exchange capacity (CEC) and Exchangeable calcium, potassium, magnesium and sodium.

The information gathered during the fieldwork and that from the chemical analyses was used in conjunction with recent aerial photography (1994) of scale 1:25,000 for East Usambara and Landsat Imagery to produce soil and vegetation map at a scale of 1:10,000.

4. SOILS AND VEGETATION

4.1 General soils condition.

The soils in the study area are generally shallow to very deep, dominantly well drained, sandy clay to clay. In places the soils are sandy loam or loamy, dark reddish brown to dark brown or brown. In some of the plots the soils have rock outcrops or even are rocky without surface stoniness. The slope gradients for the study area ranges from 3 to 30 %.

The chemical data presented in Table 2 shows that generally the soils in the area are very strongly acid or strongly acid to neutral. The electrical conductivity indicate that the soils are non-saline. Organic carbon and total nitrogen are variable in the study area. In some of the mapping units the level of organic carbon and total nitrogen varies from medium to high or very high. In some of the plots organic carbon are even very high. The tendency is that these parameters usually decreases with increase in soil depth. This clearly show that the amount of organic matter in the soils within the study area is high or very high especially in the topsoil and the organic matter is of good quality as indicated by the C/N ratio.

Available phosphorus in all plots is low while exchangeable bases vary from medium to high. Such low levels of the available phosphorus is probably due to the fact that the materials from which the soils are formed are dominantly low in phosphorus. The ability of the soil to retain and supply nutrient for plant uptake is dominantly variable. It varies from medium levels in the topsoil to low levels in the subsoil. Cation exchange capacity in this case generally decrease with increase in soil depth. The level of exchangeable calcium is dominantly high to very high. It seems that the parent material from which the soils are formed is rich in calcium while poor in phosphorus.

4.2 General vegetation conditions

The type of vegetation in the area are dominantly dense forest with minimum disturbances but in some of the plots the vegetation are disturbed such that the vegetation are either slightly dense or open forest with or without tree dominance. In such lands the areas or plots have been under human influence such as cultivation and or logging.

Occurrence of tree species in the study area is variable. Some of the tree species commonly occur in several plots while others are specific in some plots. Common tree species in the area include *Scorodophloeus fischeri*, *Manilkara sulcata*, *Cola usambarensis*, *Lecaniodiscus fraxinifolius*, *Markhamia lutea*, *Cussonia zimmermanii*, *Pandanus rabaiensis*, *Pandanus stuhlmannii*, *Julbernardia magnistipulata*, *Combretum schumannii*, *Diospyros kabuyeana*, *Diospyros natalensis*, *Diospyros mespiliformis*, *Vincentella passargei*, *Fernandoa magnifica*, *Dombeya shupangae*, *Stereospermum kunthianum*, *Ricinodendron heudelotii*, *Xylopia parviflora*, *Milicia excelsa*, *Cynometra fischeri*, *Cynometra webberi*, *Dialium holtsii*, *Markhamia lutea*, *Bombax rhodognaphalon*, *Dorstenia kameruniana*, *Newtonia paucijuga*, *Lonchocarpus bussei*, *Albizia glaberrima*, *Antiaris toxicaria*.

Table 2. Analytical data for representative plots in Bamba Ridge Forest Reserve.

PLOT/NO BASES DEPTH	PARTICLE SIZE ANALYSIS				pH		ORG.	TOTAL	C/N	AVAILABLE P	CEC	EXCHANGEABLE		
	<2	2-20	20-50	50-2000	1:2.5		C	N		BRAY I		Ca	Mg	
K Na					H2O	KCl	-----%-----			mg/kg	-----	Cmolc/kg----		
1a 0.01	38	6	1	55	5.60	5.40	2.80	0.23	12.00	3.80	13.40	7.20	3.30	0.45
1b 0.08	52	4	6	38	5.00	4.90	1.04	0.09	11.00	1.00	8.10	2.80	2.40	0.21
2a 0.07	25	16	9	50	6.80	6.50	3.40	0.35	10.00	5.60	16.50	11.40	5.60	0.68
2b 0.04	63	6	5	26	5.90	5.00	1.00	0.10	10.00	2.30	9.70	8.30	2.10	0.36
3a 0.05	40	3	7	50	6.50	5.80	2.65	0.28	9.00	6.40	20.10	10.40	3.60	1.30
3b 0.02	68	2	4	26	6.00	5.20	0.90	0.12	10.00	1.50	11.30	6.10	3.00	0.86
4a 0.01	40	7	3	50	5.60	4.50	1.80	0.16	11.00	1.03	12.00	11.30	2.80	1.48
4b 0.09	70	3	1	26	5.00	4.00	0.60	0.10	9.00	0.80	5.40	5.80	1.90	0.95
6a 0.09	15	18	12	55	6.50	5.10	4.80	0.31	15.00	6.80	23.60	8.80	2.80	0.50
6b 0.02	29	8	3	60	5.80	4.40	1.40	0.20	9.00	2.30	15.70	5.10	1.90	0.31
7a 0.08	40	6	2	52	6.10	5.50	2.90	0.34	9.00	3.10	13.50	6.60	4.80	0.90
7b 0.03	54	7	1	38	5.60	4.10	0.10	0.12	8.00	1.90	11.80	2.80	3.00	0.54
8a 0.06	30	8	12	50	6.60	5.90	3.20	0.25	13.00	6.70	21.60	9.70	5.60	0.70
8b 0.01	60	10	7	23	5.80	4.30	0.80	0.10	11.00	3.90	12.00	6.10	2.10	0.25
9a 0.18	26	15	9	50	6.40	6.00	2.80	0.30	9.00	5.10	15.00	13.80	6.10	0.95
9b 0.07	45	7	18	30	5.90	4.70	1.30	0.10	13.00	1.80	10.90	6.20	2.80	0.61
10a 0.12	25	8	13	54	6.30	5.60	3.00	0.37	8.00	4.30	19.60	18.00	3.90	1.25
10b 0.05	40	7	5	48	5.40	4.20	1.70	0.11	9.00	2.50	8.40	10.10	1.20	0.80
11a 0.15	35	10	15	40	6.20	5.10	3.40	0.25	14.00	3.50	18.10	10.20	3.20	0.40

11b	54	8	17	21	5.10	4.80	0.93	0.09	10.00	0.90	11.20	8.10	1.80	0.16
0.10														
12a	26	6	13	55	6.50	6.00	3.60	0.45	8.00	6.10	22.60	6.50	4.60	0.32
0.05														
12b	40	3	10	47	6.00	5.20	1.40	0.16	9.00	2.30	13.40	2.10	2.90	0.26
0.04														
13a	35	11	5	49	5.90	5.00	3.10	0.20	14.00	4.10	17.10	7.80	3.10	0.31
0.06														
13b	37	9	4	50	5.10	4.80	1.70	0.16	11.00	1.30	8.20	5.10	1.90	0.20
0.04														
14a	21	8	8	63	6.60	5.70	2.81	0.35	8.00	2.40	12.10	8.80	2.50	1.35
0.05														
14b	65	3	18	14	5.80	5.10	0.70	0.05	13.00	0.90	5.20	6.70	0.90	0.13
0.02														
15a	20	11	9	60	6.40	6.00	4.20	0.38	11.00	3.30	24.30	9.60	5.60	0.60
0.09														
15b	30	6	14	50	6.10	5.80	1.90	0.16	12.00	1.40	13.10	4.50	2.70	0.20
0.06														
16a	41	8	5	46	5.50	5.00	2.50	0.25	10.00	6.20	15.40	6.00	5.10	0.56
0.05														
16b	50	10	10	30	5.20	4.00	0.80	0.08	10.00	1.80	9.10	4.80	3.70	0.41
0.03														
17a	67	5	9	19	6.50	6.10	3.50	0.39	9.00	4.70	16.50	8.10	3.60	0.15
0.08														

Table 2 continued.

PLOT/NO BASES DEPTH K Na	PARTICLE SIZE ANALYSIS				pH		ORG.	TOTAL	C/N	AVAILABLE P	CEC	EXCHANGEABLE		
	<2	2-20	20-50	50-2000	1:2.5 H2O	KCl	C -----%-----	N		BRAY I mg/kg		Ca -----Cmolc/kg----	Mg	
17b 0.02	61	8	4	27	6.20	5.90	1.20	0.09	13.00	0.90	11.60	7.60	2.00	0.10
18a 0.07	35	16	18	31	5.80	4.90	3.00	0.03	10.00	2.60	13.80	11.20	6.10	0.80
18b 0.05	48	10	20	22	5.60	5.00	1.40	0.12	12.00	0.80	10.10	9.30	3.80	0.22
19a 0.10	31	15	29	25	6.90	6.10	3.70	0.34	11.00	5.10	20.60	6.10	5.10	0.60
19b 0.06	42	20	18	20	5.80	5.20	0.85	0.09	10.00	2.20	10.30	4.40	2.80	0.10
20a 0.05	15	18	7	60	5.40	5.10	2.60	0.22	12.00	4.30	17.50	8.90	5.60	0.30
20b 0.04	36	14	4	46	5.10	4.90	0.95	0.09	11.00	1.40	9.30	6.20	1.90	0.16
21a 0.06	30	12	10	48	5.40	4.90	2.00	0.20	10.00	2.60	21.50	6.90	3.60	1.80
21b 0.05	45	20	9	26	5.10	4.80	3.30	0.30	11.00	0.80	12.60	3.30	2.10	0.70
22a 0.08	38	14	18	30	6.30	5.80	4.90	0.38	13.00	3.50	19.70	4.90	5.50	1.30
22b 0.07	52	10	20	18	6.00	5.50	1.60	0.16	10.00	1.10	11.40	4.60	2.60	1.00
23a 0.05	43	20	10	27	5.60	5.20	2.00	0.14	14.00	6.70	13.60	4.20	3.80	1.56
23b 0.05	50	19	16	15	5.10	5.00	0.90	0.10	9.00	1.40	8.30	2.60	1.45	1.20
24a 0.05	25	11	8	56	5.90	5.10	4.10	0.41	10.00	5.60	18.70	5.50	2.70	1.68
24b 0.05	64	16	10	10	5.40	4.80	1.20	0.13	9.00	2.10	10.50	4.80	1.30	0.90
25a 0.10	33	15	9	43	6.20	5.30	3.15	0.35	9.00	4.35	15.10	3.00	6.10	1.41
25b 0.08	50	10	12	28	6.00	5.10	1.65	0.15	11.00	1.60	9.70	0.80	4.80	0.85
26a 0.05	45	3	2	50	6.50	5.90	5.10	0.39	13.00	3.16	22.40	8.40	5.50	1.50
26b 0.05	48	17	9	26	6.20	5.30	1.45	0.12	12.00	0.90	16.50	3.50	3.10	1.00
27a 0.09	31	15	6	48	5.80	5.00	5.52	0.46	12.00	3.90	21.00	6.00	2.80	0.95

27b	46	20	5	29	5.30	4.80	3.50	0.27	13.00	1.20	14.80	2.90	1.20	0.30
0.05														
28a	40	7	3	50	6.70	6.00	3.00	0.30	10.00	5.80	11.60	7.20	5.40	1.40
0.08														
28b	55	7	18	20	5.80	5.40	0.72	0.09	8.00	1.30	6.50	3.60	3.80	1.10
0.05														
29a	45	10	21	24	6.15	5.90	3.10	0.28	11.00	6.00	15.80	8.00	2.90	1.91
0.15														
29b	57	8	13	22	5.80	5.60	0.70	0.07	10.00	1.70	10.20	5.60	1.05	1.10
0.08														
30a	34	30	20	16	5.70	5.30	5.40	0.45	12.00	4.80	17.80	5.30	2.90	1.20
0.05														
30b	60	11	15	14	5.20	4.80	2.16	0.18	12.00	1.90	9.70	2.16	1.50	0.50
0.05														
31a	40	18	10	32	6.10	5.30	4.20	0.32	13.00	6.50	18.20	8.70	4.60	1.30
0.05														
31b	42	22	16	20	5.90	5.00	1.70	0.14	12.00	2.40	11.50	3.60	3.00	0.80
0.05														
32a	48	4	2	46	5.70	4.90	3.80	0.32	12.00	5.10	23.60	7.50	4.20	1.85
0.15														
32b	60	8	4	28	5.20	4.60	1.20	0.12	10.00	2.10	15.70	2.56	2.80	1.20
0.10														
33a	36	8	6	50	6.00	5.20	4.60	0.46	10.00	4.70	16.80	6.40	3.70	1.40
0.08														
33b	51	9	11	29	5.30	4.80	2.10	0.20	11.00	3.10	10.40	3.30	2.10	0.60
0.06														

NB. a- Topsoil (0-20 cm)
b- Subsoil (25-50 cm)

4.3 Description of the plots

4.3.1 Plot 1

The plot covers the middle part of the slope at 300 m above sea level. Slope gradient ranges from 20 to 25 %. The soils in the plot are moderately deep with hardrock observed at 50 cm from the surface, well drained, dark reddish brown, sandy clay to caly soils. The plot is also characterised by 60 % rockoutcrops that are 3 to 15 m apart.

The reaction of the soils in the this plot are medium acid (pH 5.60) and decreases to strongly acid or very strongly acid (pH 5.00) in the subsoil. Organic carbon in the soil ranges from high (2.80 %) in the topsoil to medium (1.04 %) in the subsoil. Total nitrogen on the otherhand is medium with levels that varies from 0.23 % in the topsoil and decreases to very low or low levels in the subsoil (0.1 %). Carbon to nitrogen ratio indicates that the organic matter in both topsoil and subsoil are of good quality. They indicate possibility of net mineralisation of added organic matter. Available phosphorus is low with levels generally less than 4 mgP/kg both in topsoil and subsoil.

The ability of the soil to retain and supply nutrients for plant uptake as expressed by cation exchange capacity (CEC) is medium (13.40 Cmolc/kg) in the topsoil and decreases to low levels in the subsoil with levels of about 8.10 Cmolc/kg. Exchangeable calcium ranges from very high to high in topsoil and subsoil respectively. The levels varies from 7.20 Cmolc/kg in the topsoil to 2.80 Cmolc/kg in the subsoil. The levels of the exchangeable magnesium is high (3.30 Cmolc/kg) in the topsoil and decreases to medium levels (2.40 Cmolc/kg) in the subsoil. Exchangeable potassium on the otherhand is medium (0.45 Cmolc/kg) in the topsoil and decreases to low levels (0.21 Cmolc/kg) in the subsoil. Exchangeable sodium is generally very low with levels that are dominantly less than 0.1 Cmolc/kg

The plot is characterised by open forest of which the dominating tree species include *Markhamia lutea* (Benth.) K.Schum, *Lecaniodiscus fraxinifolius* Bak., *Lettowianthus stellatus diels*, *Scorodophloeus fischeri* (tanb.) J. Leon, *Leptonychia Usambarensis* K. Schum, *Sorindeia Madagascariensis* Thou, *Cola Microcarpa Brenan*, *Milletia usambarensis tanb. var. usambarensis*, *Drypetes usambarica* (pax) hutch, *Diospyros kabuyeana* F. white (suy.) D. Brucei white, *Ziziphus mucronata* wild, *Cardia africana* lour, *Drypetes usambarica* (pax) hutch, *Grewia microcarpa* K. Schum, *Cola discoglypsemnophylla brenan*, *Cola microcarpa brenan* and *Lettowianthus stellatus diels*.

4.3.2 Plot 2

This plot occupies mid-slope part of the landscape at an altitude 150 m above sea level. The slope gradient varies from 10 to 15 %. The soils are generally deep, well drained, dark brown, sandy clay to clay soils.

The soil reaction in the plot ranges from neutral (pH 6.8) in the topsoil to medium acid (pH 5.90) in the subsoil. Organic carbon ranges from high levels (3.40 %) in the topsoil and decreases significantly to low levels (1.00 %) in the subsoil. Total nitrogen on the otherhand is dominantly medium (0.35 %) in topsoil but decreases to low levels (0.10 %) in the subsoil. The C/N ratio indicates that the organic matter in the plot are of good quality. Implying net mineralisation of the added organic matter. The available phosphorus is generally low with levels less than 7 mgP/kg. The cation exchange capacity (CEC) of the soils in this plot ranges

from medium to low levels in the soil. The values varies from 16.50 Cmolc/kg in the topsoil to 9.70 Cmolc/kg in the subsoil. Exchangeable calcium are generally very high in both topsoil and subsoil while the levels of the exchangeable magnesium are high (5.60 Cmolc/kg) in topsoil and medium (2.10 Cmolc/kg) in the subsoil. Exchangeable potassium varies from medium levels (0.68 Cmolc/kg) in the topsoil to very low levels (0.36 Cmolc/kg) in the subsoil. The levels of the exchangeable sodium is dominantly very low with levels less than 0.1 Cmolc/kg.

The dominating tree species in the plot include *Citrus aurantium*, *Rothmannia manganjae*, *Erythrophleum suaveolens*, *Markhamia lutea*, *Malacantha alnifolia*, *Antiaris toxicaria*, *Garcinia volvensii*, *Synsepalum msolo*, *Cola usambarensis*, *Pachystela msolo*, *Zanthoxylum usambarensis*, *Synsepalum msolo (pachystela msolo)*, *Synsepalum msolo (pachystela)*, *Entada parsuetua*, *Bequaertiodendron natalens*, *Tarrena nigrescens*, *Newtonia paucijuga*, *Lettowinathus stellatus*, *Bequaertiodendron natalense*, *Sorindeia madagaascariensis*, *Malacantha alnofolia*, *Erythrophleum suaveolens*, *Synsepalum msolo (pachystela msolo)*, *Grewia goetziana*, *Lannea welwitschii*, *Celtis wightii*, *Pachystela msolo*, *Funtumia africana* and *Rytigynia flavida (syn. R. Schumannii)*

4.3.3 Plot 3

The plot covers gentle lower slope with slope gradient ranging from 15 to 20 %. It occurs at 340 m above sea level. The soils in this plot are very shallow to shallow with effective rooting depth of less than 20 cm, well drained, very dark grayish brown and sandy clay is texture. Presence of rock outcrops are the characteristics of this plot.

The pH of the soils ranges from medium acid in the topsoil to strongly acid in the subsoil. The levels of the pH varies from 5.80 to 5.20 in the topsoil and subsoil respectively. The organic carbon ranges from high levels in the topsoil (2.65 %) in the topsoil to low levels in the subsoil. The levels in the subsoil is 0.9 %. Total nitrogen is medium in the topsoil (0.28%) to low levels in the subsoil (0.12 %). The carbon to nitrogen ratio, C/N ratio indicates that the organic matter in the soils are of good quality. They indicate net mineralisation the organic matter added in the soil. Available phosphorus on the otherhand is low with levels varying from 6.40 mgP/kg in the topsoil to 1.50 mgP/kg in the subsoil.

The ability of the soil to retain and supply nutrients for plant uptake is medium in the topsoil to low levels in the subsoil. The values ranges from 20.10 to 11.30 Cmolc/kg in the topsoil and subsoil respectively. Calcium levels are generally very high in both topsoil and subsoil. Exchangeable magnesium on the otherhand is medium in both topsoil and subsoil. The levels are 10.4 Cmolc/kg in the topsoil to 6.10 Cmolc/kg in the subsoil. The levels varies from 3.60 to 3.00 Cmolc/kg in the topsoil and subsoil respectively. The potassium levels are high (1.30 Cmolc/kg) in topsoil to medium level (0.86 Cmolc/kg) in the topsoil. Exchangeable sodium is very low.

It is characterised by the presence of dense forest, mature mixed without dominance. The plot show some signs of old harvesting or logging. However the commonly occurring tree species in the plot include *Celtis wightii*, *Lecaniodiscus fraxinifolius*, *Angylocalyx braunii*, *Diospyros mespiliformis*, *Diospyros natalensis*, *Bequaertiodendron natalense*, *Celtis africana*, *Drypetes usambarensis*, *Scorodophloeus fischeri*, *Morinda atheroscepa*, *Drypetes gerrardii*, *Sericanthe odoratissima*, *Morinda atheroscepa*, *Sericanthe odoratissima*, *Angylocalyx braunii*, *Milicia excelsa*, *Diospyros abyssinica*, *Sericanthe odoratissima*, *Drypetes usambarensis*, *Combretum*

schumannii, *Manilkara sulcata*, *Antiaris toxicaria*, *Terminalia sambesiaca*, *Sericanthe odoratissima*, *Diospyros mespiliformis*, *Lannea welwitschii*, *Premna chrysoclada*, *Sericanthe odoratissima*, *Mimusops sp.*, *Angylocalyx Braunii*, *Uvariadendron sp.* and *Dorstenia kameruniana*,

4.3.4 Plot 4

The plot occurs at gullied part of the study area. The soils in this plot are moderately deep, well drained, dark reddish brown, sandy clay to clay.

The soil reaction in the plot ranges from medium acid (pH 5.60) in the topsoil to strongly acid (pH 5.00) in the subsoil. Organic carbon ranges from medium levels (1.80 %) in the topsoil and decreases significantly to low levels (0.60 %) in the subsoil. Total nitrogen on the otherhand is dominantly low in both topsoil and subsoil. The values varies from 0.16 to 0.10 % in the topsoil and subsoil respectively. The C/N ratio indicates that the organic matter in the plot are of good quality. Implying net mineralisation of the added organic matter. The available phosphorus is generally low with levels less than 2 mgP/kg.

The cation exchange capacity (CEC) of the soils in this plot ranges from medium to low levels in the soil. The values varies from 12.00 Cmolc/kg in the topsoil to 5.40 Cmolc/kg in the subsoil. Exchangeable calcium are generally very high in both topsoil and subsoil while the levels of the exchangeable magnesium is medium both in topsoil and subsoil. The levels are 2.80 and 1.90 Cmolc/kg in topsoil and subsoil respectively. Exchangeable potassium varies from low levels (1.48 Cmolc/kg) in the topsoil to very low levels (0.95 Cmolc/kg) in the subsoil. The levels of the exchangeable sodium dominantly very low with levels less than 0.1 Cmolc/kg.

Vegetation types within the plot include dense forest, mature mixed without dominance. Within the plot there is no sign of harvesting or logging. It seem the plot has not yet disturbed as the result of human influence. However the commonly occurring tree species in the plot include *Barringtonia racemosa*, *Markhamia lutea*, *Lannea welwitschii*, *Barringtonia racemosa*, *Trilepsium madagascariense*, *Fernandoa magnifica*, *Malacantha alnifolia*, *Dorstenia kameruniana* (syn. *Craterogyn kameruniana*), *Rinorea ferugginea*, *Scorodophloeus fischeri*, *Newtonia paucijuga*, *Rinorea ferugginea*, *Diospyros squarrosa*, *Celtis mildbraedii*, *Antiaris toxicaria*, *Combretum schumannii*, *Malacantha alnifolia*, *Porterandia penduliflora*, *Scorodophloeus fischeri*, *Lettowianthus stellatus*, *Newtonia paucijuga*, *Terminalia sambesiaca*, *Grewia goetziana*, *Lecaniodiscus fraxinifolius*, *Malacantha alnifolia*, *Combretum schumannii*, *Terminalia sambesiaca*, *Celtis mildbraedii* and *Rytigynia flavida* (syn. *R. schumannii*).

4.3.5 Plot 6

The plot is found at steep lower slope. Slope gradient varies from 30 to 40 % and plot occurs at 300 m above sea level. The soils in this plot are moderately deep with hardrock observed at 50 cm from the surface, well drained, dark reddish brown, sandy loam in texture. About 40 % of the plot is characterised by the presence of rock outcrop.

pH of the soil in the plot indicates that the soils are slightly acid or neutral (pH 6.50) in the topsoil and decreases to medium acid (pH 5.80) in the subsoil. Organic carbon is very high (4.80 %) in the topsoil and decreases to medium levels (1.40 %) in the subsoil. Total nitrogen

on the otherhand varies from medium levels (0.31 %) in the topsoil to low levels or slightly medium in the subsoil. The carbon to nitrogen ratio in the soil indicate that the organic matter in the soil are of good quality to moderate quality in both topsoil and subsoil respectively. Available phosphorus in the soil is generally low. The values are dominantly less than 7 mgP/kg.

Cation exchange capacity (CEC) of the soils in this plot is dominantly medium in both topsoil and subsoil with levels varies from 23.60 to 15.70 Cmolc/kg in topsoil and subsoil respectively. Exchangeable calcium is very high in both topsoil and subsoil. The levels varies from 8.80 to 5.10 Cmolc/kg in topsoil and subsoil. Magnesium levels are medium over the sampled soil depth. The levels varies from 2.80 Cmolc/kg in the topsoil to 1.70 Cmolc/kg in topsoil and subsoil respectively. Potassium levels on the otherhand varies from medium (0.5 Cmolc/kg) in the topsoil to low levels (0.31 Cmolc/kg) in the subsoil. sodium levels are generally low in both topsoil and subsoil.

Vegetation types in the plot are characterised by open forest, mature mixed with dominance. The forest has been harvested or logged such that the dominating tree species in the plot include *Scorodophleus fischeri*, *Manilkara sulcata*, *Diospyros mespiliformis*, *Cola usambarensis*, *Combretum schumannii*, *Angylocalyx braunii*, *Diospyros natalensis*, *Dorstenia kameruniana*, *Sorindeia madagascariensis*, *Garcinia volkensii*, *Trilepsum madagascariense*, *Fernandoa magnifica*, *Celtis wightii*, *Markhamia lutea*, *Dombeya shupangae*, *Cola greenwayi*, *Rhodognaphalon schumannianum*, *Blighia unijugata*, *Markhamia lutea*, *Julbernardia magnistipulata*, *Vitex keniensis* and *Garcinia volkensii*.

4.3.6 Plot 7

This plot is found on the steep upper slope with dominating slope gradient that ranges from 15 to 20 %. The plot occurs at 450 m above sea level. The soils in this plot are shallow with effective rooting depth of 40 cm, well drained, dark reddish brown, sandy clay soils.

The soil reaction in this plot varies from slightly acid (pH 6.10) in the topsoil to medium acid (pH 5.60) in the subsoil. Organic carbon is high (2.90 %) and decreases to low levels (0.10 %) in the subsoil. Total nitrogen on the otherhand varies from medium levels to low levels in the topsoil and subsoil respectively. The values ranges from 0.34 to 0.12 % respectively. The ratio of carbon to nitrogen indicates that the organic matter in the plot are good quality. This implies that net mineralisation is possible over the added organic matter. Available phosphorus is low with levels less than 4 mgP/kg.

The ability of the soil to retain and supply nutrients for plant uptake is overall medium levels in both topsoil and subsoil. The levels are 13.50 Cmolc/kg in the topsoil to 11.80 Cmolc/kg in the subsoil. Exchangeable calcium is very high in the topsoil (6.60 Cmolc/kg) in the topsoil but decreases to high levels (2.80 Cmolc/kg) in the subsoil. The levels of magnesium in this plot is both high in topsoil and subsoil. The values ranges from 4.80 to 3.00 Cmolc/kg respectively. Exchangeable potassium is as well medium. The levels varies from 0.90 Cmolc/kg in the topsoil to 0.54 Cmolc/kg in the subsoil. Exchangeable sodium is low.

Within the plot there is influence of cultivation and settlement such that the vegetation forms an open and mature forest that is colonising. The forest has been harvested or logged in such a way that the dominating tree species include *Lannea welwitschii*, *Albizia glaberrima*, *Morus mesozygia*, *Albizia adianthifolia*, *Commiphora zimmermannii*, *Morus mesozygia*, *Markhamia*

obtusifolia, *Albizia* sp., *Antiaris toxicaria*, *Albizia glaberrima*, *Voacanga thouarsii*, *Sapium ellipticum*, *Markhamia lutea*, *Lannea welwitschii*, *Rytigynia schumannii*, *Bequartiodendron natalense*, *Voacanga thoursii*, *Trilepsium madagascariense*, *Malacantha alnifolia*, *Cussonia zimmermannii*, *Mangifera indica*, *Funtumia africana*, *Bridelia micrantha*, *Milicia excelsa*, *Millettia oblata* and *Oxyanthus speciosus*.

4.3.7 Plot 8

This plot is at the middle part of the slope at 470 m above sea level. Slope gradient ranges from 20 to 30 %. The soils in the plot are shallow, well drained, dark reddish brown to reddish brown, sandy clay in texture.

The soil reaction in this plot varies from neutral (pH 6.60) in the topsoil to medium acid (pH 5.80) in the subsoil. Organic carbon is high (3.20 %) in the topsoil and decreases to low levels (0.80%) in the subsoil. Total nitrogen is medium (0.25 %) in the topsoil which becomes low levels (0.10 %) in the subsoil. The C/N ratio show that the organic matter in the plot are of good quality. Available phosphorus is low in both topsoil and subsoil. The levels varies from 6.70 mgP/kg to 3.90 mgP/kg in topsoil and subsoil respectively.

Cation exchange capacity is medium in both topsoil and subsoil. The levels varies from 21.60 to 12.00 Cmolc/kg in both topsoil and subsoil respectively. Exchangeable calcium in very high with levels dominantly over 5.00 Cmolc/kg. Magnesium levels on the otherhand is high (5.60 Cmolc/kg) in the topsoil which decreases to medium levels (2.10 Cmolc/kg) in the subsoil. Potassium levels varies from medium (0.70 Cmolc/kg) to low levels in the subsoil. The value in the subsoil is 0.25 Cmolc/kg. Exchangeable sodium is very low with levels less than 0.1 Cmolc/kg.

The plot is characterised by the presence of open forest that forms grassland. It seems the forest has been harvested and or logged and some places show signs of cultivation which might have been carried within the plot some years ago. The commonly occurring tree species in the plot include *Cussonia zimmermannii*, *Lonchocarpus bussei*, *Fernandoa magnifica*, *Albizia glaberrima*, *Pteleopsis myritifolia*, *Markhamia lutea*, *Grewia goetziana*, *Allophyllus Calophyllus*, *Antidesma membranaceum*, *Combretum molle*.

4.3.8 Plot 9

Plot 9 is found at steep upper part of the slope with slope gradient that varies from 30 to 40 %. It occurs at 480 m above sea level. The soils in this plot are moderately deep with effective rooting depth of 45 cm, well drained, dark reddish brown, sandy clay in texture with rockoutcrop spaced at 5 to 10 m apart.

The soil reaction as indicated by the pH of the soil is slightly acid to medium acid with pH ranges from 6.40 in the topsoil and decreases to 5.90 in the subsoil. Total nitrogen in topsoil is medium 0.3 % but it decreases to low levels in the subsoil with value of 0.1 %. The organic carbon found in this unit is high (2.8 %) in the topsoil and decreases to medium levels (1.3 %) in the subsoil. The C/N ratio which gives more information on the availability of nitrogen and hence showing the quality of organic matter are of good quality. The levels ranges from 9 to 13.

The cation exchange capacity of the soils in the plot varies from medium level in the topsoil to low levels in the subsoil. The respective values are 15.00 Cmolc/kg and 10.90 Cmolc/kg. The available phosphorus are low with levels ranging from 1.8 to 5.10 mgP/kg. The exchangeable calcium on the other hand is medium with levels that varies from 13.80 in the topsoil to 6.20 Cmolc/kg in the subsoils. Exchangeable magnesium are dominantly high ranging from 6.10 in the topsoil to 2.80 Cmolc/kg in the subsoils. Potassium levels are medium both for the topsoil and subsoils with values ranging from 0.95 to 0.61 Cmolc/kg respectively. The exchangeable sodium are generally low with levels in the topsoil 0.18 and decreases to very low levels less than 0.1 Cmolc/kg.

The plot is characterised by the presence of dense forest, mature mixed without dominance. However the commonly occurring tree species in the plot include *Newtonia paucijuga*, *Millettia oblata*, *Teclea simplicifolia*, *Fagaropsis angolensis*, *Commiphora eminnii* (ssp *zimmermannii*), *Grewia goetzeana*, *Millettia stuhlmannii*, *Pandanus stuhlmannii*, *Manilkara sulcata*, *Millettia oblata*, *Scorodophloeus fischeri*, *Lettowianthus stellatus*, *Gyrocarpus americanus*, *Rhodognaphalon schumannianum*, *Gyrocarpus americanus*, *Syzigium sp.*, *Cussonia zimmermannii*, *Milicia excelsa*, *Albizia glaberrima*, *Julbernardia magnistipulata*, *Ficus scassellattii* (syn. *F. kirkii*), *Ximenia americana*, *Syzigium sp.*, *Malacantha alnifolia*, *Grewia bicolor*, *Cynometra webberi*, *Leptonychia usambarensis*, *Manilkara sulcata* and *Parkia filicoidea*.

4.3.9 Plot 10

The plot is located at the mid-slope. The soils in this plot are moderately deep, well drained, dark red to reddish brown, sandy clay in texture.

The soil reaction of the soils as shown by the pH of the soil is slightly acid to strongly acid with pH values that ranges from 6.30 in the topsoil and decreases to 5.40 in the subsoils. Total nitrogen in the topsoil is medium 0.37 % but decreases to low levels in the subsoils with values 0.11 %. The organic carbon is high (3.0 %) in the topsoil and decreases to medium levels (1.7 %) in the subsoils. The C/N ratio which gives more information on the availability of nitrogen and hence showing the quality of organic matter are of good quality. The levels ranges from 8 to 9 in topsoil and subsoil respectively.

The ability of the soil in the plot to retain and supply nutrient for plant uptake is variable. While in the topsoil the value is medium (19.60 Cmolc/kg) in the topsoil the value in the subsoil decreases to low levels (8.40 Cmolc/kg). The available phosphorus is low with levels ranging from 2.50 to 4.30 mgP/kg. The exchangeable calcium on the other hand is high with levels that varies from 18.0 Cmolc/Kg in the topsoil to 10.0 Cmolc/Kg in the subsoils. Exchangeable magnesium is high in the topsoil (3.90 Cmolc/kg) and becomes medium in the subsoils (1.2 Cmolc/kg). Potassium level is high in the topsoil (1.25 Cmolc/kg) and decreases to medium level in the subsoils (0.80 Cmolc/kg). The exchangeable sodium is generally low in the topsoil (0.12 Cmolc/kg) and decreases to very low levels in the subsoils (0.05 Cmolc/kg).

The dominating tree species in the plot include *Scorodophloeus fischeri*, *Zanthoxylum usambarensis*, *Grewia goetzeana*, *Zanthoxylum usambarensis*, *Lecaniodiscus fraxinifolius*, *Terminalia sambesiaca*, *Diospyros squarrosa*, *Cussonia zimmermannii*, *Zanthoxylum usambarensis*, *Combretum schumannii*, *Cola greenwayi*, *Millettia oblata*, *Euphorbia candelabrum*, *Ricinodendron heudelotii*, *Sterculia appendiculata*, *Dracaena steudneri*,

Newtonia paucijuga, *Lannea welwitschii*, *Combretum schumannii*, *Sterculia appendiculata*, *Entada pursaantha* (liana), *Diospyros squarrosa*, *Oxyanthus* sp., *Ziziphus mucronala*, *Mildbraedia fallax*, *Senna singueana*, *Zanthoxylum usambarensis*, *Uvariadendron* sp., *Mildbraedia fallax*, *Vincentella passargei*.

4.3.10 Plot 11

The plot covers gentle lower slope at 290 m above sea level. Slope gradient varies from 15 to 20 %. Soils in this plot are moderately deep with maximum rooting depth of 60 cm, well drained, dark reddish brown to yellowish red, sandy clay soils.

The Soil reaction of the soils as shown by the pH of the soils is slightly acid to strongly acid with values ranging from 6.20 in the topsoil and decreases to 5.10 in the subsoils. Total nitrogen on the other hand is medium in the topsoil (0.25 %) and decreases to very low values in the subsoils (0.09 %). The organic carbon values are high in the topsoil (3.4 %) and becomes low in the subsoils (0.93 %). The carbon to nitrogen ratio shows that the organic matter is of good to moderate quality. The levels ranges from 10 to 14 respectively.

The available phosphorus in the soil is low. The cation exchange capacity, which is the ability of the soils to retain and supply nutrients for plant uptake is as well medium (18.10 Cmolc/kg). The levels decreases with increase in soil depth thereby becoming low (11.20 Cmolc/kg in the subsoil). The exchangeable calcium in this unit is high in the topsoil and decreases to medium levels in the subsoils with values 10.20 and 8.10 Cmolc/kg respectively. On the other hand soils in this unit has high levels of magnesium in the topsoil and becomes medium in the subsoils with values 3.20 and 1.80 Cmolc/kg respectively. Potassium level is low in the topsoil while the subsoils are very low with values 0.40 and 0.16 Cmolc/kg respectively. The exchangeable sodium level is generally low with values ranging from 0.15 to 0.10 (Cmolc/kg).

The plot is characterised by dense forest and colonising forest. The plot show some sign of harvesting or logging such that the remaining and dominating tree species in the plot include *Albizia glaberrima*, *Ficus exasperata*, *Antiaris toxicaria*, *Zanha golungensis*, *Milicia excelsa*, *Millettia oblata* and *Allophylus callophyllus*.

4.3.11 Plot 12

The plot covers gentle lower slope at 260 m above sea level. It moderately deep with effective rooting depth of 70 cm, well drained, dark reddish brown topsoil to reddish brown subsoil. The soils are sandy clay. At 50 cm there is rock fragments and rock outcrops occur within the area at a distance of 5 to 10 m apart.

The pH of the soil is slightly acid with values that ranges from 6.5 in the topsoil while decrease to 6.0 in the subsoils. Total nitrogen on the other hand has shown medium levels in the topsoil (0.45 %) and decreases to low levels in the subsoils (0.16 %). The organic carbon levels are very high in the topsoil (3.6 %) and decreases to medium levels in the subsoils (1.4 %). The ratio of carbon to nitrogen shows the quality of organic matter is of good quality. The levels ranges from 8 to 9 respectively.

Cation exchange capacity of the soils in this plot is dominantly medium both in topsoil and subsoil. The levels varies from 22.60 Cmolc/kg to 13.40 Cmolc/kg in topsoil and subsoil

respectively. The available phosphorus is generally low with levels less than 7 mgP/kg. The exchangeable calcium levels are medium in the topsoil and becomes low in the subsoils with values that ranges from 6.50 to 2.10 Cmolc/kg. The exchangeable magnesium is high in the topsoil 4.60 Cmolc/kg and becomes medium in the subsoils 2.90 Cmolc/kg. Potassium levels are generally low with values that range from 0.32 Cmolc/kg in the topsoil and 0.26 Cmolc/kg in the subsoils. The exchangeable sodium for both topsoil and subsoils is low <0.10 Cmolc/kg.

The plot is characterised by the presence of open forest that makes grassland. It seems the forest has been harvested or logged or cultivated some years ago. The commonly occurring vegetation in this plot include *Xeroderris stuhlmannii* (*syn. ostryoderris stuhlmanii*), *Senna spectabilis*, *Albizia glaberrima*, *Mangifera indica*, *Antiaris toxicaria*, *Markhamia lutea*, *Senna singueana*, *Markhamia lutea* and *Deinbolia borbonica*.

4.3.12 Plot 13

This plot is on mid-slope and occurs at 360 m above sea level. The soils in this plot are shallow with effective rooting depth less than 30 cm, well drained, very dark brown, sandy clay in texture.

The soil reaction which is always expressed in terms of soil pH ranges from medium acid to strongly acid with values that varies from pH 5.90 in the topsoil and decreases to pH 5.1 in the subsoils. The levels of total nitrogen are generally low with values 0.2 % in the topsoil and 0.16 % in the subsoils. The organic carbon found in this unit shows high levels in the topsoil 3.10 % and decreases to medium level in the subsoils 1.70 %.

The ratio of carbon to nitrogen indicates the organic matter to be of moderate to good quality. The levels ranges from 11.0 to 14.0.

The ability of the soils within the plot to retain and supply nutrients for plant uptake varies from medium levels (17.10 Cmolc/kg) in the topsoil and decreases with soil depth to low levels (8.20 Cmolc/kg) in the subsoil. The available phosphorus is generally low. The levels of the available phosphorus is less than 7 mgP/kg. Exchangeable calcium is generally medium with levels that varies from 7.80 Cmol/kg in the topsoil and decreases to 5.10 Cmolc/kg in the subsoils. The magnesium levels are high in the topsoil and becomes medium in the subsoils with values 3.10 Cmolc/kg and 1.90 Cmolc/kg respectively. The exchangeable potassium levels are generally low with values that ranges from 0.31 Cmolc/kg in the topsoil and 0.20 Cmolc/kg in the subsoils. The exchangeable sodium has shown very low levels for both topsoil and subsoils with values less than 0.10 Cmolc/kg.

The forest structure include dense forest, mature mixed without dominance. It seems the forest has been harvested or logged and in some places there is sign of cultivation such that the dominating tree species in this plot include *Newtonia paucijuga*, *Bequaertidendron natalense*, *Celtis mildbraedii*, *Antiaris toxicaria*, *Scorodophloeus fischeri*, *Manilkara densifolia*, *Manilkara sulcata*, *Albizia gummifera*, *Cola greenwayi*, *Lecaniodiscus fraxinifolius*, *Drypetes usambarica*, *Diospyros squarrosa*, *Diospyros mespiliformis*, *Manilkara sulcata*, *Cussonia zimmermannii* and *Diospyros abyssinica*.

4.3.13 Plot 14

This plot occurs at the middle part of the slope at 410 to 425 m above sea level. The soils in the plot are moderately deep with rotten rock observed at 50 cm, well drained, black topsoil to dark yellowish brown subsoil, sandy clay in texture.

The pH of the soil is neutral to medium acid with values that ranges from 6.60 in the topsoil and decreases to 5.80 in the subsoils. The levels of total nitrogen varies from medium (0.35 %) in the topsoil and becomes very low in the subsoils (0.05 %). The organic carbon level found in this plot is high in the topsoil (2.81 %) while the subsoils has registered low value (0.71 %). The C/N ratio which gives more information on the availability of Nitrogen and hence showing the quality of organic matter is of good quality. The levels ranges from 8 to 13.

Dominantly low levels of CEC are found in the soils. The values are 12.10 in the topsoil to 5.20 Cmolc/kg in the topsoil and subsoil respectively. The available phosphorus registered low values for both topsoil and subsoils. The levels are less than 7 mgP/kg. The exchangeable calcium for both topsoil and subsoils are registered medium levels which ranges from 8.80 Cmolc/kg and 6.70 Cmolc/kg respectively. While magnesium shows medium levels for topsoil and decreases to low levels in the subsoil. The values are 2.50 Cmolc/kg and 0.92 Cmolc/kg respectively. Potassium levels on the otherhand are high in the topsoil (1.35 Cmolc/kg) and decreases to low levels in the subsoils (0.13 Cmolc/kg). On the other hand exchangeable sodium registered very low values less than 0.10 Cmolc/kg).

The forest structure in the plot include open forest that occurs at the forest edge. There is no signs of harvesting or logging such that the commonly occurring tree species in the plot include *Stereospermum kunthianum*, *Albizia gummifera*, *Lonchocarpus bussei*, *Cussonia zimmermannii*, *Albizia gummifera*, *Steganotaenia araliacea*, *Strychnos innocua*, *Lannea welwitschii*, *Strychnos innocua*, *Senna singueana*, *Lonchocarpus bussei*, *Annona senegalensis*, *Acacia senegal*, *Combretum molle*, *Antiaris toxicaria*, *Allophylus melliodorus*, *Maytenus acuminata* and *Margaritaria discoidea*.

4.3.14 Plot 15

The plot covers the gentle lower part of the slope with slope gradient ranging from 15 to 20 %. It occurs at 305 m above sea level. The soils in the plot are moderately deep with effective rooting depth of 50 cm from the surface, well drained, dark yellowish brown, sandy loam to sandy clay in texture.

The reaction of the soils as indicated by the pH of the soil is slightly acid both for topsoil and subsoils with values that ranges from 6.40 to 6.10 respectively. The total nitrogen, however shows medium levels in the topsoil (0.38 %) and decreases to low levels (0.16 %) in the subsoils. The organic carbon level in the topsoil is very high (4.20 %) and becomes low in the subsoils (1.90 %). The carbon to nitrogen ratio (C/N) shows good quality organic matter. The levels ranges from 11 to 12. This indicate net mineralisation of the added source of nitrogen into the soils.

The levels of the cation exchange capacity varies from medium levels (24.30 Cmolc/kg) in the topsoil and decreases to low levels (13.10 Cmolc/kg) in the subsoil. The available phosphorus levels are low dominantly with values less than 7 mgP/kg. The exchangeable

calcium is medium in the topsoil 9.60 Cmolc/kg and decreases with soil depth thereby becoming low in the subsoils 4.20 Cmolc/kg. The exchangeable magnesium levels are high in the topsoil 5.60 Cmolc/kg and decreases to medium levels in the subsoils 2.70 Cmolc/kg. Potassium levels are medium in 0.60 Cmolc/kg in the topsoil and becomes low in the subsoils 0.20 Cmolc/kg. The exchangeable Sodium levels are very low for both the topsoil and subsoils. The values are less than 0.10 Cmolc/kg.

The forest is characterised by the presence of dense fores, mature mixed without dominance. Within the plot there is signs of harvesting or logging as an indication of human influence in the plot. Dominating tree species in the plot include *Lecaniodiscus fraxinifolius*, *Cola usambarensis*, *Drypetes natalensis*, *Pandanus stuhlmannii*, *Diospyros abyssica*, *Diospyros natalensis*, *Pandanus stuhlmannii*, *Scorodophloeus fischeri*, *Manilkara sulcata*, *Cola greenwayi*, *Craibia brevicaudata*, *Dorstenia kameruniana*, *Cynometra webberi*, *Cola usambarensis* and *Kenurea ferruginea*.

4.3.15 Plot 16

This plot covers the mid-slope at an altitude of 340 m above sea level. The slope gradient ranges from 15 to 20 %. The soils in this plot are moderately deep, well drained, dark reddish brown and sandy clay in texture.

The pH of the soils in the plot indicate that the soils are strongly acid in both topsoil and subsoils with values ranging from 5.50 to 5.20 respectively. The total nitrogen levels are medium in the topsoil (0.25 %) and decreases with soil depth thereby becoming very low in the subsoils (0.08 %). The organic carbon levels found in this plot is medium (2.5 %) and becomes low in the subsoils (0.8 %). The carbon to nitrogen ratio indicates good quality organic matter with levels being 10.

The cation exchange capacity of the soils in the plot varies from medium in the topsoil to low levels in the subsoil. The valuea are 15.40 and 9.10 Cmolc/kg in topsoil and subsoil respectively. The available phosphorus is generally low for both the topsoil and subsoils with values less than 7 mgP/kg. The Exchangeable calcium shown medium levels in the topsoil 6.0 Cmolc/kg while becomes low in the subsoils 4.80 Cmolc/kg. The exchangeable magnesium levels area generally high for both the topsoil and subsoils with values 6.0 Cmolc/kg and 4.80 Cmolc/kg respectively. Potassium levels in the topsoil are medium 0.56 Cmolc/kg and becomes low in the subsoils 0.41 Cmolc/kg. The exchangeable sodium are generally very low for both the topsoil and subsoils with values less than 0.10 Cmolc/kg.

Vegetation characteristics within the plot include dense forest, mature mixed without dominance. Within the plot there is an indication that the forest has been harvested or logged and in places signs exists which indicate that the plot has been under cultivation for some years ago. However the remaining and dominant tree species in the plot include *Scorodophloeus fischeri*, *Drypetes natalensis*, *Drypetes usambarica*, *Manilkara sulcata*, *Manilkara sansibarensis*, *Cynometra webberi*, *Millettia oblata*, *Fernandoa magnifica*, *Celtis africana*, *Newtonia paucijuga*, *Xylopi holtzii*, *Lecaniodiscus fraxinifolius*, *Lannea welwitschii*, *Craibia sp.*, *Dorstenia kumeruniana* (syn. *Craterogyne kumeruniana*), *Xylopi pariflora*, *Celtis mildbraedii*, *Dorstenia kameruniana*, *Angylocalyx braunii*, *Blighia unijugata*, *Manilkara sulcata*, *Rothmannia manganjae* and *Ritingynia sp.*

4.3.16 Plot 17

Plot 17 covers the steep upper slope with slope gradient that varies from 20 to 30 %. It occurs at 440 m above sea level. The plot is characterised by the presence of rock outcrop that makes the plot to be rocky. About 80 to 90 % of the plot are rocky. The soils in the plot are very shallow with hard rock observed at 20 cm from the surface, well drained, black topsoil to dark red subsoil.

The soil reaction of the soil as indicated by the pH of the soil is slightly acid with pH values that ranges from 6.50 in the topsoil and decreases to 6.20 in the subsoil. On the other hand total Nitrogen levels are medium in the topsoil (0.39 %) and decreases to very low values in the subsoil (0.09 %). The organic carbon are high in the topsoil (3.5 %) and decreases to low levels in the subsoil (1.2 %). The carbon to nitrogen ratio show that the organic matter are of good quality.

The levels of the CEC varies from medium to low levels in topsoil and subsoil respectively. The values are The levels of the available phosphorus is dominantly low with values less than 7 mgP/kg. The exchangeable calcium in this unit are medium for both topsoil and subsoil with values 8.10 Cmolc/kg and 7.60 Cmolc/kg respectively. On the other hand exchangeable magnesium levels are high in the topsoil 3.60 Cmolc/kg and decreases to medium levels in the subsoil 2.00 Cmolc/kg while potassium levels are very low with values less than 0.20 Cmolc/kg. The exchangeable sodium levels are very low with values less than 0.10 Cmolc/kg.

The plot is characterised by the presence of the dense forest, mature mixed without dominance. The commonly occurring tree species in the plot include *Vernonia colorata*, *Antiaris toxicaria*, *Anyglocalyx braunii*, *Trilepsium madagascariense*, *Dialium holtzii*, *Sorindeia madagascariensis*, *Trema orientalis*, *Zanha golungensis*, *Trilepsium madagascariense*, *Voacanga thouarsii*, *Anyglocalyx braunii*, *Croton sylvaticus*, *Trema orientalis*, *Pachystela msolo* and *Celtis gomphopylla* (*syn.c.durandi*)

4.3.17 Plot 18

The plot covers the upper part of the slope particularly at the summit with slope gradient that ranges from 2 to 5 %. It occurs at 550 m above sea level. The soils in the plot are moderately deep with hard rock observed at 40 cm from the surface, well drained, strong brown to dark brown, sandy clay in texture. No rock outcrops are observed within the plot.

The soil reaction of the soil as indicated by the pH of the soil is medium acid with pH values that ranges from 5.80 in the topsoil and decreases to 5.60 in the subsoil. Total nitrogen on the other hand show low values for both topsoil (0.03 %) and subsoil (0.12 %). The organic carbon levels are high (3.0 %) and decreases with increase in soil depth to medium levels in the subsoil (1.40 %).

While the available phosphorus is generally low, the cation exchange capacity is dominantly low or medium especially in the topsoil. The exchangeable calcium levels in this mapping unit are high in the topsoil with values 11.20 Cmolc/kg and decreases to medium levels in the subsoil with values 9.30 Cmolc/kg. Magnesium has shown very high levels in the topsoil 6.10 Cmolc/kg and decreases to high levels in the subsoils 3.80 Cmolc/kg. The exchangeable Potassium levels are medium in the topsoil 0.80 Cmolc/kg and decreases to low levels in the

subsoil 0.22 Cmolc/kg while exchangeable sodium levels are very low with values less than 0.10 Cmolc/kg.

The forest structure in the plot is characterised by dense forest, mature mixed, without dominance. The plot shows no signs of harvesting or logging. The dominating tree species in the plot include *Fernandoa magnifica*, *Drypetes usambarica*, *Celtis mildbraedii*, *Julbernardia magnistipulata*, *Scorodophloeus fischeri*, *Manilkara densiflora*, *Lecaniodiscus fraxinifolius*, *Rhodognaphalon schumannianum*, *Gymnosporia amaniensis*, *Commiphora eminii* (spp. *zimmermannii*), *Erythrina abyssinica*, *Millettia stuhlmannii*, *Xylopiia parviflora*, *Teclea trichocarpa*, *Cola greenwayi*, *Maytenus acuminata* and *Ficus kirkii*.

4.3.18 Plot 19

The plot covers the gentle lower slope with 10 to 15 % slope gradient. It occurs at 300 m above sea level. The soils in the plot are moderately deep with hardrock observed at 40 cm from the surface, well drained, dark reddish brown, sandy clay soils. About 10 % of the plot are characterised by the presence of rockoutcrops that are located at 10 to 15 m apart.

The soil reaction indicated by the pH values of the soil is neutral to medium acid with values that ranges from 6.90 in the topsoil and decreases to 5.80 in the subsoil. Total nitrogen is medium with levels around 0.30 % but it decreases to very low levels in the subsoil with values of about 0.09 %. The organic matter found in this unit is very high (3.7 %) in the topsoil and decreases to low levels in the subsoil (0.85 %). The C/N ratio that gives more information on the availability of nitrogen and hence showing the quality of organic matter is of good quality. The levels range from 9 to 11.

Cation exchange capacity varies from medium (20.60 Cmolc/kg) in the topsoil and decreases to low levels (10.30 Cmolc/kg) in the subsoil. The available phosphorus is low with levels that range from 5.10 to 2.20 mgP/kg. The exchangeable calcium levels are medium in the topsoil and decreases to low levels in the subsoil. The values are 6.10 and 4.40 Cmolc/kg respectively. Magnesium in this unit has shown high levels in the topsoil 5.10 Cmolc/kg and a decline in the subsoil to 2.80 Cmolc/kg. Potassium levels are medium in the topsoil (0.60 Cmolc/kg) and decreases to very low levels in the subsoil (0.10 Cmolc/kg). Exchangeable sodium levels are generally low to very low with values 0.10 Cmolc/kg or less.

The plot is characterised by forest structure that is dense forest, mature mixed without dominance. It seems the plot has been harvested or logged. There are also some signs of cultivation. The remaining and dominating tree species in the plot include *Brachystegia microphylla*, *Drypetes usambarica*, *Newtonia paucijuga*, *Scorodophloeus fischeri*, *Euphorbia candelabrum*, *Nersogodonia* (check), *Pandanus stuhlmannii*, *Lecaniodiscus fraxinifolius*, *Erythrina abyssinica* and *Teclea amaniensis*.

4.3.19 Plot 20

The plot covers the mid slope with slope gradient that varies from 15 to 20 %. The plot occurs at 440 m above sea level. The soils in the plot are moderately deep with maximum rooting depth of 60 cm, well drained, dark reddish brown, sandy loam to sandy clay soils. The plot has few rockout crop that are situated at 10 to 15 m apart.

The soil reaction indicated by the pH of the soil is strongly acid with pH values range from 5.40 in the topsoil and decrease to 5.10 in the subsoil. The total nitrogen in the topsoil is medium with levels around 0.22 % but it decreases to very low levels in the subsoil with values around 0.09 %. The organic Carbon levels found in the soil of this unit is medium (2.6 %) in the topsoil and decreases to low levels (0.95 %) in the subsoil.

Cation exchange capacity varies from medium levels in the topsoil to low levels in the subsoil. The available phosphorus levels are generally low with values less than 7 mgP/kg. The exchangeable calcium levels are medium with values 8.90 Cmolc/kg in the topsoil and decreases to 6.20 Cmolc/kg in the subsoil. Magnesium levels are high in the topsoil (5.60 Cmolc/kg) and decreases to low levels in the subsoil (1.90 Cmolc/kg). The exchangeable potassium levels are low in the topsoil (0.30 Cmolc/kg) and decreases to very low level in the subsoil (0.16 Cmolc/kg). The exchangeable sodium are generally very low with levels less than 0.10 Cmolc/kg.

The plot is characterised by the presence of open forest, poorly mixed with low canopy and plot do not show any signs of harvesting and or logging. The dominating tree species in the plot include *Terminalia sambesiaca*, *Lecaniodiscus fraxinifolius*, *Diospyros squarrosa*, *Commiphora eminii* (spp. *zimmermanni*), *Julbernardia magnistipulata*, *Celtis africana*, *Grewia bicolor*, *Celtis africana*, *Cola usambarensis*, *Markhamia lutea*, *Malacantha alnifolia*, *Celtis mildbraedii*, *Celtis zenkeri*, *Dombeya shupangae* and *Bequatiodendron natalense*.

4.3.20 Plot 21

The plot covers the lower part of the slope with slope gradient that varies from 1 to 5 %. It occurs at 450 m above sea level. The soils in this plot are shallow with effective rooting depth of 30 cm, well drained, dark reddish brown, sandy clay in texture. In places the plot is gullied and prone to gullying.

The soil reaction as indicated by the pH of the soil is strongly acid with pH values range from 5.40 in the topsoil and 5.10 in the subsoil. Total nitrogen levels are medium in the topsoil 0.3 % and decreases to low levels in the subsoil 0.2 %. The organic carbon levels found in this unit is medium in the topsoil and increases in the subsoil. The levels are 2.0 % and 3.30 % respectively. The C/N ratio which gives information on the availability of Nitrogen shown the quality of organic matter to be good.

Medium levels of CEC are found in the topsoil (21.50 Cmolc/kg) which decreases to low levels (12.60 Cmolc/kg) in the subsoil. The available phosphorus in this unit are generally low with values less than 7 mgP/kg. The exchangeable calcium level in the soil is medium in the topsoil and decreases to low levels in the subsoil. The values are 6.90 and 3.30 Cmolc/kg. The exchangeable magnesium levels are high in the topsoil and decreases to medium levels in the subsoil with values ranging from 3.60 to 2.10 Cmolc/kg. Potassium registered high levels in the topsoil and shown a significant decline of levels in the subsoil. The values are 1.80 and 0.70 Cmolc/kg. Overall exchangeable sodium levels are low with values less than 0.10 Cmolc/kg.

Forest struture include the presence of dense forest, mature mixed without dominance. It seems that the forest has been harvested or logged such that the remaining and dominating tree species in the plot include *Cola scheffleri*, *Ficus exasperata*, *Xylopia parviflora*, *Trilepsium madagascariensis*, *Zanha golungensis*, *Artocarpus heterophyllus*,

Tabernaemontana holstii, *Grewia goetziana*, *Millettia stuhlmannii*, *Ficus vallis choudae*, *Trilepsium madagascariensis*, *Leptonychia usambarensis*, *Trelipsium madagascariense*, *Malacantha alnifolia*, *Entandrophragma excelsum*, *Parkia filicoidea*, *Milicia excelsa*, *Bombax rhodognaphalon*, *Antiaris toxicaria*, *Markhamia lutea*, *Bequaertiodendron natalense*, *Oxyanthus speciosus*, *Cola usambarensis* and *Rytinginia flyavida* (syn. *R. schumanii*).

4.3.21 Plot 22

Plot 22 covers the gentle lower at 300 m above sea level. The slope gradient ranges from 10 to 15 %. The soils in this plot are deep, well drained, dark reddish brown to yellowish red, sandy loam to sandy clay or clay. The plot has very few rock outcrop.

The pH of the soils in this plot indicate that the soils are slightly acid in the topsoil to medium acid in the subsoil with values that range from 6.30 to 6.00 respectively. Total nitrogen found in this soil is medium in the topsoil with values around 0.38 % and decreases to low levels in the subsoil with values about 0.16 %. The organic carbon on the other hand registered very high levels in the topsoil and decreases to medium levels in the subsoil. The values are 4.90 % and 1.60 % respectively. The C/N ratio of this soil indicated the quality of organic matter is good.

The levels of the available phosphorus in this soil are overall low. Cation exchange capacity is medium in the topsoil which decreases to low levels in the subsoil. The levels are 19.70 and 11.40 Cmolc/kg in topsoil and subsoil respectively. The levels are generally less than 7 mgP/kg. On the other hand exchangeable calcium levels are medium with values varying between 4.90 and 4.60 Cmolc/kg. The exchangeable magnesium registered high levels in the topsoil and a decrease medium levels in the subsoil with values 5.50 and 2.60 Cmolc/kg respectively. Potassium levels are high to medium with values ranging from 1.30 in the topsoil and 1.00 Cmolc/kg in the subsoil. The exchangeable sodium levels are generally very low with values less than 0.10 Cmolc/kg.

The plot is characterised by open forest that has formerly being encroached and colonising. The forest has been harvested and logged. Commonly occurring tree species in the plot include *Cola greenwayi*, *Lecaniodiscus fraxinifolius*, *Rinorea usambarensis*, *Dracaena steudneri*, *Ricinodendron heudelotii*, *Grewia goetzeana*, *Cussonia zimmermannii*, *Scorodophloeus fischeri*, *Cynometra webberi*, *Sterculia appendiculata*, *Diospyros mespiliformis*, *Nersogodonia sp.*, *Gyrocarpus americanus*, *Rinorea usambarensis*, *Alchornea hirtella*, *Acacia schweinfurthii* (liana), *Drypetes sp.*, *Manilkara sulcata* and *Dracaena stuedineri*.

4.3.22 Plot 23

This plot covers the mid-slope at 500 m above sea level. Slope gradient varies from 20 to 30 %. The soils in the plot are moderately deep with effective rooting depth of 70 cm from the surface, well drained, very dark brown to very dark grayish brown, sandy clay to clay soils. Very few and large rock outcrops are present within the plot.

The soil reaction of the soil is medium acid to strongly acid with pH values that ranges from 5.60 in the topsoil to 5.10 in the subsoil. Total nitrogen in this unit is low with values that varies from 0.14 % in the topsoil and 0.10 % in the subsoil. On the other hand organic carbon

levels are medium in the topsoil and decreases to low levels in the subsoil with values 2.00 % and 0.9 %. The ratio of carbon to nitrogen indicates the quality of organic matter is good.

The available phosphorus in this unit is generally low. Exchangeable calcium registered low values that varies from 4.20 Cmolc/kg in the topsoil and 2.60 Cmolc/kg in the subsoil. The exchangeable magnesium levels are high in the topsoil and decreases to medium levels in the subsoil. The values are 3.80 and 1.45 Cmolc/kg respectively. The exchangeable potassium are high in the topsoil 1.56 Cmolc/kg and decreases to 1.20 Cmolc/kg in the subsoil. The overall exchangeable sodium levels are very low with values less than 0.10 Cmolc/kg.

Vegetation characteristics includes the presence of an open forest that formerly has been encroached and colonised. The plot shows some signs of harvesting and or logging and some signs of cultivation as well are present. However the remaining tree species in the plot include *Celtis gomphophylla* (syn. *C. durandii*), *Ficus usambarensis*, *Trilepsium madagascariense*, *Celtis wightii*, *Voacanga thouarsii*, *Bequaertiodendron natalense*, *Cola usambarensis*, *Cola usambarensis*, *Scorodophloeus fischeri*, *Diospyros mespiliformis*, *Diospyros abyssinica*, *Bequaertiodendron natalense*, *Diospyros sp.*, *Tricalysia myrtofolia*, *Celtis mildbraedii*, *Sterculia appindiculata*, *Morinda asteroscepa* and *Ficus sp.*

4.3.23 Plot 24

The plot covers the gentle lower slope at 250 m above sea level. Slope gradient varies from 20 to 25 %. Soils in the plot are shallow with effective rooting depth of 40 cm from the surface, well drained, very dark grayish brown to reddish brown, sandy clay to clay.

The soil reaction of the soil is medium acid to strongly acid with pH values that varies from 5.90 in the topsoil to 5.40 in the subsoil. Total nitrogen levels are medium in the topsoil (0.41 %) and becomes low in the subsoil (0.13 %). The organic carbon has shown very high levels in the topsoil (4.10 %) and decreases to low levels in the subsoil (1.20 %). The ratio of carbon to nitrogen (C/N) indicates that the quality of organic matter are of good quality. The levels of C/N ratio ranges from 9.0 to 10.0 in topsoil and subsoil respectively.

While the available phosphorus levels in this unit are generally low, the exchangeable calcium levels in are medium in the topsoil and becomes low in the subsoil with values that varies from 5.50 Cmolc/kg to 4.80 Cmolc/kg respectively. Exchangeable Magnesium registered medium levels that varies from 2.70 Cmolc/kg in the topsoil and 1.30 Cmolc/kg in the subsoil. The exchangeable Potassium levels are medium in the topsoil 1.68 Cmolc/kg while a decline is not in the subsoil 1.30 Cmolc/kg. The exchangeable Sodium levels are very low with values less than 0.10 Comlc/kg.

The forest struture include the presence of open forest, low canopy and poorly mixed. The dominating tree species in the plot include *Lecaniodiscus fraxinifolius*, *Albizia zimmermanii*, *Grewia goetziana*, *Cussonia zimmermannii*, *Deinbollia barbonica*, *Lecaniodiscus fraxinifolius*, *Bridelia melanthesoides*, *Ricinodendron heudelotii*, *Lannea schweinfurthii*, *Trichilia emetica*, *Diospyros squarrosa*, *Manilkara sulcata* and *Millettia oblata*.

4.3.24 Plot 25

The plot covers gentle lower slope. The soils in this plot are moderately deep, well drained, dark reddish brown, sandy clay to clay in texture.

The soil reaction of the soil as indicated by the pH of the soil is slightly acid to medium acid with values that varies from 6.20 in the topsoil to 6.00 in the subsoil. The total nitrogen levels are medium in the topsoil 0.35 % and decreases to low levels in the subsoil. The organic carbon levels are high in the topsoil 3.15 % while becomes medium in the subsoil 1.65 %. The C/N ratio show the quality of organic matter is of good quality.

The levels of the available phosphorus are generally low. The values are generally less than the critical levels which in most cases 7 mgP/kg. CEC in the soils varies from medium levels (15.10 Cmolc/kg) in the topsoil and decreases to low levels (9.70 Cmolc/kg) in the subsoil. The exchangeable calcium levels are low in the topsoil 3.00 Cmolc/kg and decreases to even lower values in the subsoil 0.80 Cmolc/kg. On the other hand magnesium levels in this soil is registered very high in the topsoil 6.10 Cmolc/kg and 4.80 Cmolc/kg in the subsoil. Exchangeable potassium show high levels in the topsoil 1.41 Cmolc/kg and becomes medium in the subsoil (0.85 Cmolc/kg). The exchangeable sodium are generally low with values less than 0.10 Cmolc/kg.

4.3.25 Plot 26

This plot covers the mid slope. The soils are deep, well drained, dark reddish brown, sandy clay to clay in texture.

The soil reaction of the soil is slightly acid as indicated by the pH of the soil with values that varies from 6.50 in the topsoil and 6.20 in the subsoil. Total nitrogen levels in this mapping unit are medium in the topsoil (0.39 %) and decreases to low levels in the subsoil (0.12 %). While the organic carbon registered very high levels in the topsoil 5.10 % and decreases to medium levels in the subsoil. The C/N ratio indicated the quality of organic matter to be good. The levels range from 12 to 13.

The ability of the soil to retain and supply nutrients for plant uptake is dominantly medium in both topsoil and subsoil. The levels are 22.40 and 16.50 Cmolc/kg respectively. The available phosphorus are generally very low with values less than 7 mgP/kg. The exchangeable calcium registered medium levels in the topsoil 8.40 Cmolc/kg while a decline to low level in the subsoil 3.50 Cmolc/kg. The exchangeable magnesium levels are generally high with values that varies from 5.50 Cmolc/kg in the topsoil and 3.10 Cmolc/kg. Potassium levels are high in the topsoil 1.50 Cmolc/kg while decreases to 1.00 Cmolc/kg in the subsoil. Exchangeable sodium is generally low with values less than 0.10 Cmolc/kg.

In terms of vegetation the plot is characterised by dense forest which is colonising and the plot shows no signs of harvesting and or logging. However the dominating tree species in the plot include *Markhamia lutea*, *Celtis wightii*, *Milicia excelsa*, *Sorindeia madagascariensis*, *Bequaertiodendron natalense*, *Manihot glaziovii*, *Combretum schumannii*, *Albizia glaberrima*, *Erythrophleum suaveolens*, *Antiaris toxicaria*, *Diospyros mespiliformis*, *Allophylus melliodorus*, *Pterocarpus tinctorius*, *Lecaniodiscus fraxinifolius*, and *Grewia bicolor*.

4.3.26 Plot 27

This plot covers steep upper slope with slope gradient varying from 20 to 25 %. The plot occurs at 500m above sea level. The plot is dissected. The soils in this plot are moderately

deep with effective rooting depth of 60 cm, well drained, very dark brown to dark yellowish brown, loam to sandy clay or clay in texture.

The pH of the soil is medium acid to strongly acid with pH values that varies from 5.80 in the topsoil to 5.30 in the subsoil. Total nitrogen of this soil is very low with values that ranges in the topsoil 0.46 % and decreases to 0.27 % in the subsoil. The organic carbon levels are very high in the topsoil 5.52 % and becomes high in the subsoil 3.50 %. The C/N ratio indicate that the organic matter are of good quality. The levels range from 12 to 13.

The available phosphorus levels are generally low. The cation exchange capacity are overall medium in both topsoil and subsoil. The values ranges from 21.00 and 14.80 Cmolc/kg in topsoil and subsoil. The exchangeable calcium levels in the soil are medium to low with values that varies from 6.0 Cmolc/kg in the topsoil and 2.90 Cmolc/kg in the subsoil. The exchangeable magnesium on the other hand registered medium levels that varies from 2.80 Cmolc/kg in the topsoil to 1.20 Cmolc/kg in the subsoil. Potassium levels are medium in the topsoil 0.95 Cmolc/kg and decreases to low levels in the subsoil 0.30 Cmolc/kg. The exchangeable Sodium are generally very low with values less than 0.10 Cmol/kg.

The plot is characterised by dense forest, mature mixed without dominance. There is no signs of harvesting or logging within the plot. However the tree species occurring in the plot include *Croton sylvaticus*, *Celtis gomphophylla*, *Tabernaemontana pachysiphon*, *Celtis mildbraedii*, *Trilepsium madagascariense*, *Ricinodendron heudelotii*, *Premna chrysoclada*, *Poemna erisoclada*, *Monodora sp.*, *Combretum schumannii*, *Antiaris toxicaria*, *Ficus exasperata*, *Trema orientalis*, *Lecaniodiscus fraxinifolius* and *Cola scheffleri*.

4.3.27 Plot 28

Plot covers steep upper slope. Slope gradient varies from 10 to 18 % at 440 m above sea level. The soils in the plot are moderately deep with hardrock observed at 50 cm from the surface, well drained, very dark brown to dark reddish brown, sandy clay to clay in texture. Rockoutcrops spaced at 10 to 25 m apart are present.

The soil reaction of the soil as indicated by the pH of the soil is neutral to medium acid with pH values ranging from 6.70 in the topsoil to 5.80 in the subsoil. Total nitrogen levels of the soil are medium 0.3 % in the topsoil and decreases to very low levels in the subsoil 0.09 %. The organic carbon levels are high in the topsoil 3.00 % and becomes low in the subsoil 0.72 %. The C/N ratio of the soil indicated that the quality of organic matter is good. The levels range from 8 to 10.

Cation exchange capacity of the soil in this plot are generally low in both topsoil and subsoil. The levels varies from 11.60 and 6.50 Cmolc/kg in topsoil and subsoil. Available phosphorus are generally low with values below the critical levels. The exchangeable calcium levels are medium in the topsoil and becomes low in the subsoil. The levels are 7.20 Cmolc/kg and 3.60 Cmolc/kg respectively. The exchangeable magnesium levels in the soil are high with values that varies from 5.40 in the topsoil and 3.80 Cmolc/kg in the subsoil. Potassium shown high levels in the topsoil 1.40 Cmolc/kg and becomes medium in the subsoil 1.10 Cmolc/kg. The exchangeable sodium levels are generally very low with values less than 0.10 Cmolc/kg.

The plot is characterised by the presence of open forest, low canopy and poorly mixed. The plot indicate some signs of cultivation such that the dominating tree species include *Millettia*

obtala, Albizia schimperana, Antiaris toxicaria, Milicia excelsa, Cussonia zimmermannii, Manihot glaziovii, Ricinodendron heudelotii, Manihot glaziovii, Millettia stuhlmannii, Lannea welwestchii, Ficus exasperata, Scorodophleus fischeri, Croton silvaticus, Albizia adianthifolia, Croton silvaticus, Ficus kirkii, Fernandoa magnifica, Lannea welwestchii, Sterculia appendiculata, Lecaniodiscus fraxinifolius, Millettia stuhlmannii, Sorindeia madagascariensis, Commiphora zimmermannii, Dracaena steudneri and Drypetes usambarica.

4.3.28 Plot 29

The plot covers middle part of the slope in which slope gradient varies from 15 to 20 % located at 460 m above sea level. The plot has very few rock outcrops, shallow with effective rooting depth of 40 cm, well drained, dark reddish brown, sandy clay to clay.

The soil pH indicates that the soils are slightly acid to medium acid with values that varies from 6.15 in the topsoil to 5.80 in the subsoil. Total nitrogen of the soil registered medium values in the topsoil 0.28 % while in the subsoil becomes low 0.07 %. The organic carbon levels are high in the topsoil 3.10 % and decreases to low levels in the subsoil 0.7 %. The C/N ratio of the soil shown that the quality of organic matter is good. The levels range from 10 to 11.

The available Phosphorus levels are overall low. The exchangeable calcium levels are medium with values that varies from 8.0 Cmolc/kg in the topsoil to 5.60 in the subsoil. The exchangeable magnesium levels are medium with values that range from 2.90 Cmolc/kg in the topsoil to 1.05 Cmolc/kg in the subsoil. Potassium shown high levels in the topsoil 1.91 Cmolc/kg and 0.10 Cmolc/kg in the subsoil while sodium levels are low in the topsoil and becomes very low in the subsoil. The values are 0.15 and 0.08 Cmolc/kg.

Vegetation structure within the plot include the presence of open forest, low canopy and poorly mixed. The commonly occurring tree species include *Ficus exasperata, Antiaris toxicaria, Albizia gummifera, Bredelia micrantha, Funtumia africana, Milicia excelsa, Sapium ellipticum, Ricinodendron heudelotii, Macaranga capensis and Rauwolfia mombasiana.*

4.3.29 Plot 30

The plot covers the middle part at the boundary of the forest. The plot is located at 365 m above sea level. Slope gradient varies from 13 to 15 %. The soils are moderately deep with effective rooting depth of 60 cm, well drained, dark reddish brown to dark red, clay loam to clay soil.

The soil reaction of the soil as indicated by the pH of the soil is medium in the topsoil to strongly acid with pH values that varies from 5.70 in the topsoil and 5.20 in the subsoil. Total nitrogen levels in the soil are medium in the topsoil while becomes low in the subsoil. The values are 0.45 % and 0.18 % respectively. The organic carbon levels found in the soil are very high in the topsoil 5.40 % and decreases to medium levels in the subsoil 2.16 %. The C/N ratio indicated that the quality of organic matter is good. The levels are 12.

The available Phosphorus levels are generally low with values less than 7 mgP/kg. CEC varies from medium levels in the topsoil to low levels in the subsoil. The values are 17.80 and 9.70 Cmolc/kg in topsoil and subsoil respectively. The exchangeable levels are medium in the

topsoil 5.30 Cmolc/kg and becomes low in the subsoil 2.16 Cmolc/kg. The exchangeable magnesium are medium with values 2.90 Cmolc/kg in the topsoil and 1.50 Cmolc/kg in the subsoil. The exchangeable potassium levels in the soil are medium with values that decreases with depth. The values are 1.20 in the topsoil and 0.50 Cmolc/kg in the subsoil. The exchangeable sodium are very low with values less than 0.10 Cmolc/kg.

The plot is characterised by the presence of open forest that has formerly encroached and colonised. The forest indicate some signs of harvesting and or logging such that the remaining tree species in the plot are *Artocarpus heterophyllus*, *Ficus persicifolia*, *Trilepsium madagascariense*, *Manihot glaziovii*, *Coccus nucifera*, *Antiaris toxicaria* and *Markhamia lutea*.

4.3.30 Plot 31

The plot covers the steep upper slope and occurs at 700 m above sea level. Slope gradient varies from 30 to 35 %. The plot is characterised by the soils that are shallow with effective rooting depth of 40 cm, well drained, dark reddish brown, clay in texture.

The soil reaction of the soil as indicated by the pH of the soil is slightly acid to medium acid with pH values that varies from 6.10 in the topsoil to 5.90 in the subsoil. Total nitrogen levels are medium in the topsoil 0.32 % and becomes low in the subsoil 0.14 %. The levels organic carbon are high in the topsoil 4.20 % and becomes low in the subsoil 1.70 %. The carbon to nitrogen ratio indicated the quality of organic matter is good. The levels are 12 and 13.

The available phosphorus levels in the soil are generally low. The exchangeable calcium levels in this soil are medium in the topsoil and becomes low in the subsoil with values less 8.70 and 3.60 Cmolc/kg respectively. The exchangeable magnesium levels are high in the topsoil 4.60 Cmolc/kg while the values decreases to low levels in the subsoil 3.00 Cmolc/kg. The potassium levels are high in the topsoil and becomes low in the subsoil. The levels are 1.30 and 0.80 Cmolc/kg respectively. The exchangeable sodium levels are generally very low with values less than 0.10 Cmolc/kg.

Vegetation structure within the plot include dense forest, mature mixed with dominance. The plot has not yet harvested as there is no signs of harvesting and or logging. The tree species common in the plot include *Treculia africana*, *Tarena nigrescens*, *Celtis mildbraedii*, *Symphonia globulifera*, *Allanblachia stuhlmannii*, *Tarbanae montana pachysiphon*, *Allanblachia stuhlmannii*, *Myianthus holstii*, *Sorindeia madagascariensis*, *Leptonychia usambarensis*, *Mesogyne insignis*, *Symphonia globulifera*, *Treculia africana*, *Strombosia scheffleri*, *Macaranga capensis*, *Cylicomapha parriflora*, *Bequaertiodendron natalense*, *Cola scheffleri*, *Quassia undulata* (syn. *Odyendea zimmermannii*), *Isobertia scheffleri*, *Sorindeia madagascariensis*, *Celtis mildbraedii*, *Leptonychia usambarensis*, *Macaranga capensis*, *Tabernaemontana pachysiphon*, *Allanblachia stuhlmannii*, *Oxyanthus speciosus*, *Isobertia scheffleri*, and *Cola microcarpa*.

4.3.31 Plot 32

The plot is located at 635 m above sea level at middle part of the slope. The slope gradient varies 42 to 45 %. The soils in the plot are moderately deep with effective rooting depth of 45 cm, well drained, dark reddish brown, sandy clay to clay. Rockoutcrop that are spaced at 3 to 5 m apart are present.

The soil reaction of the soil as indicated by the pH of the soil is medium acid to strongly acid with pH values that varies from 5.70 to 5.20 in the subsoil. The total nitrogen levels in the soil are medium in the topsoil 0.32 % and decreases to low values in the subsoil 0.12 %. The organic carbon levels are very high in the topsoil 3.80 % and decreases to low values in the subsoil 1.20 %. The C/N ratio shown that the quality of organic matter is good. The levels range from 10 to 12.

Low levels of the available phosphorus are very common. Cation exchange capacity of the soils in this plot is dominantly medium in both topsoil and subsoil. The corresponding levels are 23.60 and 15.70 Cmolc/kg. The exchangeable calcium levels found in this unit are medium in the topsoil 7.50 Cmolc/kg and decreases to low values in the subsoil 2.56 Cmolc/kg. The exchangeable magnesium levels are high in the topsoil and becomes medium in the subsoil. The values are 4.20 Cmolc/kg and 2.80 Cmolc/kg respectively. The exchangeable potassium levels are high in the topsoil 1.85 Cmolc/kg while becomes medium in the subsoil 1.20 Cmolc/kg. The exchangeable sodium levels are low with values that varies from 0.15 Cmolc/kg in the topsoil to 0.10 Cmolc/kg in the subsoil.

Vegetation structure include dense forest, mature mixed without dominance. The plot shows no signs of harvesting or logging such that the commonly occurring tree species in the plot are *Lecanidiscus fraxinifolius*, *Enantia kummeriae*, *Trilepsium madagascariense*, *Tabernaemontana ventricosa*, *Leptonychia usambarensis*, *Bequaertiodendron natalense*, *Leptonychia usambarensis*, *Celtis africana*, *Antiaris toxicaria*, *Enantia kummerie*, *Leptonychia usambarensis*, *Rothmania manganjae*, *Drypetes gerrardii*, *Teclea amaniensis*, *Rinorea ferruginea*, *Afrosersalisia cerasifera*, *Cola scheffleri*, *Cola usambarensis*, *Premna chrysoclada*, *Albizia gummifera*, *Celtis mildbraedii* and *Ricinodendron heudelotii*.

4.3.32 Plot 33

The plot covers gentle lower slope with slope gradient that varies from 10 to 15 %. The plot occurs at 640 m above sea level. The soils in the plot are moderately deep with maximum depth of 50 cm beyond which hard rock is encountered, well drained, dark reddish brown and sandy clay to clay in texture. Rock outcrops spaced at 10 to 15 m apart are present.

The soil reaction of the soil as indicated by the pH of the soil is medium acid to strongly acid with pH values that varies from 6.00 in the topsoil to 5.3 in the subsoil. Total nitrogen levels are medium in the topsoil 0.46 % and becomes low in the subsoil 0.20 %. The organic carbon levels in the soil are very high in the topsoil 4.60 % and becomes medium in the subsoil 2.10 %. The C/N ratio indicated that the quality of organic matter is good. The levels range from 10 to 11 in topsoil and subsoil respectively.

Medium levels of the CEC are found in the topsoil which decreases to low levels in the subsoil. The corresponding values are 16.80 and 10.40 Cmolc/kg. The available phosphorus levels in the soil are generally low with values less than 7 mgP/kg. The exchangeable calcium levels are medium in the topsoil 6.40 Cmolc/kg and becomes low in the subsoil. The exchangeable magnesium levels are high in the topsoil and becomes low in the subsoil with values 3.70 and 2.10 Cmolc/kg respectively. Potassium levels in this unit is found to be high in the topsoil 1.40 Cmolc/kg and decreases to low values in the subsoil 0.60 Cmolc/kg. The exchangeable sodium levels are generally very low with values less than 0.10 Cmolc/kg.

The plot is characterised by the presence of open forest at the forest edge or colonising. Tree species which are dominating the plot include *Tabernaemontana pachysiphon*, *Leptonychia usambarensis*, *Funtumia africana*, *Ricinodendron heudelotii*, *Leptonychia usambarensis*, *Quassia undulata* (*syn. odyndea zimmermanii*), *Lanea welwestchii*, *Artocarpus heterophyllus* (Jackfruit), *CreMASpora triflora*, *Funtumia africana*, *Leptonychia usambarensis*, *Cola scheffleri*, *Uvariadendron sp.*, *Ficus vallis choudae*, *Isobertia scheffleri* and *Myrianthus holstii*.

REFERENCES

FAO, 1977. Guidelines for soil profile description. FAO, Rome, Italy.

Geological Survey Division. 1965. Geological survey of Tanzania. Quarter degree sheet 91 and 110, Daluni. Geological Survey Division. Dodoma, Tanzania.

Hyytiäinen, K. 1995. Land use classification and mapping for the East Usambara mountains. East Usambara Catchment Forest Project. Technical paper No. 12.

Ikerra, S.T; D.N. Kimaro; V.Y. Mahava and A. S. Msangi. 1994. Soil fertility status of Lugongo sisal estate (Maramba in Muheza District, Tanga, Tanzania).

Kimaro D.N. and A.E. Kiwelu. 1994. Sustainable land use for out growers tea cultivation in the East Usambara tea growing areas (Muheza district, Tanzania).

Mbogoni J.D.J. 1989. Towards Sustainable land use in the East Usambara Mountains. Site Evaluation report S12. National Soil Service. Agricultural Research Institute, Mlingano, Tanga, Tanzania.

Munsell Colour Charts Inc; 1973, Munsell Colour Charts.

ANNEX 1: GUIDE TO SOIL FERTILITY EVALUATION

Organic matter and total nitrogen

	very low	low	medium	high	very high
Organic matter %	<1.0	1.00-2.0	2.10-4.20	4.30-6.0	>6.0
Organic C %	<0.60	0.60-1.25	1.26-2.50	2.51-3.50	>3.50
Total N %	<0.10	0.10-0.20	0.21-0.50	>0.50	

C/N ratios give more information about the availability of nitrogen than total N levels only. C/N ratios indicate the quality of the organic matter:

C/N 8-13: good quality

C/N 14-20: moderate quality

C/N >20 : poor quality

Soil reaction

Soil reaction (pH H₂O) is classified as follows:

Reaction	pH
extremely acid	below 4.5
very strongly acid	4.5 to 5.0
strongly acid	5.1 to 5.5
medium acid	5.6 to 6.0
slightly acid	6.1 to 6.5
neutral	6.6 to 7.3
mildly alkaline	7.4 to 7.8
moderately alkaline	7.9 to 8.4
strongly alkaline	8.5 to 9.0
very strongly alkaline	above 9.0

Available phosphorus

	low	medium	high
Avail. P (Kurtz-Bray I) mg/kg Avail.	<7	7-20	>20
P (Olsen) mg/kg	<5	5-10	>10

Available phosphorus is determined by the Kurtz-Bray I method if the pH H₂O of the soil is less than 7.0. In soils with a pH H₂O of more than 7.0 the Olsen method is used.

Exchangeable calcium

	very low	low	medium	high	very high
Ca (clayey soils rich in 2:1 clays) Cmolc/kg	<2.0	2.0-5.0	5.1-10.0	10.1-20.0	>20.0
Ca (loamy soils) Cmolc/kg	<0.5	0.5-2.0	2.1-4.0	4.1- 6.0	> 6.0
Ca (kaolinitic and sandy soils) Cmolc/kg	<0.2	0.2-0.5	0.6-2.5	2.6- 5.0	> 5.0

Exchangeable magnesium

	very low	low	medium	high	very high
Mg (clayey soils) Cmolc/kg	<0-3	0.3-1.0	1.1-3.0	3.1-6.0	>6.0
Mg (sandy soils) Cmolc/kg	<0.2	0.2-0.5	0.5-1.0	1.1-2.0	>2.0

For loamy soils a classification has to be used with figures in between the two sets presented for clayey and sandy soils.

The desired saturation level of exchangeable Mg is 10 to 15 percent; for sandy and kaolinitic soils 6 to 8 percent Mg saturation is still sufficient.

Ca/Mg ratios of 2 to 4 are favourable.

Exchangeable potassium

	very low	low	medium	high	very high
K (clayey soils) Cmolc/kg	<0.20	0.20-0.40	0.41-1.20	1.21-2.00	>2.00
K (loamy soils) Cmolc/kg	<0.13	0.13-0.25	0.26-0.80	0.81-1.35	>1.35
K (sandy soils) Cmolc/kg	<0.05	0.05-1.10	0.11-0.40	0.41-0.70	>0.70

The desired saturation level of exchangeable K is 2 to 7 percent.

Favourable Mg/K ratios for most crops are in the range of 1 to 4.

Exchangeable sodium

	very low	low	medium	high	very high
Na (Cmolc/kg)	<0.10	0.10-0.30	0.31-0.70	0.71-2.00	>2.00

ANNEX 2. GUIDE TO SOIL DEPTH CLASSIFICATION

Very shallow	: <20 cm
Shallow	: 20-40 cm
Moderately deep	: 40-80 cm
Deep	: 80-120 cm
Very deep	: >120cm

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17. Kamugisha, S.M. & Materu, E.M.A. 1995. Preliminary results from a study on water flow and in Sigi and Bombo rivers in the East Usambara mountains.
18. Ellman, A., Tye, A., Rwamugira, S., Mallya, B., Mahenge, F. and Mndolwa, A. 1995. Development of forest trails and drive routes in the Amani Nature Reserve.
19. Ellman, A.E. 1996. Handing over the stick? Report of a village forest management and farm forestry consultancy
20. Katigula, M.I.L., Mmasi, S.E., Matiko, W., Mshana, L., Kijazi, M.S., Rwamugira, S. 1995. Planning ourselves. Evaluation report on the participatory planning of the EUCFP Phase II project document.
21. Fowler, S. & Nyambo, B. 1996. Invasive species and biodiversity - Report of a short consultancy on the potential of biological control of invasive species in Amani Nature Reserve. International Institute for Biological Control & EUCFP.
22. Howard, P.C. 1996. Baseline biological surveys in selected East Usambara forest reserves and forests, 1995-96 - project evaluation report
23. Woodcock, K. 1995. Indigenous knowledge and forest use: two case studies from the East Usambaras, Tanzania.
24. Shaka, J.M. & A. Msangi. 1996. Soils and vegetation of Bamba Ridge Forest Reserve, Maramba Division, Muheza District, Tanga.

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