TECHNICAL PAPER 26

SOILS AND VEGETATION OF KAMBAI FOREST RESERVE BOMBWERA DIVISION, MUHEZA DISTRICT, TANGA.

Shaka J.M., W. Kabushemera and A. Msangi

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

1996

Detailed Soil Survey Report, 1996

SOILS AND VEGETATION OF KAMBAI FOREST RESERVE, BOMBWERA DIVISION, MUHEZA DISTRICT, TANGA.

Shaka J.M., W. Kabushemera and A. Msangi.

Ministry of agriculture
National Soil Service
Agricultural Research Institute - Mlingano
Tanga

Ministry of Natural Resources and Tourism, Tanzania
Forestry and Beekeeping Division

Department of International Development Co-operation, Finland
Finnish Forest and Park Service

Tanga 1997

EAST USAMBARA CATCHMENT FOREST PROJECT

For more information:

Forestry and Beekeeping Division
P.O. Box 426, Dar es Salaam, Tanzania
Tel: 255-51-111 061/2/3/4
Fax: 255-51-114 659
TLX 41853 misitu tz
E-mail: misitu@twiga.com

East Usambara Catchment Forest Project
P.O. Box 5869, Tanga, Tanzania
Tel: 255-53-43453, 46907, 43820
Fax: 255-53-43820
E-mail: usambara@twiga.com

Department for Development Co-operation
Ministry for Foreign Affairs
Katajanokanlaituri 3
FIN-00160 Helsinki, Finland
Tel 358-9-134 161
Fax 358-9-1341 6293

Finnish Forest and Park Service
P.O. Box 94, FIN-01301 Vantaa, Finland
Tel: 358-9-857 841
Fax: 358-9-8578 4401
E-mail: knowhow@metsa.fi

Cover painting: Jaffary Aussi (1995)

ISSN 1236-620X
ISBN 952-446-006-8

SUMMARY

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

The study area covering an area of about 1050 ha is located in Bombwera division, Muheza District. The climate within the area is characterised by bi-modal rainfall pattern with long and short rain seasons from March to May and October to December respectively.

Kambai Forest Reserve is divided into three major physiographic units summit and upper slope, mid-slope and lower slopes. Slope gradient of the study area dominantly ranges from 10 to 45 % at an elevation that varies from between 600 to 200 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, well drained, clay loam to clay, dark reddish brown to dark red or red. The soils in the area are dominantly characterised by the presence of rock outcrops such that some plots are even rocky. They have variable soil reaction that vary from slightly acid to strongly or very strongly acid. The soils in the study area have very high to high levels of the organic carbon and total nitrogen that decreases with the soil depth. 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 is generally high. Potassium levels are medium to low or very low. Cation exchange capacity (CEC) is generally medium especially in the topsoil and decreases with soil depth..

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, Malkhamia lutea Cussonia zimmermanii*, *Pandanus rabaiensis Julbernadia magnistipulata, Combretum shumannii, Diospyros kabuyeana, Diospyros natalensis, Vincentella passargei, Fernandoa magnifica, Antiaris toxicaria, Dombeya shupangae, Stereospermum kuthianum, Ricinodendron haudelotii, 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 Kambai Forest Reserve (1050 ha) located at Bombwera 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.

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 in April 1996 by NSS Soil Surveyors. Soil samples collected during fieldwork were analyzed by the NSS Central Laboratory. Vegetation classification is based on vegetation survey conducted by a botanist from Amani botanical garden.

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 Kambai Forest Reserve. Table 1 presents a summary of the rainfall data from Mlingano Agricultural Research Institute which is the nearest climatic recording station.

Table 1. Mean monthly rainfall (mm) and mean monthly temperatures (°C) at Mlingano Agricultural Research Institute (1950 -1979)

Months	Mean monthly rainfall (mm)	Mean min. temp. (°C)	Mean max. temp. (°C)
Jan	60.4	21.6	32.5
Feb	32.0	21.7	33.1
Mar	98.8	21.9	33.0
Apr	192.5	21.9	30.6
may	179.0	21.7	29.2
Jun	51.1	19.5	28.2
Jul	46.5	18.6	27.6
Aug	50.7	18.4	28.1
Sep	70.3	18.8	28.6
Oct	122.6	19.7	29.8
Nov	143.4	20.7	30.7
Dec	92.7	21.6	32.1

The rainfall pattern within 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 also 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^{o}C and the warmest one is February with mean maximum temperatures of 33.1^{o}C.

2.2 Landform and Geology

Kambai Forest Reserve can be divided into three major physiographic units which include summit and upper slopes, mid-slopes and lower slopes. The study area is situated at an elevation ranging from 600 to 2000 m above sea level. Slope gradient is variable. It dominantly ranges from 10 % to 45 %.

The East Usambara in general and Kambai forest reserve in particular is characterised by Metamorphic rocks of the Usagaran system (Precambrian 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 Kambai 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.

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 or the area has been formerly under cultivation.

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 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 51 auger hole observations 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 soil 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. Forests were 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 National Soil Service (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.

4. SOILS AND VEGETATION

4.1 General soils condition.

The soils in the study area are generally shallow or very shallow to deep, dominantly well drained and clay loam to clay, dark reddish brown to dark red or in places red. The soils in most plots within the study area are characterised by the presence of the rock outcrops. In some plots these rock outcrops occupies greater part of the area such that even sampling becomes difficulty. Slope gradient for most of the plot is variable. It varies from dominantly 10 % to 45 %. Most of the plots occur at altitude that varies from 600 to 2000 m.a.s.l.

Soil chemical characteristics of the soils in the study area indicates that the soils reaction ranges from are slightly acid in the topsoil to medium or strongly acid in the subsoil. Organic carbon in the plots are dominantly very high in the topsoil and decreases to low or very low levels in the subsoil. Total nitrogen are also high in the topsoil and decreases to low levels in the subsoil.

Available phosphorus in all plots is low while exchangeable bases vary from very high 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 medium especially in the topsoil and

dominantly becomes low in the subsoil. Cation exchange capacity in this case generally decrease with increase is soil depth. Such low levels of the cation exchange capacity within the subsoil is due to the fact that organic matter which to large extent determine the ability of the soils to release and or retain nutrient decreases with increase in soil depth. The level of exchangeable calcium is dominantly very high to high. It seems that the parent material from which the soils are formed is rich in calcium while poor in phosphorus. Magnesium levels are as well high while exchangeable sodium very low.

4.2 General vegetation conditions

The type of vegetation in the area is dominantly dense or open forest and mature mixed without dominance. In some plots dominance is common. In plots where disturbances due to human influence has been too high the forests are characteristically open or slightly dense. Such disturbances include former encroachment for cultivation or cutting poles as building materials 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, Julbernadia magnistipulata, Combretum schumannii, Diospyros kabuyeana, Diospyros natalensis, Diospyros mespiliformis, Vincentella passargei, Fernandoa magnifica, Dombeya shupangae, Stereospermum kunthianum, Ricinodendron heudelotii, Xylopia parviflora, Millicia excelsa, Cynometra fischeri, Cynometra webberi, Dialium holtsii, Markhamia lutea, Bombax rhodognaphalon, Dorstenia kumeruniana, Newtonia pancijuga, Lonchocarpus bussei, Albizia glaberrima, Antiaris toxicaria*.

Table 2. Analytical data for Kambai.

PLOT NO.	PARTICLE SIZE ANALYSIS				pH		ORG.	TOTAL	C/N	AVAILABLE P	CEC	EXCHANGEABLE BASES		
/DEPTH	<2	2-20	20-50	50-2000	1:2.5		C	N		BRAY I		Ca	Mg	K Na
					H20	KCl	------%------			mg/kg	----------Cmolc/kg----------			
1a	40	15	8	37	6.50	6.00	7.50	0.68	11	4.10	18.50	7.80	4.80	0.60 0.04
1b	45	10	8	47	6.00	5.50	1.80	0.16	10	3.50	15.60	7.50	4.50	0.58 0.05
2a	38	8	10	44	5.80	5.50	5.20	0.52	10	3.80	14.50	5.60	3.20	0.56 0.06
3a	42	9	10	39	5.60	5.00	5.50	0.61	9	2.50	15.30	5.00	3.00	0.50 0.06
4a	35	14	10	51	5.30	4.80	5.00	0.55	9	3.00	13.00	4.80	3.50	0.45 0.05
5a	52	18	12	18	6.10	5.70	5.80	0.52	11	3.20	15.80	5.80	4.00	0.58 0.06
6a	46	11	13	30	6.70	6.00	7.00	0.63	11	4.80	20.50	6.50	3.60	0.65 0.06
6b	50	12	6	32	6.10	5.20	1.20	0.10	11	1.30	9.60	6.10	2.30	0.40 0.05
7a	36	13	6	45	6.00	5.80	5.10	0.50	12	3.60	16.00	5.50	3.20	0.55 0.04
8a	48	10	9	33	6.50	6.00	5.40	0.42	10	5.20	17.30	5.40	4.50	0.70 0.06
8b	45	9	7	39	5.80	4.80	1.00	0.15	10	1.60	8.10	4.80	2.70	0.35 0.06
9a	40	12	7	41	5.80	5.60	5.50	0.54	10	3.80	12.00	3.10	2.90	0.60 0.07
9b	38	11	9	42	5.10	5.00	0.80	0.08	9	1.50	10.50	1.40	2.20	0.24 0.05
10a	40	10	9	41	6.20	5.60	6.00	0.51	11	3.60	16.50	6.50	3.20	0.65 0.05
11a	48	13	5	34	5.50	5.10	5.50	0.55	10	2.50	15.30	6.10	3.00	0.45 0.06
11b	46	17	11	26	5.00	4.20	0.60	0.14	10	2.00	11.20	3.80	1.20	0.40 0.06
12a	31	12	10	47	5.60	5.20	6.50	0.54	12	2.80	14.10	6.70	3.60	0.56 0.06
12b	40	13	10	37	5.00	4.00	1.80	0.15	12	2.40	9.20	5.00	2.40	0.30 0.06
13a	42	6	5	47	5.80	5.10	6.00	0.60	10	5.60	15.10	5.60	3.10	0.60 0.03
14a	40	10	8	42	5.00	4.60	6.10	0.61	10	4.50	14.00	5.20	3.50	0.50 0.04
14b	50	20	6	34	4.80	4.50	1.30	0.13	12	4.00	10.60	3.60	2.50	0.30 0.04
15a	38	15	10	37	5.80	5.50	5.00	0.38	13	5.80	11.50	6.00	3.80	0.55 0.05

15b	60	7	4	29	5.40	5.00	0.80	0.05	14	5.60	8.40	5.20	3.20	0.40
0.05														
16a	45	11	5	39	6.00	5.80	4.60	0.41	11	6.00	16.50	4.00	4.40	0.65
0.03														
17a	45	10	6	39	6.50	6.00	3.20	0.32	10	6.20	10.10	3.50	3.10	0.60
0.03														
17b	55	8	3	34	6.00	5.00	1.50	0.18	8	6.00	9.70	3.00	2.50	0.55
0.03														
18a	40	13	4	43	7.00	6.50	5.00	0.55	9	5.60	16.00	6.80	4.20	0.61
0.04														
18b	50	10	6	34	6.80	6.00	1.30	1.13	10	5.00	10.10	4.50	4.00	0.50
0.06														
19a	42	18	4	36	6.50	5.80	5.80	0.58	10	5.60	14.60	6.00	2.50	0.48
0.06														
19b	58	15	4	23	6.00	5.00	0.60	0.05	12	3.50	10.80	4.60	2.00	0.50
0.06														
20a	48	8	3	41	6.60	6.00	6.00	0.54	11	6.50	15.00	4.20	4.80	0.60
0.05														
20b	60	16	4	20	6.20	5.50	1.20	0.09	13	4.00	11.80	3.80	3.50	0.51
0.04														
21a	50	18	5	27	5.30	5.00	4.10	0.34	12	3.80	13.50	3.70	2.50	0.45
0.04														
21b	55	6	6	33	4.80	4.50	1.60	0.08	12	3.00	10.60	3.00	2.30	0.40
0.03														
22a	51	10	5	34	5.00	4.00	3.00	0.21	14	3.60	14.90	3.60	3.20	0.48
0.04														
23a	50	5	5	40	5.10	3.80	4.20	0.30	14	3.20	10.60	3.20	2.60	0.42
0.05														
24a	50	8	4	38	5.60	5.60	5.60	0.45	12	6.50	14.90	9.00	4.50	0.80
0.02														
24b	55	6	3	36	5.00	4.80	1.00	0.08	12	6.00	7.80	8.40	3.60	0.40
0.02														
25a	40	10	4	56	4.50	4.00	4.00	0.30	13	5.10	12.60	4.60	3.00	0.60
0.04														
26a	38	15	5	42	4.80	4.60	5.00	0.50	10	3.10	12.00	4.00	3.50	0.65
0.03														

PLOT NO.	PARTICLE SIZE ANALYSIS				pH		ORG.	TOTAL	C/N	AVAILABLE P	CEC	EXCHANGEABLE BASES		
/DEPTH	<2	2-20	20-50	50-2000	1:2.5		C	N		BRAY I		Ca	Mg	K
Na					H20	KCl	------%------			mg/kg	----------Cmolc/kg----------			

28a	35	10	6	49	5.10	5.00	4.80	0.43	10	4.40	13.00	5.20	4.60	0.48
0.03														
29a	40	4	5	51	5.60	5.40	4.60	0.51	9	5.80	15.50	5.00	3.80	0.70
0.03														
29b	45	8	5	42	5.40	5.50	0.60	0.07	8	5.50	9.10	4.00	2.50	0.65
0.03														
30a	39	10	4	47	4.70	3.80	4.20	0.38	11	3.30	12.50	3.60	3.00	0.60
0.04														

30b	42	10	5	43	3.30	2.50	0.80	0.05	14	2.10	10.20	2.40	2.00	0.40
0.04														
31a	40	9	5	46	4.50	4.00	4.40	0.44	10	3.00	13.50	4.80	4.00	0.35
0.04														
32a	40	6	4	50	4.60	3.70	4.30	0.43	10	2.80	13.00	4.00	3.80	0.50
0.05														
33a	45	5	3	47	5.00	4.20	5.40	0.49	11	3.20	14.00	3.50	3.10	0.60
0.05														
34a	46	6	2	46	6.20	5.10	5.00	0.33	15	4.60	16.80	5.50	4.40	0.60
0.04														
34b	48	5	4	43	5.80	5.50	1.20	0.12	10	4.00	6.70	4.20	3.80	0.40
0.03														
35a	50	10	5	35	4.80	4.40	4.20	0.30	13	4.80	14.60	2.80	3.00	0.50
0.04														
35b	40	8	5	47	4.50	4.30	1.50	0.12	12	4.50	11.30	2.30	2.80	0.40
0.03														
36a	45	5	4	46	4.10	4.00	3.00	0.37	8	3.90	11.50	3.50	2.60	0.45
0.03														
37a	50	4	5	41	6.10	5.60	4.00	0.44	9	3.50	18.40	5.10	4.30	0.65
0.04														
37b	55	5	5	35	5.20	4.80	0.50	0.10	10	3.00	6.10	4.00	3.30	0.51
0.04														
38a	40	25	4	31	6.00	5.00	5.50	0.45	12	5.00	15.00	4.80	4.50	0.60
0.04														
38b	45	28	5	32	5.20	4.00	1.20	0.12	10	4.50	8.60	2.30	4.10	0.35
0.04														
39a	50	18	5	27	6.40	5.60	6.80	0.61	11	6.00	12.00	13.00	3.80	0.70
0.05														
39b	55	22	4	19	5.00	3.80	0.90	0.08	11	3.10	11.00	11.00	3.20	0.50
0.04														
40a	46	28	6	20	4.50	4.00	6.50	0.71	10	4.00	14.50	15.00	3.60	0.65
0.05														
41a	48	15	5	32	6.50	6.10	6.00	0.52	10	5.50	18.00	12.00	4.20	0.60
0.05														
41b	50	14	3	33	5.40	5.20	0.80	0.10	9	5.00	7.30	10.40	4.00	0.25
0.05														
42a	58	12	4	36	6.20	4.90	7.00	0.87	8	3.80	13.50	11.00	3.60	0.35
0.03														
42b	60	15	4	21	5.30	3.60	0.90	0.09	10	2.15	10.00	10.50	3.20	0.21
0.04														
43a	50	20	5	25	5.50	5.00	6.00	0.54	11	4.00	16.00	12.00	3.40	0.50
0.05														
44a	50	16	5	29	6.30	4.40	5.10	0.41	12	3.50	12.40	13.50	3.00	0.40
0.04														
45a	55	12	5	28	5.60	5.20	4.40	0.40	10	3.10	14.50	8.60	3.10	0.60
0.05														
46a	58	10	3	29	6.60	6.00	4.80	0.60	8	4.50	17.50	9.50	4.10	0.65
0.05														
46b	66	5	3	26	6.00	5.70	1.00	0.07	13	2.70	8.80	7.30	2.80	0.41
0.05														
47a	68	9	2	21	5.80	5.10	5.80	0.58	10	3.60	15.00	10.00	3.80	0.55
0.03														

47b	70	8	4	18	5.60	4.00	1.30	0.09	14	2.50	9.20	6.20	3.20	0.40
0.03														
48a	48	12	5	35	5.90	5.20	4.60	0.30	15	4.15	20.50	8.50	3.10	0.55
0.02														
48b	50	18	6	26	5.40	5.10	0.80	0.06	12	3.30	6.40	6.60	2.80	0.37
0.04														
49a	50	16	4	30	6.10	4.80	4.60	0.41	11	3.80	15.90	11.50	3.50	0.44
0.05														
49b	55	15	4	26	5.70	4.50	0.70	0.07	10	1.70	8.20	5.00	2.30	0.21
0.04														
50a	55	5	7	33	5.85	4.20	3.80	0.38	10	6.60	15.50	9.80	3.20	0.65
0.04														
51a	60	8	12	20	6.40	4.60	4.20	0.42	11	6.20	16.20	6.10	3.80	0.60
0.05														
51b	65	10	8	17	6.15	3.80	0.60	0.05	11	2.80	7.10	2.40	2.10	0.50
0.05														

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

4.3 Plot description

4.3.1 Plot 1

The plot is located at the lower part of the slope, near Miembeni river and has a slope gradient that varies from 20 to 30 % at an altitude of approximately 800 m above sea level. The soil are well drained, deep to very deep with effective rooting depth greater than 100 cm, dark reddish brown and clay in texture. The plot is characterised by the presence of a very few rock outcrops that are in most cases found in clusters.

The soils in the area are slightly acid (pH 6.5) in the topsoil and increases to medium acid (pH 6.0) in the subsoil. Organic carbon in this plot is very high in the topsoil and decreases significantly to medium or low levels in the subsoil. The values range from
7.5 % to 1.8 % respectively. Total nitrogen on the other hand is high (0.68 %) in the topsoil and decreases to low (0.16 %) levels in the subsoil. The C/N ratio which indicate the level of mineralisation or immobilisation and hence the quality of the organic matter is of good quality with values that ranges from 11 to 10 in the topsoil and subsoil respectively. This indicate the possibility of net mineralisation.

Available phosphorus is low with values ranging from 4.10 mgP/kg in the topsoil to 3.50 mgP/kg in the subsoil.

Cation exchange capacity is medium both in topsoil and subsoil with levels that varies from 18.50 Cmolc/kg to 15.60 Cmolc/kg respectively. The exchangeable calcium is very high both in topsoil and subsoil. The levels varies from 7.80 Cmolc/kg in the topsoil and slightly decreases to 7.50 Cmolc/kg in the subsoil. The magnesium levels is generally high both in topsoil and subsoil. The levels are 4.80 Cmolc/kg in the topsoil to 4.50 Cmolc/kg in the subsoil respectively. Potassium levels in this plot is medium both in topsoil and subsoil with levels that ranges from 0.60 Cmolc/kg to 0.58 Cmolc/kg in the subsoil. The level of exchangeable sodium in the plot is generally very low.

As regard to the vegetation the plot has forest that are dense and mature mixed without dominance. Riverine forest with undergrowth is inclusive in the plot. Dominant tree species include C*eltis africana, Anglocalyx braunii, Trilepsium madagascariensis, Antiaris toxicaria, Fernandoa magnifica, synsepalum msolo, Dialium holtzii, Barringtonia racemosa, Rothmannia mangajae, Sorindeia madagascariensis, Lettowianthus stellatus, Funtumia africana, Pouteria alnifolia, Erythrophleum suaveolens, Suregada zanzibariensis, Chrysophyllum sp. and Ficus exasperata.*

4.3.2 Plot 2

The plot is found at the middle part of the slope with a slope gradient of 50 % at an altitude of 1200 m approximately above sea level. The soils are shallow or even very shallow with effective rooting depth which is less or equal to 30 cm, well drained, dark reddish brown and clay in texture. Rock outcrops are seen on the surface and constitute about 30 - 40 % of the top surface area.

Chemical characteristics of the soils is that the soils in this plot are generally medium acid. The pH levels in this plot is 5.60 and decreases with increase in soil depth thereby becoming

more acidic. The organic carbon is generally very high with levels around 5.20 %. Total nitrogen is high (0.52 %). Based on the C/N ratios the organic matter content are of good quality. It implies that net mineralisation is possible within the plot.
Available phosphorus is low (3.80 mgP/kg). Cation exchange capacity the parameter which indicate the capacity of the soils to retain and supply nutrients for plant uptake is medium. The level is 14.50 Cmolc/kg which decreases with soil depth. Low levels of the cation exchange capacity is most likely in the subsoil due to low levels of the organic matter.
The exchangeable calcium is high or very high with levels that are above
5.60 Cmolc/kg. The magnesium levels is generally medium (3.20 Cmolc/kg). Potassium is medium (0.56 Cmolc/kg) and the exchangeable sodium is very low with values dominantly less than 0.1 Cmolc/kg.

The plot has dense forest, with mature mixed and undergrowth spp. Dominant trees species include *Julbernadia magnistipulata, Craibia revicaudata, Scorodophleus fischeri, Lecaniodiscus fraxinifolius, Drypetes gerrardii, Albizia zimmermannii, Euphorbia candelabrum, Markhamia lutea, Pandanus stuhlmanii, Cola usambarensis and Milletia oblata.*

4.3.3 Plot 3

This plot occurs on the middle part of the slope with slope gradient of about 40 % at an altitude approximately 1200 m above sea level. The soil are shallow with effective depth less than 30 cm, well drained, dark reddish brown and clay or clay loam in texture. Rock outcrops are common in the plot.

Soil chemical characteristics of the soils in this plot indicate that the soils are medium acid (pH 5.80). The organic carbon varies from very high levels (5.50 %)in the topsoil and significantly decreases with increase in soil depth. In the subsoil organic carbon is of low levels.. Total nitrogen is as well very high (0.61 %) in the topsoil which becomes low or very low in the subsoil. The C/N ratio indicates that the organic matter are good quality.

Available phosphorus is low with values ranging from 2.50 mgP/kg to even less in the the subsoil.

Cation exchange capacity varies from medium level (15.30 Cmolc/kg) and decreases with soil depth. This shows that the cation exchange capacity decreases with decreases in organic matter. The exchangeable calcium is very high (5.00 Cmolc/kg) while magnesium level is high or very high (3.00 Cmolc/ kg). Potassium is medium (0.50 Cmolc/kg). The level of the exchangeable sodium is generally very low.

The plot is characterised by the vegetation types that are dense, with mature mixed without dominance. Dominant trees under this plot include *Diospyros squarrosa, Diospyros mespiliformis, Diospyros natalensis, Dorstonia kameruniana, Antiaris toxicaria, Lecaniodiscus fraxinifolius, Englerophytum natalense, Milicia excelsa, Premna chrysoclada, Rothmannia mangajae, Cola greenwayi, Sorindeia madagascariensis, Vepris nobilis, Dialium holtzii, Pterocarpus tinctorius, Fernandoa magnifica, Albizia glaberrima, Celtis philippensis, Morus mesozygia, Markhamia lutea, Blighia unijugata, Tricalysia myrtifolia, Ochna spp and Placodiscus amaniensis*

4.3.4 Plot 4

The position on which the plot is located is at middle part of the slope with slope gradient of 35 % at an altitude approximately 1400 m above sea level. Rock outcrops are seen and it makes about 90 % of the whole plot area. The soils are very shallow, well drained, dark reddish brown, sandy loam in texture with a lot of litter cover.

The soil reaction which is indicated by the pH of the soil is strongly acid (pH 5.30) and decreases to very strongly acid in the subsoil. The organic carbon is generally very high with levels around 5.00 %. Total nitrogen is also high in the topsoil (0.55 %) which decreases with soil depth to low or very low levels. The C/N ratios indicate that the organic matter within the plot are of good quality.

Available phosphorus is low with values ranging from 3.00 mgP/kg in the topsoil and decreases with soil depth.

Cation exchange capacity varies from medium (13.00 Cmolc/kg) in the topsoil and decreases to low or very low levels in the subsoil. This is due to the fact that cation exchange capacity decreases with decrease in the organic matter content. The exchangeable calcium is medium (4.80 Cmolc/kg) in the topsoil and decreases to low levels in the subsoil. The magnesium levels is generally high. Potassium level is very high. The levels are 0.45 Cmolc/kg. The exchangeable sodium is generally very low.

The forest in this plot is characteristically dense and mature mixed with dominance of *Scorocophleus* and the undergrowth of *Pentus sp, Dorstenia* bushes and *Cycas sp*. Dominant trees species include *Scorodophleus fischeri, Dialium holtzii, Pandanus stuhlmannii, Englerophytum natalense, Lecaniodiscus fraxinifolins, Cleistanthus polystachyus, Blighia unijugata, Erythrina caffra, Commi parsagei, Vincentella parsagei and Lannea welwitschii.*

4.3.5 Plot 5

The plot is located on the middle part of the slope with slope gradient 30 % at an altitude ranging from 1800 - 2400 m a.s.l. Rock outcrops make 30 % of the plot area. The soils are shallow with very thin topsoil, well drained, dark red to red and clay in texture,.

The soil reaction is slightly acid in the topsoil and decreases to medium acid or strong acid in the subsoil. The values are (pH 6.10) in the topsoil. The organic carbon is very high with levels around 5.80 % in the topsoil and decreases to low very low levels in the subsoil. Total nitrogen is very high (0.52 %) in the topsoil the level which decreases with the soil depth. The C/N ratio indicates that the organic matter content in this plot are of good quality.
Available phosphorus is low with values ranging from 3.20 mgP/kg or less in the subsoil.

Cation exchange capacity varies from medium (15.80 Cmolc/kg) in the topsoil. This level decreases with soil depth and hence in the subsoil this parameter is low or very low. The exchangeable calcium is very high (5.80 Cmolc/kg) in the topsoil and decreases to low levels in the subsoil. The magnesium levels is high with values that are around 4.00 Cmolc/kg. Potassium levels is medium (0.58 Cmolc/kg). The exchangeable sodium levels is generally low to very low.

The forest is dense and mature mixed with the dominance of *Millettia sp* and *Englesophytum* with undergrowth spp. The trees under this plot include *Pteleopsis myrtifolia, Milicia excelsa,Synsepalum msolo, Zanha gohungensis, Celtis africana, Englerophytum natalense, Tricalysia myrtifolia, Millettia oblata, Celtis philippensis, Vincetella parsagei and Lecaniodiscus fraxinifolius, Zanthoxylum usambarensis, Scorodophleus fischeri, Markhamia lutea, Millettia stuhlmannii, Termnalia sambesiaca, Bombax rhodognaphalon and Ziziphus mucronata*

4.3.6 Plot 6

The plot is located at the upper part of the slope. Slope gradient varies from 15 to 20 % at an altitude ranging from 1800 - 2400 m a.s.l. Rock outcrops make 30 % of the plot area. The soils in the plot are deep, well drained, dark red, clay loam to clay in texture. Rock outcrops are not the characteristic of the ploy.

Chemical characteristics of the soils is that the soils are neutral (pH 6.70) in the topsoil and decreases to slightly acid (pH 6.10) in the subsol. The organic carbon are generally very high with levels around 7.00 % in the topsoil and decreases to low or very low levels (1.20 %) in the subsoil. The carbon to nitrogen ratio (C/N) indicates that the organic matter are of good quality. This implies net mineralisation of the nutrients.

Available phosphorus is low or very low with values ranging from 4.80 mgP/kg in the topsoil to 1.30 mgP/kg in the subsoil.

Cation exchange capacity varies from medium (20.50 Cmolc/kg) in the topsoil and decreases to low levels (9.60 Cmolc/kg) in the subsoil. Exchangeable calcium is high both in topsoil and subsoil with levels that varies from 6.50 Cmolc/kg to 6.10 Cmolc/kg respectively. The magnesium levels is medium both in the topsoil and subsoil. The levels are 3.60 % in the topsoil and 2.30 % in the subsoil respectively. Potassium is very high both in topsoil and subsoil. The levels are 0.65 and 0.40 Cmolc/kg respectively. The exchangeable sodium is generally very low.

The forest is slightly open with dominance of Vincentella bushes and Millettia species. The natives nearby the area have been cutting poles for hut construction. The vegetation cover include *Millettia oblata, Dialium holtzii, Ricinodendron hendelotii, Englyrophytum natalense, Vincentella passargei, Newtonia pancijuga, Morus mesozygia, Terminalia sambesiaca, Markhamia lutea, Lecaniodiscus fraxinifolius, Suregada zanzibarensis, Mystroxylon aethiopicum, Millettia stuhlmannii, Vepris nobilis and Albizia schimperiana.*

4.3.7 Plot 7

The plot is located on the middle part of the slope with slope gradient that varies from 40 to 45 % at an altitude approximately 1600 m a.s.l. The soils are shallow with effective rooting depth of 30 cm, well drained, reddish brown, clay loam to clay. The soils in the plot are characterised by the presence of rock outcrops.

The reaction of the soils in this plot indicates that the soils are medium acid with levels that are around pH 6.00. The organic carbon are generally very high with levels around 5.10 % in

the topsoil and decreases to low or very low levels in the subsoil. Total nitrogen is high (0.50 %) which decrease significantly to low levels in the subsoil. The C/N ratios show that the organic matter content are of good quality.

Available phosphorus is low or very low with values that are around 3.60 mgP/kg in the topsoil or less in the subsoil.

Cation exchange capacity varies from medium (16.00 Cmolc/kg) in the topsoil and decrease to low levels in the subsoil. The exchangeable calcium is very high (5.50 Cmolc/kg) and decreases to low levels in the subsoil. The magnesium levels is high (3.20 %) and may decreases to medium or low levels in the topsoil and subsoil respectively. Potassium is very high 0.70 %. The exchangeable sodium is generally very low with levels that are less than 0.1 Cmolc/kg.

The forest in the plot is dense mature mixed without dominance. Also undergrowth species of *Millettia (climbers), Mildbraedia* and shrubs of *bracaena and Asparagus* specie are inclusive. Tree species include *Lecaniodiscus fraxinifolius, Milletia oblata, Millettia stuhlmannii, Vepris simplicifolia, Scorodophleus fischeri, Gyrocarpus americanus, Euphorbia candelabrum, Markhamia lutea, Cola usambarensis, Dialium holtzii, Albizia Zimmermannii and Manilkara sulcata.*

4.3.8 Plot 8

The plot occupies lower part of the slope with slope gradient that varies from 20 to 25 % at an altitude approximately 800 m a.s.l. The soils are deep with effective rooting depth greater than 80 cm, well drained, dark reddish brown and clay in texture. Localised rock outcrops are common within the plot.

Soil chemical characteristics of the soils varies from slightly acid (pH 6.50) in the topsoil to medium acid (pH 5.80) in the subsoil. Organic carbon is very high with levels around 5.40 % in the topsoil and decreases to low or very low (1.00 %) levels in the subsoil. Total nitrogen varies from medium level in the topsoil to low levels in the subsoil with values that ranges from 0.42 % to 0.15 % respectively. Organic matter content are of good quality. This is indicated by the C/N ratio.

Available phosphorus is low with values ranging from 5.20 mgP/kg in the topsoil to 1.60 mgP/kg in the subsoil.

Cation exchange capacity varies from medium (17.30 Cmolc/kg) in the topsoil to low levels (8.10 Cmolc/kg) in the subsoil. Exchangeable calcium is high both in the topsoil and subsoil. The levels varies from 5.40 Cmolc/kg in the topsoil and decreases to low levels 4.80 Cmolc/kg in the subsoil. The magnesium levels is high (4.50 Cmolc/kg) in the topsoil and decreases to medium levels (2.70 Cmolc/kg) in the subsoil. Potassium is medium (0.70 Cmolc/kg) in the topsoil and (0.35 Cmolc/kg) in the subsoil. The levels of the exchangeable sodium is low.

Under this plot the forest is dense mixed without dominance. Tree species that dominate the plot include *Markhamia lutea, Antiaris toxicaria, Albizia glabernina, Ptereocarpus mildbraedii, Lanea welwitschii, Grewia holstii, Newtonia pancijuga, Diospyros natalensis,*

*Ficus vallis-choudae, Ricinodendron heudelotii, Scorodophleus fischeri, Bombax rhodognaphalon, Pandanus stuhlmannii, Terminalia sambesiaca, Lecaniodiscus fraxinifolius, Euphorbia candelabrum, Erythrina caffra and Cussonia zimmermauni*i,

4.3.9 Plot 9

The plot occupies mid slope with slope gradient that is around 20 % at an altitude approximately 950 m a.s.l. Rock outcrops are localized. They are found in places. The soils in the plot are deep with effective rooting depth greater than 85 cm, well drained, dark red or dark reddish brown, clay loam to clay with localised rock outcrops.

The soil reaction varies from medium acid (pH 5.80) in the topsoil to strongly acid (pH 5.10) in the subsoil. Organic carbon is very high with levels around 5.50 % in the topsoil and decreases to low or very low (0.80 %) levels in the subsoil. Total nitrogen varies from very high (0.54 %) in the topsoil to low levels (0.08 %) in the subsoil. Based on the C/N ratios the organic matter content are of good quality implying that net mineralisation is possible.

Available phosphorus is low with values ranging from 3.80 mgP/kg in the topsoil to 1.50 mgP/kg in the subsoil.

Cation exchange capacity varies from medium (12.00 Cmolc/kg) in the topsoil to low levels (10.5 Cmolc/kg) in the subsoil. Exchangeable calcium is high (3.10 Cmolc/kg) in the topsoil and decreases to medium levels (1.40 Cmolc/kg) in the subsoil. Magnesium levels is medium both in topsoil and subsoil with values that ranges from 2.90 Cmolc/kg in the topsoil to 2.20 Cmolc/kg in subsoil. Potassium is medium (0.60 Cmolc/kg) in topsoil and decreases to low levels (0.24 Cmolc/kg) in the subsoil. The levels of the exchangeable sodium is generally very low.

The forest is open, mature woodland mixed with Acacia spp. The vegetation under the plot include *Julbernadia magnistipulata, Albizia zimmermannii, Millettia oblata, Monodora minor, Commiphora eminii, Bridelia melanthesoides, Fernandoa magnifica, Dialium holtzii, Afzelia quanzensis, Drypetes usambarica, Diospyros natalensis, Nersogodonia holstii, Bombax rhodognaphalon, Gyrocarpus americanus, Manilkara sulcata, Uvariodendron spp, Millettia stuhlmannii, Galiniera saxifraga and Albizia zimmermanii.*

4.3.10 Plot 10

The plot is located on the lower part of the slope with a slope gradient of 20 % at an altitude of approximately 1000 m a.s.l. The soils are shallow with effective rooting depth of 30 cm or even less, well drained, dark red, clay in texture without rock outcrops.

The soil reaction is slightly acid (pH 6.20) in the topsoil which decreases with soil depth thereby becoming more acidic. Organic carbon is very high with levels around 6.00 %. that decreases to low or very low levels in the subsoil. Total nitrogen is high (0.51 %). This level decreases with soil depth. The organic matter content are of good quality.

Available phosphorus is low with values ranging from 3.60 mgP/kg in the topsoil to even less values in the subsoil.

Cation exchange capacity varies from medium (16.50 Cmolc/kg) in the topsoil and decreases with soil depth. Exchangeable calcium is very high (6.50 Cmolc/kg) in the topsoil and decreases to low levels in the subsoil. Magnesium levels is high (3.20 %) in the topsoil but decreases with soil depth. Potassium is medium (0.65 Cmolc/kg). The levels of the exchangeable sodium is very low.

The forest under this plot is slightly dense, mature mixed without dominance. Trees under this plot include *Margaritaria discoidea, Rothmannia mangajae, Cola clavata, Vincentella pasargie, Synsepalum msolo, Mimusops kummel, Mkima fragrams, Diospyros natalensis, Grewia goetzeana, Milicia excelsa, Dombeya shupangae, Dialium holtizii, Scorodophleus fischeri, Lecaniodiscus fraxinifolius, Markhamia lutea and Obetia pinnatifida.*

4.3.11 Plot 11

The plot is located on the upper part of the slope with slope gradient of 55 % at an altitude of approximately 1400 m a.s.l. The soils are moderately deep with an effective depth 50 cm, well drained, dark reddish brown to dark red, clay loam to clay.

The soil reaction in the plot varies from strongly acid or medium acid in the topsoil (pH 5.50) but becomes dominantly strongly acid (pH 5.0) in the subsoil. Organic carbon is very high with levels around 5.50 % in the topsoil and decreases to low or very low (0.60 %) levels in the subsoil. Total nitrogen on the otherhand is high in the topsoil and decreases to low levels (0.14 %) in the subsoil. The C/N ratios shows that the organic matter are of good quality.

Available phosphorus is low with values ranging from 2.50 mgP/kg in the topsoil to 2.00 mgP/kg in the subsoil.

Cation exchange capacity varies from medium (15.30 Cmolc/kg) in the topsoil to low levels (11.20 Cmolc/kg) in the subsoil. Exchangeable calcium is very high (6.10 Cmolc/kg) in the topsoil and decreases to high levels (3.80 Cmolc/kg) in the subsoil. Magnesium levels is medium both in topsoil and subsoil with values ranging from 3.00 Cmolc/kg in the topsoil to 1.30 Cmolc/kg in the subsoil. Potassium is medium (0.45 Cmolc/kg) in the topsoil which decreases to low levels (0.40 Cmolc/kg) in the subsoil. The level of the exchangeable sodium is very low.

The plot is characterised by the forest that is dense, mature mixed without dominance. Trees include *Millettia oblata, Lecanidiscus fraxinifolius, Drypetes usambarica, Combretum schumannii, Newtonia paucijuga, Markahamia lutea, Albizia zimmermannii, Englerophytum natalense, Celtis africana, Celtis mildbraedii and Dialium holtzii.*

4.3.12 Plot 12

The plot occurs at the upper slope with a slope gradient of about 15 % at an altitude of approximately 850 a.s.l. The soils in the plot are moderately deep, well drained, dark reddish brown, clay in texture without rock outcrops.

The soil reaction which is determined by the pH of the soil indicate that the plot is having medium acid soils (pH 5.60) that becomes dominantly strongly acid (pH 5.00) in the subsoil. Organic carbon is very high with levels around 6.50 % in the topsoil and decreases to

medium levels (1.80 %) in the subsoil. Total nitrogen is high (0.54 %) in the topsoil but decreases to low levels (0.15 %) in the subsoil. The ratio of carbon to nitrogen (C/N) indicates that the organic matter content are of good quality implying net mineralisation.

Available phosphorus is low with values ranging from 2.80 mgP/kg in the topsoil to 2.40 mgP/kg in the subsoil.

Cation exchange capacity varies from medium (14.10 Cmolc/kg) in the topsoil to low levels (9.20 Cmolc/kg) in the subsoil. Exchangeable calcium is dominantly high or very high in both topsoil and subsoil. The values ranges from 6.70 Cmolc/kg in the topsoil 5.00 Cmolc/kg in the subsoil. The level of magnesium is high (3.60 Cmolc/kg) in the topsoil and decreases to medium levels (2.40 Cmolc/kg) in the subsoil. Potassium is medium (0.56 Cmolc/kg) in the topsoil but decreases to low levels (0.30 Cmolc/kg) in subsoil. The levels of the exchangeable sodium is low to very low.

The forest under this plot is slightly dense with undergrowth shrubs spp of *Rinorea, Mildbraedia and Englerophytum Natalense dominant spp being scorodophleus. The vegetation cover of this plot consists of Combretum schumannii, Scorodophleus fischeri, Pteerocarpus tinctorius, Milicia excelsa, Terminalia sambesiaca, Lecaniodiscus fraxinifolius, Englerophytum natalense, Mimusops kummel, Cola greewayi, Millettia oblata, Bombax rhodognaphalon and Ziziphus mucronata.*

4.3.13 Plot 13

The plot is located on the upper part of the slope with slope gradient 60 % at an altitude greater than 2600 m a.s.l. The soils are shallow, well drained, reddish brown, clay in texture. The plot is characterised by the presence rock outcrops.

The soils within the plot are medium acid (pH 5.80) in the topsoil and the soil reaction decreases to strongly acid in the subsoil. Organic carbon is very high with levels around 6.00 % in the topsoil and decreases to low or very low levels in the subsoil. Total nitrogen is high (0.60 %) in the topsoil and decreases to low or very low levels in the subsoil. From the data on the C/N ratios the organic matter content are of good quality.

Available phosphorus is low with values ranging from 5.60 mgP/kg in the topsoil to even less levels in the subsoil.

Cation exchange capacity varies from medium (15.10 Cmolc/kg) in the topsoil but decreases with soil depth. Exchangeable calcium is very high (5.60 Cmolc/kg) in the topsoil and decreases with soil depth. Magnesium levels is high (3.10 Cmolc/kg) which decreases with increase in soil depth. Potassium levels is medium (0.60 Cmolc/kg) the level which decreases with soil depth. The level of the exchangeable sodium is generally very low.

The forest within the plot is slightly dense with undergrowth shrubs spp of *Rinorea, Mildbraedia and Englerophytum Natalense* dominant spp being *scorodophleus*. The vegetation cover of this plot consists of *Combretum schumannii, Scorodophleus fischeri, Pteerocarpus tinctorius, Milicia excelsa, Terminalia sambesiaca, Lecaniodiscus fraxinifolius, Englerophytum natalense, Mimusops kummel, Cola greenwayi, Millettia oblata, Bombax rhodognaphalon and Ziziphus mucronata.*

4.3.14 Plot 14

The plot is located on the middle part of the slope with slope gradient 30 % at an altitude approximately 1800 m a.s.l.. The soils are deep with effective depth greater than 80 cm, well drained, dark reddish brown, clay with very few and localised rock outcrops.

Chemical characteristics of the soils is that the soils are strongly acid or very strongly acid (pH 5.00) in the topsoil. This value slightly decreases to very strongly acid (pH 4.80) in the subsoil. Organic carbon is very high with levels around 6.00 % in the topsoil and decreases to low or very low levels (1.30 %) in the subsoil. Total nitrogen is high (0.61 %) in the topsoil which decreases to low levels in the subsoil. The level in the subsoil is 1.30 %. The C/N ratio of the indicates that the organic matter are of moderate quality.

Available phosphorus is low with values ranging from 4.50 mgP/kg in the topsoil to 4.00 mgP/kg in the subsoil.

Cation exchange capacity varies from medium (14.00 Cmolc/kg) in the topsoil to low levels (10.60 Cmolc/kg) in the subsoil. Exchangeable calcium is very high (5.20 Cmolc/kg) in the topsoil and decreases to high levels (3.60 Cmolc/kg) in the subsoil. Magnesium levels is high (3.60 Cmolc/kg) in the topsoil and decreases to medium levels (2.40 Cmolc/kg) in the subsoil. Potassium is medium (0.50 Cmolc/kg) in the topsoil which becomes low (0.30 Cmlc/kg) in the subsoil. The levels of the exchangeable sodium is very low.

The forest in this plot is open colonized with dominance of *Sapium sp* and other undergrowth spp. Trees include *Celtis gomphophylla, Morrinda asteroscepa, Sapium ellipticum, Trema orientalis, obentia pinnatifida, Synsepalum msolo, Erythrophleum suaneolens and Bombax rhodognaphalon.*

4.3.15 Plot 15

The plot is located on the middle part of the slope with slope gradient that varies from 10 to 15 % at an altitude approximately 1400 m a.s.l. The soils are moderately deep, well drained, dark red, clay loam to clay without rock outcrops.

The soils in the plot are medium acid (pH 5.80) in the topsoil and slightly decreases to strongly acid in the subsoil (pH 5.40). The organic carbon are very high with levels around 5.00 % in the topsoil and decreases to low or very low (0.80 %) levels in the subsoil. Total nitrogen is medium (0.38 %) in the topsoil but decreases to low or very low in the subsoil. The levels in the subsoil is 0.05 %. Based on the C/N ratios the organic matter content are of good quality implying that net mineralisation is possible.

Available phosphorus is low with values ranging from 5.60 mgP/kg in the topsoil to 6.00 mgP/kg in the subsoil.

Cation exchange capacity varies from medium or low (11.50 Cmolc/kg) in the topsoil to low levels (8.40 Cmolc/kg) in the subsoil. Exchangeable calcium is very high both in topsoil and subsoil with values ranging from 6.00 Cmolc/kg in the topsoil to 5.20 Cmolc/kg in the subsoil. The levels of the exchangeable magnesium are dominantly high. The levels ranges from 3.80 Cmolc/kg in the topsoil to 3.20 Cmolc/kg in the subsoil. Potassium is medium

(0.55 Cmolc/kg) in the topsoil thereby becoming low (0.40 Cmolc/kg) in the subsoil. The levels of exchangeable sodium is generally very low.

The plot is characterised by the forest which is dense, mixed without dominance. Trees under this plot include *Milletia oblata, lecaniodiscus fraxirifolius, Englerophytum natalense, Diospyros mespiliformis, Dialium holtzii, Drypetes usambarensis, Cola greenwayi, Terminalia sambesiaca, Pouteria alrifolia, Vincentella passargei, Maytenus acuminata, Markhamia lutea, Oxyanthus speciosus, Cola clavata, Drypetes usambarica*

4.3.16 Plot 16

The plot appears on the lower part of the slope with slope gradient 10 % at an altitude approximately 1000 m a.s.l. The soils area shallow, well drained with rock outcrops.

The soil reaction is medium acid to slightly acid (pH 6.00) in the topsoil and the soil reaction decreases with increase in soil depth. The organic carbon is very high with levels around 4.60 % in the topsoil and decreases with increase soil depth. Total nitrogen is medium (0.41 %). This level becomes low or very low with increase in soil depth. Based on the C/N ratios the organic matter content are of good quality implying that net mineralisation is possible.

The level of the available phosphorus is low with values ranging from 6.00 mgP/kg in the topsoil that decreases with soil depth.

Cation exchange capacity is medium (16.50 Cmolc/kg) in the topsoil. This value decrease with soil depth. The exchangeable calcium is high (4.00 Cmolc/kg) in the topsoil and decreases to medium or low levels in the subsoil. Magnesium levels is high (4.40 Cmolc/kg). This value decrease with soil depth. Potassium is medium (0.65 Cmolc/kg) in the topsoil to low or very low in subsoil. The exchangeable sodium is generally very low.

The forest is dense mixed with dominance. In this plot the trees *include Pandanus stulhmanii, Ficus usambarensis, Sorindeia madagascariensis, Scorodophleus fischeri, Margaritaria discoidea, Celtis philippensis, Barringtonia racemosa, Chrysophyllum spp, Cola usambarensis, Milleltia oblata, Markhamia lutea, Xylopia parviflora and Dorsteria Kameruniana.*

4.3.17 Plot 17

The plot occupies the lower part of the slope with slope gradient 10 % at an altitude approximately 1000 m a.s.l. The soils are deep, well drained, dark reddish brown to dark red, clay with rock outcrops.

The soil reaction varies from slightly acid (pH 6.50) in the topsoil to medium acid (pH 6.00) in the subsoil. Organic carbon is high with levels around 3.20 % in the topsoil and decreases to low or very low (1.50 %) levels in the subsoil. Total nitrogen varies from medium (0.32 %) in the topsoil to low levels (0.18 %) in the subsoil. The C/N ratio indicate that the organic matter content are of good quality.

The levels of the available phosphorus is low with values ranging from 6.20 mgP/kg in the topsoil to 6.00 mgP/kg in the subsoil.

Cation exchange capacity varies from medium (16.00 Cmolc/kg) in the topsoil to low levels (9.70 Cmolc/kg) in the subsoil. The level of exchangeable calcium is dominantly high both in topsoil and subsoil with values ranging from 3.50 Cmolc/kg in the topsoil to 3.00 Cmolc/kg in the subsoil in respectively. The magnesium levels are generally very high (3.10 Cmolc/kg) in the topsoil and decreases to medium levels (2.50 Cmolc/kg) in the subsoil respectively. Potassium levels are dominantly medium both in topsoi and subsoil. The level are 0.60 and 0.55 Cmolc/kg in topsoil and subsoil respectively.

The forest under this plot is dense and riverine with undergrowth species of *Phyllanthus, Sanseviera kirkii, Millettia and impatens. The vegetation under the plot include Markhamia lutea, Scorodophleus fischeri, Vincetella passargei, Englyrophytum natalense, Parkia felicoidea, Pandanus stuhlmannii, Synometra webberi, Millettia Stuhlmannii, Millettia oblata, Ficus scassellattii, Lecaniodiscus fraxinifolius, Terminalia sambesiaca, Diospyro squarrosa and Lannea welwitschii.*

4.3.18 Plot 18

The plot occupies the lower part of the slope with slope gradient that ranges from 10 % to 15 % at an altitude approximately 1000 m a.s.l. The soils are moderately deep, well drained, dark red and clay in texture with rock outcrops.

The pH of the soils in this plot is dominantly neutral (pH 7.00) in the topsoil that slightly decrease to with soil depth. In the subsoil the pH level is 6.80. Organic carbon is generally very high with levels around 5.00 % in the topsoil and decreases to low or very low (1.30 %) levels in the subsoil. Total nitrogen varies from high levels (0.55 %) in the topsoil to low levels (1.13 %) in the subsoil. The C/N ratio indicates that the organic matter are of good quality.

Available phosphorus is low with values that varies from 5.60 mgP/kg in the topsoil to 5.00 mgP/kg in the subsoil.

Cation exchange capacity varies from medium (16.00 Cmolc/kg) in the topsoil to low levels (10.10 Cmolc/kg) in the subsoil. Exchangeable calcium is very high (6.80 Cmolc/kg) in the topsoil and decreases slightly to high level (4.50 Cmolc/kg) in the subsoil. Magnesium levels are generally high both in topsoil and subsoil. The values are 4.20 Cmolc/kg and 4.00 Cmolc/kg in topsoil and subsoil respectively. Potassium is dominantly medium in both topsoil and subsoil with values ranging from 0.61 Cmolc/kg in the topsoil to 0.50 Cmolc/kg in the subsoil. The level exchangeable sodium is generally very low.

The forest under this plot is open and encroached with cultivation and bushes of *Grewia, Acacia* with some grass of *Olyra*. The vegetation under the plot include *Englerophytum natalense, Millettia stuhlmannii, Vincentella parsagei, Ziziphus mucronata, Markhamia lutea, Millettia oblata, Bridelia micrantha, Dracaena steudneri, Celtis zenkeri, Ricinodendron hendelotii, Lecaniodiscus fraxinifolius, Milicia excelsa, Millettia stuhlmannii, Celtis philippensis, Maytenus acuminata, Lttowianthus stellatus, Grewia bicolor, Vepris nobilis, Vepris simplicifolia and Diospyros natalensis*

4.3.19 Plot 19

The plot is located on the lower part of the slope with slope gradient 55 % at an altitude approximately 1800 m a.s.l. The soils are moderately deep with an effective depth of 50 cm, well drained, dark red, clay loam to clay in texture with localised rock outcrop.

The soils are slightly acid (pH 6.5) in the topsoil and the soil reaction decreases and become medium acid (pH 6.0) in the subsoil. Organic carbon is high with levels around 5.80 % in the topsoil and decreases to low or very low (0.60 %) levels in the subsoil. Total nitrogen varies from high (0.58 %) in the topsoil to low or very low levels (0.05 %) in the subsoil. Good quality organic matter are found in the plot.

Exchangeable phosphorus is low with values ranging from 5.60 mgP/kg in the topsoil to 3.50 mgP/kg in the subsoil.

Cation exchange capacity varies from medium (14.60 Cmolc/kg) in the topsoil to low levels (10.80 Cmolc/kg) in the subsoil. The level of exchangeable calcium is very high (6.00 Cmolc/kg) in the topsoil and decreases to high levels (4.60 Cmolc/kg) in the subsoil. Magnesium levels is medium both in topsoil and subsoil with levels ranging from 2.50 Cmolc/kg in the topsoil to 2.00 Cmolc/kg in topsoil and subsoil respectively. Potassium is medium both in topsoil and subsoil with values ranging from 0.48 Cmolc/kg in the topsoil to 0.50 Cmolc/kg in the subsoil. The exchangeable sodium is generally very low.

The forest is dense and mature mixed without dominance. Under this plot trees include *Scorodophleus fischeri, Vincentella parsagei, Cynometra webberi, Zanha golungensis, Pandanus stuhlmannii, Sterculia appendiculata, Dialium holtzii, Millettia oblata, Albizia zimmermannii, Englephytum natalense and Fernandoa magnifica*

4.3.20 Plot 20

The plot is located on the lower part of the slope with slope gradient 20 % at an altitude of approximately 1300 m a.s.l. The soils are moderately deep with effective depth 60 cm, well drained, dark reddish brown, clay in texture with rock outcrops.

Soil chemical characteristics indicates that the plot has soils that are slightly acid or neutral (pH 6.60) in the topsoil and the soil reaction decreases to slightly acid (pH 6.20) in the subsoil. Organic carbon is very high with levels around 6.00 % in the topsoil and decreases to low or very low (1.20 %) levels in the subsoil. Total nitrogen varies from high (0.54 %) in the topsoil to low or very low levels (0.09 %) in the subsoil. Organic matter are of good quality.

Available phosphorus is low with values ranging from 6.50 mgP/kg in the topsoil to 4.00 mgP/kg in the subsoil.

Cation exchange capacity varies from medium (15.00 Cmolc/kg) in the topsoil to low levels (11.80 Cmolc/kg) in the subsoil. The level of the exchangeable calcium is high both in topsoil and subsoil. The level are 4.20 Cmolc/kg in the topsoil and 3.80 Cmolc/kg) in the subsoil respectively. Magnesium levels are generally high. The levels varies from 4.00 Cmolc/kg in the topsoil to 3.50 Cmolc/kg in the subsoil. Potassium levels are both medium in

topsoil and subsoil. The values ranges from 0.60 Cmolc/kg in the topsoil to 0.51 Cmolc/kg in the subsoil. The exchangeable sodium is generally very low.

The area is open forest with low canopy and poorly mixed with climbers spp. Trees under this plot include *Manilkara sulcata, Albizia zimmermannii, Celtis philippensis, Markahamia lutea, Millettia oblata, Millettia stuhlmannii, Lecaniodiscus fraxinifolius, Ehretia cymosa, Vincentella parsagei, Englerophytum natalense, Milicia excelsa and Terminalia sambesiaca.*

4.3.21 Plot 21

The plot is located on the upper part of the slope with slope gradient that varies from 35 to 40 % at an altitude ranging from 1200 to 1300 m a.s.l.
The soils are deep with effective rooting greater than 110 cm, well drained, dark reddish brown, clay with rock outcrops.

The soils in this plot are strongly acid (pH 5.30) in the topsoil and decreases to very strongly acid in the subsoil. The value in the subsoil is pH 4.80. The organic carbon are generally very high with levels that ranges from (4.10 %) in the topsoil and decreases to low or very low (1.60 %) levels in the subsoil. Total nitrogen varies from medium level in the topsoil to low levels in the subsoil with values ranging from 0.34 % to 0.08 % respectively. The organic matter within the plot are of good quality.

The exchangeable phosphorus within the plot are low with values ranging from 3.80 mgP/kg in the topsoil to 3.00 mgP/kg in the subsoil.

Cation exchange capacity varies from medium (13.50 Cmolc/kg) in the topsoil to low levels (10.60 Cmolc/kg) in the subsoil. The level of exchangeable calcium is dominantly high both in topsoil and subsoil. The levels are 3.70 Cmolc/kg in the topsoil and 3.00 Cmolc/kg in the subsoil. Exchangeable magnesium is medium in both topsoil and subsoil. The levels are 2.50 Cmolc/kg in the topsoil and 2.30 Cmolc/kg in the subsoil. Potassium levels is however medium. The exchangeable sodium is low or very low.

The forest is open with woodland and shrubs of thickets. Also undergrowth species of *Harrisonia and Bridelia* bushes are inclusive. The vegetation under this plot include *Crossopteryx febrifuga, Albizia Versicolor, Combretum molle, Bridelia cathartica, Bridelia malanthesoides, Dalbergia Melanoxylon, Ormocarpum mimosoides, Dombeya Shupangae and Dombeya cincinnata.*

4.3.22 Plot 22

The plot is located on the upper slopes with slope gradient that varies from 35 to 40 % at an altitude ranging from 1200 to 1400 m a.s.l. The soils are shallow with effective rooting depth less than 30 cm, well drained, dark reddish to dark red, clay loam to clay with rock outcrops.

The pH of the soils in the plot is strongly acid (pH 5.00). This value may become more acidic in the subsoil. The levels of the organic carbon are high with levels around 3.00 % in the topsoil and decreases to low or very low levels in the subsoil. Total nitrogen is medium in the topsoil the value which decreases significantly to low levels in the subsoil. The ratio of carbon to nitrogen (C/N) shows that the organic matter are of moderate quality.

Available phosphorus is low with values ranging from 3.60 mgP/kg in the topsoil and decreases to low levels in the subsoil.

Cation exchange capacity is varies from medium (14.00 Cmolc/kg) in the topsoil and this value decreases with increase in soil depth. This is due to the fact the organic matter which determine the ability of the soil to retain and or supply nutrient decreases with soil depth. The exchangeable calcium is high (3.60 Cmolc/kg) in the topsoil and decreases with soil depth. Magnesium levels is high (3.20 Cmolc/kg) topsoil. This levels decreases with soil depth. Potassium levels is medium (0.48 Cmolc/kg) in the topsoil. This levels decrease with increase in soil depth. The exchangeable sodium is generally very low.

The area is under open forest with scrub woodland of thorn bushes. The tree species include *Combretum schumannii, Scorodophleus fischeri, Millettia oblata, Cussonia zimmermannii, Streospermum kunthianum, Ricinoderndron hendelotii, Cola usambarensis, Lecaniodiscus fraxinifolius, Sena singuena, Allophylus meliodorus, Commiphoras spp, Albizia zimmermannii.*

4.3.23 Plot 23

The plot is located on the upper part of the with slope gradient that varies from 25 to 30 % at an altitude ranging from 1250 to 1320 m a.s.l. The soils are shallow with effective depth less than 30 cm, well drained, dark red and clay in texture with localised rock outcrops.

The pH of the soils are strongly acid (pH 5.10). This value becomes more acidic as the soil depth increases. Organic carbon is generally very high with levels around 4.20 % in the topsoil and decreases to low or very low levels in the subsoil. Total nitrogen is medium (0.30 %) in the topsoil and decreases to low levels in the subsoil. The organic matter are of moderate quality. This is indicated by the C/N ratio.

Available phosphorus is low with values ranging from 3.20 mgP/kg. This value decreases with soil depth.

Cation exchange capacity low (10.60 Cmolc/kg) both in topsoil and subsoil. The level of exchangeable calcium is high (3.20 Cmolc/kg) in the topsoil and decreases to low levels in the subsoil. The level of the exchangeable magnesium is medium (2.60 Cmolc/kg) in the topsoil and decreases with soil depth. Potassium level is medium (0.42 Cmolc/kg) in the topsoil. This level decreases with soil depth. The exchangeable sodium is generally very low. The forest is dense, mature mixed with dominance of *Cynometra* and *Apodytes*. Also the under*growth species of Gonatopus boivinii, Calopsis volkensi and Encephalartos hildbrandtii on rockoutcrop are inclusive. The vegetation under this plot include Carpodiptera africana, Cynometra webberi, Sterculia appendiculata, Cola usambarensis, Apodytes dimidiata, Cordia ovalis, Pandanus stuhlmannii, Millettia oblata, Drypetes usambarica, Scorodophleus fischeri.*

4.3.24 Plot 24

The plot is located on the middle part of the slope with slope gradient that varies from 20 to 25 % at an altitude ranging from 1150 to 1200 m a.s.l. The soils in this plot are generally moderately deep, well drained, dark reddish brown, clay with rock outcrops.

Chemical characteristics of the soils ranges from medium acid (pH 5.60) in the topsoil and decreases to strongly acid or very strongly acid (pH 5.00) in the subsoil. Organic carbon ranges from very high (5.60 %) in the topsoil to low or very low (1.00 %) levels in the subsoil. Total nitrogen ranges from medium levels (0.45 %) in the topsoil to low levels (0.08 %) in the subsoil. Organic matter are of good quality.

Available phosphorus is low with values ranging from 6.50 mgP/kg in the topsoil to 6.00 mgP/kg in the subsoil.

Cation exchange capacity varies from medium (14.90 Cmolc/kg) in the topsoil to low levels (7.80 Cmolc/kg) in the subsoil. The level of exchangeable calcium is very high both in topsoil and subsoil with levels that varies from 9.00 Cmolc/kg) in the topsoil and decreases 8.40 Cmolc/kg) in the subsoil. Magnesium levels is generally high in both topsoil and subsoil. The levels are 4.50 Cmolc/kg and 3.60 Cmolc/kg. Potassium levels is medium. The levels ranges from 0.80 Cmolc/kg to 0.40 Cmolc/kg in topsoil and subsoil respectively. The exchangeable sodium is generally very low.

The forest under this plot is open, mature of low canopy formerly encroached area for pole cutting as building materials for natives around the area. The plot is dominated by *Millettia* with undergrowth specie of climbers and brumbles

4.3.25 Plot 25

The plot appears on the upper part of the slope with slope gradient 40 % at an altitude approximately 1800 m a.s.l. The soils are shallow with effective depth of 20 cm, well drained, dark reddish brown, clay loam to clay with significant amount of rock outcrops.

The soil chemical characteristics is that the soils are strongly or very strongly acid (pH 4.50) in the topsoil. This levels decreases with increase in soil depth. Organic carbon are generally very high with levels around 4.00 % in the topsoil and decreases to low or very low levels in the subsoil. Total nitrogen is medium (0.30 %) in the topsoil. This level decreases with soil depth thereby becoming low or very low. The organic matter content are of good quality.

Available phosphorus is low 5.10 mgP/kg in the topsoil and decreases with soil depth.

Cation exchange capacity varies from medium (12.60 Cmolc/kg) in the topsoil and this value decreases with soil depth. The level of exchangeable calcium is high (4.60 Cmolc/kg) in the topsoil and decreases to low levels in the subsoil. The exchangeable magnesium is high (3.00 Cmolc/kg) in the topsoil and decreases in the subsoil. Potassium is medium both in topsoil and subsoil. The levels are 0.65 Cmolc/kg. The levels of the exchangeable sodium is generally very low.

The forest under this plot is generally dense, mature mixed without dominance with undergrowth spp of *grandidiera, pandanus, Aloe and Rinorea* respectively. Tree species include *Euphorbia candelabrum, Pandanus stuhlmannii, Ludia mauritiana, Lecaniodiscus fraxinifolius, Dombeya shupangae, Cola usambarensis, Ludia mauritania, Phialodiscus zambesiaca, Englerophytum natalense, Tarenna graveolens, Diospyros mespiliformis*

4.3.26 Plot 26

The plot is located on the upper part of the slope with a slope gradient of 50 % at an altitude approximately 1800 m a.s.l. The soils are shallow, well drained dark reddish brown, clay with rock outcrops that constitute significant part of the plot.

Chemical characteristics of the soils is that the soils are very strongly acid (pH 4.80). The reaction decreases with soil depth thereby becoming more acidic. Organic carbon is very high with levels that varies from 5.00 % in the topsoil and decreases to low or very low levels in the subsoil. Total nitrogen is medium (0.50 %) in the topsoil but becomes low in the subsoil. Based on the C/N ratios the organic matter content are of good quality implying that net mineralisation is possible.

Available phosphorus is low with values ranging from 3.10 mgP/kg. This level decreases with soil depth.

Cation exchange capacity varies from medium (16.7 Cmolc/kg) in the topsoil to low levels (10.5 Cmolc/kg) in the subsoil. The level of exchangeable calcium is high (12.6 Cmolc/kg) in the topsoil and decreases to low levels (3.2 Cmolc/kg) in the subsoil. Magnesium levels is generally high to medium in the topsoil and subsoil respectively. Potassium is low to very low in the topsoil and subsoil with values ranges from 0.42 and 0.09 Cmolc/kg. The exchangeable sodium is generally very low.

The forest is dense, mature mixed without dominance with undergrowth spp of *Rinorea and Grandidera* respctively. Under the plot trees species include *Rinorea augustifolia, Cola usambarensis, Englerophytum natalense, Rothmannia Mangujae, Premna chrysoclada, Cola greenwayi, Symphonia globulifera, Rinorea ferruginea, Cola microcarpa, Lannea welwitschii, Diospyros natalensis, Ludia mauritania, Pandanus stuhlmannii, Dombeya shupangae, Bombax rhodognaphalon, Diospyros mespiliformis and Zanha golungensis.*

4.3.27 Plot 27

The plot is located on the part of the slope with slope gradient of 13 % at an altitude of 1800 m a.s.l. Rock outcrops were observed and constitutes over 90 % of the total plot area. Both augering and sampling were not possible.

However the forest in the plot is dense, mature mixed without dominance with undergrowth spp of *Rinorea, Sabaflorida, Londolphia kirkii and grandictiera bushes. Tree species under this plot include Margaritaria discoidea, Premna chrysoclada, Vincentella parsagei, Albizia gummifera, Rothmannia mangajae, Coffea robusta, Pittosporum viridiflorum, Cola scheffleri, Millicia excelsa, Bombax rhodognaphalon, Crotonsylivaticus, Funtumia africana, Trilepsium madagascariensis, Ricinodendron heudelotii, Ficus valischoudae, Zanha golungensis, Markhamia lutea and Vitex amaniensis.*

4.3.28 Plot 28

The plot is located on the upper part of the slope with slope gradient 70 % at an altitude greater than 2400 m a.s.l. The soils are shallow to moderately deep, well drained, dark reddish brown to dark red, clay loam to clay with rock outcrops.

Chemical characteristics of the soils is that the soils are strongly acid (pH 5.10). This levels becomes more acidic in the subsoil. The levels of organic carbon is generally very high (4.80 %) in the topsoil and decreases to low or very low levels in the subsoil. Total nitrogen is medium (0.43 %) in the value decreases to low levels in the subsoil. The organic matter content are of good quality.

Available phosphorus is low with values ranging from 4.40 mgP/kg in the topsoil and decreases to lower levels in the subsoil.

Cation exchange capacity varies from medium (13.00 Cmolc/kg) in the topsoil and becomes low in the subsoil. The levels of the exchangeable calcium is very high (5.20 Cmolc/kg) in the topsoil and decreases to low levels in the subsoil. Magnesium levels is generally high (4.60 Cmolc/kg) in the topsoil which decreases in the subsoil. Potassium levels is medium (0.48 Cmolc/kg) in the topsoil and decreases with soil depth. The levels of the exchangeable sodium is generally very low.

The area is under open forest formerly encroached for cultivation and this makes about 95% of the total plot area. Only grass spp seem dominant vegetation cover. Tree species include *Diospyros natalensis, Zanha golungensis, Synsepalum msolo, Leocaniodiscus fraxinifolius, Dombeya shupangae, Englerophytum natalense, Vincentella parsagei.*

4.3.29 Plot 29

The plot is located on the middle part of the slope with slope gradient
60 % at an altitude ranging from 1600 - 1680 m a.s.l. The soils are moderately deep with effective depth 50 cm, well drained, dark red and clay in texture. Presence of rock outcrops characterise the plot.

The pH of the soils ranges from medium acid (pH 5.60) in the topsoil to strongly acid (pH 5.40) in the subsoil. The organic carbon is generally very high with levels that varies from 4.60 % in the topsoil and decreases to low or very low (0.60 %) levels in the subsoil. Total nitrogen is medium to high (0.51 %) in the topsoil and significantly decrease to low or very low levels (0.07 %) in the subsoil. The plot has organic matter of good quality.

Available phosphorus is low with values ranging from 5.80 mgP/kg in the topsoil to 5.50 mgP/kg in the subsoil.

Cation exchange capacity varies from medium (15.50 Cmolc/kg) in the topsoil to low levels (9.10 Cmolc/kg) in the subsoil. The exchangeable calcium is dominantly very high in both topsoil and subsoil. The levels varies from 5.00 Cmolc/kg in the topsoil and 4.00 Cmolc/kg in th subsoil.
The magnesium levels is high (3.80 Cmolc/kg) in the topsoil and decreases to medium levels (2.50 Cmolc/kg) in the subsoil. Potassium is medium both in topsoil and subsoil. The values are 0.70 Cmolc/k and 0.65 Cmolc/kg in topsoil and subsoil respectively. The exchangeable sodium is generally very low.

The forest is open woodland formerly encroached with *olyra* grasses and *lantana* bushes. The tree species include *Pteleopsis myritifolia, Cola clavata, Albizia zimmermannii, Erythrina*

caffra, Vincentella parsagei, Englerophytum natalense, Drypetes usambarica, Ricinodendron hendelotii, Combretum schumannii, Vepris simplicifolia, Milletia oblata, Diospyros natalensis, Rothmannia urcelliformis, Terminalia sambesiaca, Newtonia paucinjuga, Cola greenwayi, Vepris trichocarpa, Cola clvata, Millettia stuhlmannii, Diospyros mespiliformis, Lecaniodiscus fraxinifolius and Ludia mauritania.

4.3.30 Plot 30

The plot is located on the upper part of the slope with slope gradient 45 % at an altitude greater than 2100 m a.s.l.. The soils are deep to very deep with effecting rooting depth greater than 80 cm and in places greater than 100 cm, well drained, dark reddish brown to dark red, clay with rock outcrops.

Chemical characteristics of the soils is that the soils are strongly acid or very strongly acid with values that ranges from pH 4.70 in the topsoil to pH 4.30 in the subsoil. The organic carbon are very high with levels around 4.2 % in the topsoil and decreases to low or very low (0.80 %) levels in the subsoil. Total nitrogen is medium (0.38 %) in the topsoil and decreases to low levels (0.07 %) in the subsoil. Organic matter are of good quality.

Available phosphorus are low with values ranging from 3.30 mgP/kg in the topsoil to 2.10 mgP/kg in the subsoil.

Cation exchange capacity varies from medium (12.50 Cmolc/kg) in the topsoil to low levels (10.20 Cmolc/kg) in the subsoil. The exchangeable calcium are high (3.60 Cmolc/kg) in the topsoil and decreases to medium or low levels (2.40 Cmolc/kg) in the subsoil. The magnesium levels high (3.00 Cmolc/kg) in the topsoil and decreases to medium level (2.00 Cmolc/kg) in the subsoil. Potassium levels are both medium in topsoil and subsoil. The levels are 0.60 Cmolc/kg in the topsoil and 0.40 Cmolc/kg in the subsoil respectively. The exchangeable sodium is generally very low.

The forest under this area is open and of low canopy mixed with climbers and Acacia. Under this plot the vegetation include *Millettia oblata, Vincentella parsagei, Nersogodonia holtsii, Verplis trichocarpa, Mystroxylon aethiopicum, Scorodophleus fischeri, Dialium holtzii, Lecaniodiscus fraxinifolius, Sterculia quinqueloba, Myxylon aethiopicum, Markhamia lutea and Albizia zimmermannii.*

4.3.31 Plot 31

The plot is located on the upper part of the slope with a slope gradient of 70 % at an altitude of 2200 m a.s.l. The soils are shallow, well drained, dark reddish brown to dark red, clay loam to clay in texture. Rock outcrops are the characteristics of the plot.

The soils in the plot are strongly or very strongly acid both in the topsoil and subsoil. The values is pH 4.50 and the value decreases with increase in the soil depth thereby becoming more acidic. Organic carbon is very high with levels that varies from 4.40 % in the topsoil and decreases to low or very low levels in the subsoil. Total nitrogen is medium (0.44 %) in the topsoil. The levels becomes low or very low in the subsoil. Organic matter are of good quality.

Available phosphorus is low with values less or equal to 3.00 mgP/kg in both topsoil and subsoil.

Cation exchange capacity varies from medium (13.50 Cmolc/kg) in the topsoil to low levels in the subsoil. The level of the exchangeable calcium is high (4.80 Cmolc/kg) in the topsoil and decreases to low levels in the subsoil. Magnesium levels on the otherhand is high in the topsoil but decreases in subsoil. Potassium level is low (0.35 Cmolc/kg) thereby becoming very low in the subsoil. The levels of exchangeable sodium is very low.

The forest is dense formerly encroached for cultivation. The undergrowth species of *olyra, Leptonychia and rinorea* are inclusive. Tree species include *Cola scheffleri, Leptonychia usambarensis, Rothmannia mangujae, Rytigynia flavida, Englerophytum natalense, Trilepsium madagascariensis, Diospyros mespiliformis, Milicia excelsa, Ricinodendron heudelotii, Pandanus stuhlmannii, Milletia stuhlmannii and Vepris nobilis.*

4.3.32 Plot 32

The plot is located on lower part of the slope with slope gradient 70 % at an altitude ranging from 2400 - 2600 m a.s.l. The soils are shallow to very shallow with effective rooting depth less than 30 cm, well drained, dark reddish brown, clay in texture. In the plot rock outcrops occupies about 90 % of the total area.

The soil reaction is strongly acid or very strongly acid (pH 4.60) in the topsoil. This value becomes more acidic in the subsoil. Organic carbon is very high with levels that ranges from 4.30 % in the topsoil and decreases to low or very low levels in the subsoil. Total nitrogen is medium (0.43 %) in the topsoil but becomes low in the subsoil. Based on the C/N ratios the organic matter content are of good quality implying that net mineralisation is possible.

Available phosphorus is low (2.80 mgP/kg) in the topsoil. This level significantly decreases with soil depth.

Cation exchange capacity varies from medium (13.00 Cmolc/kg) in the topsoil to low levels in the subsoil. The level of the exchangeable calcium is high (4.00 Cmolc/kg) in the topsoil and decreases to low levels in the subsoil while magnesium levels is high (3.80 Cmolc/kg) in the topsoil which decreases with soil depth. Potassium is medium (0.50 Cmolc/kg) bu the levels decreases to low in the subsoil. The level of the exchangeable sodium is low to very low.

The forest is dense, mature without dominance. Also undergrowth species of *rinorea albersii,londolphia and alchornea are inclusive. Tree species include Strombosia scheffleri, Synsepalium msolo, Allanblackia stuhlmannii, Mesogyne insignis, Combretum schulmannii, Leptonychia usambarensis, Trilepsium madagascariensis, Sapium ellepticum, Ficus exasperata, Blighia unijugata, Cola microcarpa, Funtumia africana, Strombosia scheffleri.*

4.3.33 Plot 33

The plot occupies upper part of the slope with slope gradient that ranges fro 30 to 35 % at an altitude greater than 1800 m a.s.l. The soils are shallow, well drained, dark red and clay loam to clay in texture. Rock outcrops are the characteristics of the plot.

The reaction of the soils is dominantly very strongly acid or strongly acid (pH 5.00). The levels decreases significantly with soil depth thereby becoming more acidic. Organic carbon is generally very high with levels around 5.40 % in the topsoil and decreases to low or very low levels in the subsoil. Total nitrogen is medium (0.49 %) in the topsoil but becomes low in the subsoil. Organic matter are of good quality.

Available phosphorus is low (3.20 mgP/kg) in the topsoil. This level decreases further in the subsoil.

Cation exchange capacity varies from medium (14.00 Cmolc/kg) in the topsoil to low levels in the subsoil. The levels of the exchangeable calcium is high (3.50 Cmolc/kg) in the topsoil and decreases to low levels in the subsoil. On the otherhand magnesium levels is high (0.31 Cmolc/kg) in the topsoil and decreases with soil depth. Potassium is medium (0.60 Cmolc/k) in the topsoil to low to very low subsoil. The exchangeable sodium is generally very low.

The forest is open and of low canopy formerly encroached for cultivation of "shambas". The vegetation under this plot include tree species of *Leptonychia usambarensis, Funtumia africana, Rothmannia mangujae, Anyglocalyx braunii, Morus mesozygia, Cola microcarpa, Cola scheffleri, Antiaris toxicaria, Albizia gummifera, Premna chrysoclada, Croton sylivaticus, Tabernaemontana pachysiphon, Milicia excelsa, Rauvolfia caffra, Allophylus melliodorus, Allophylus melliorus, Sapium ellepticum and Hallea rubrostipulata.*

4.3.34 Plot 34

The plot occupies upper part of the slope with slope gradient that ranges fro 35 to 45 % at an altitude greater than 1750 m a.s.l. The soils are moderately deep with effective depth 50 cm, well drained, dark red and clay in texture. Rock outcrops constitutes 20 - 30 % of the total plot area.

The pH of the soils in the plot varies from slightly acid (pH 6.20) in the topsoil to medium acid (pH 5.80) in the subsoil. Organic carbon varies from very high levels (5.00 %) in the topsoil and decreases to low or very low (1.20 %) levels in the subsoil. Total nitrogen ranges from medium levels in the topsoil to low levels (0.12 %) in the subsoil. Information from the C/N ratios indicate that the plot has organic matter of good quality.

Available phosphorus is low with values ranging from 4.60 mgP/kg in the topsoil to 4.00 mgP/kg in the subsoil.

Cation exchange capacity varies from medium (16.80 Cmolc/kg) in the topsoil to low levels (6.70 Cmolc/kg) in the subsoil. The exchangeable calcium levels is dominantly high both in topsoil and subsoil. The level varies from 5.50 Cmolc/kg in the topsoil and decreases slightly to 4.20 Cmolc/kg in the subsoil. The level of magnesium is high (4.40 Cmolc/kg) both in the topsoil and subsoil. Potassium is medium (0.60 Cmolc/kg) in the topsoil. The exchangeable sodium is generally very low.

The forest under this area is open consisting of woodland/scrub with grasses of *Aspilia, Smilax and Oplismenus sp*. The vegetation under this plot include species of *Stereospermum*

kunthianum, Vangueria infusiata, Lonchocarpus bussei, Annona senegalensis, Dombeya shupangae, Combretum molle and Albizia gummifera.

4.3.35 Plot 35

The plot occupies upper part of the slope with slope gradient 45 % at an altitude greater than 2000 m a.s.l. The soils are moderately deep with effective depth 50 cm. The soils in the plot are well drained, dark reddish to dark red and clay loam to clay in texture. It is characterised by the presence rock outcrops.

Chemical characteristics of the soils is that the soils are strongly acid or very strongly acid in both topsoil and subsoil. The levels varies from pH 4.80 in the topsoil to pH 4.50 in the subsoil. Organic carbon is very high with levels around 4.20 % in the topsoil and decreases to low or very low (1.50 %) levels in the subsoil. Total nitrogen varies from medium level (0.30%) in the topsoil to low levels (0.12 %) in the subsoil. The C/N ratio indicate that the organic matter are of good quality.

Available phosphorus is low with values ranging from 4.80 mgP/kg in the topsoil to 4.50 mgP/kg in the subsoil.

Cation exchange capacity varies from medium (14.60 Cmolc/kg) in the topsoil to low levels (11.30 Cmolc/kg) in the subsoil. The exchangeable calcium is high (2.80 Cmolc/kg) in the topsoil and decreases to 2.30 Cmolc/kg) in the subsoil. The levels of exchangeable magnesium is high to medium in the topsoil (3.00 Cmolc/kg) and becomes dominantly medium (2.80 Cmolc/kg) in the subsoil. Potassium is medium (0.50 Cmolc/kg) in the topsoil and decreases to low (0.40 Cmolc/kg) in the subsoil. The exchangeable sodium is generally very low.

The forest is dense, mature mixed without dominance. Also the undergrowth species of *rinorea, Acacia, Pandanus and Sansiviera kirkii on the rock outcrops are inclusive. Tree species include Pandanus stuhlmannii, Cola scheffleri, Synsepalum msolo, Margaritaria discodea, Zanha golungensis, Englerophytum natalense, Pitlosporum viridiflorum, Lannea welwistchii, Cola usambarensis, Craibia brevicandata, Homalium longistylum, Rinorea ferruginea, Ludia mauritania, Caloncoba welwitschii, Diospyros mespiliformis, Sapium ellipticum, Syzigium sp, Symphonia globulifera, Dypetes natalensis, Cola scheffleri, Dombeya shupangae, Bersama abyssinica, Vepris nobilis, Lecaniodiscus fraxinifolius, Vepris mespiliformis.*

4.3.36 Plot 36

The plot occupies upper part of the slope with slope gradient 45 % at an altitude greater than 2000 m a.s.l. The soils are shallow with effective depth rooting depth of 40 cm, well drained, dark red, clay loam to clay in texture with rock outcrops.

The soil pH is strongly acid (pH 4.10) that significantly decreases with soil depth thereby becoming more acidic. Organic carbon is high with levels around 3.00 % in the topsoil and decreases to low or very low levels in the subsoil. Total nitrogen is medium (0.37 %) in the topsoil to low in the subsoil. The C/N ratio shows that the organic matter to be good quality.

Available phosphorus is low with values ranging from 3.90 mgP/kg in the topsoil and decreases further with the soil depth.

Cation exchange capacity varies from medium to low (11.50 Cmolc/kg) in the topsoil. Further decrease is found the subsoil. The levels of the exchangeable calcium is high (3.50 Cmolc/kg) in the topsoil and decreases to low levels in the subsoil while magnesium levels is medium (2.80 Cmolc/kg) in the topsoil and decreases with soil depth. Potassium is medium (0.45 Cmolc/kg) in the topsoil and decreases further with the soil depth. The exchangeable sodium is generally very low.

The forest under this plot is dense and mature mixed without dominance. The undergrowth species of *Olyra latifolia, Dracaena deremensis, Erythrococca usambarica and pandanus stuhlmannii are inclusive. The vegetation include tree species of Synsepalum msolo, Vepris simplicifolia, Pandanus stuhlmannii, Cremaspora triflora, Englerophytum natalense, Tricalysia myritifolia, Zanha golungensis, Ficus exasperata, Premna chrcysoclada, Milicia excelsa and Trilepsium madagascariensis.*

4.3.37 Plot 37

The plot occupies upper part of the slope with slope gradient 45 % at an altitude greater than 2000 m a.s.l. The soils are moderately deep with effective depth 75 cm, well drained, dark reddish brown to dark red, clay with characteristically presence of rock outcrops.

The soil reaction varies from slightly acid (pH 6.10) in the topsoil to strongly acid (pH 5.20) in the subsoil. Organic carbon is very high to low or very low in the subsoil. The levels are 4.00 % and 0.05 % in the topsoil and subsoil respectively. Total nitrogen ranges from medium (0.44 %) in the topsoil to low levels (1.00 %) in the subsoil. Organic matter are of good quality.

Available phosphorus is low with values ranging from 3.50 mgP/kg in the topsoil to 3.00 mgP/kg in the subsoil.

Cation exchange capacity varies from medium (18.40 Cmolc/kg) in the topsoil to low levels (6.10 Cmolc/kg) in the subsoil. Exchangeable calcium is very high both in topsoil and subsoil. The levels are 5.10 Cmolc/kg and 4.00 Cmolc/kg respectively. Magnesium levels are generally high both in topsoil and subsoil. The values are 4.30 Cmolc/kg and 3.30 Cmolc/kg respectively. Potassium is dominantly medium in both topsoil and subsoil. The levels are 0.65 Cmolc/kg and 0.50 Cmolc/kg. The exchangeable sodium is generally very low.

The forest is dense, mature with dominance. The undergrowth species of *Mildbraedia fallax, Acacia and Sanseviera kirkii are inclusive. The vegetation include tree species of Celtis philippensis, Scorodophleus fischeri, Pandanus stuhlmannii, Manilkara obovata, Bombax rhodognaphalon, Cynometra webberi, Ochna densicoma, Millettia oblata, Nersogodonia holstii, Ptereocarpus mildbraedii, Millettia stuhlmannii and Vincentella parsagei.*

4.3.38 Plot 38

The plot occupies middle part of the slope with slope gradient 30 % at an altitude of about 1450 m a.s.l. The soils are deep with effective rooting depth of 120 cm, well drained, dark red, clay loam to clay in texture with rock outcrops.

The pH of the soils in the plot varies from medium acid or slightly acid (pH 6.00) in the topsoil to strongly acid (pH 5.20) in the subsoil. The organic carbon are generally very high with levels around 5.50 % in the topsoil and decreases to low or very low (1.20 %) levels in the subsoil. Total nitrogen on the otherhand varies from medium (0.45 %) in the topsoil to low levels (0.12 %) in the subsoil. Based on the C/N ratios the organic matter content are of good quality implying that net mineralisation is possible.

Available phosphorus is low with values ranging from 5.00 mgP/kg in the topsoil to 4.50 mgP/kg in the subsoil.

Cation exchange capacity varies from medium (15.00 Cmolc/kg) in the topsoil to low levels (8.60 Cmolc/kg) in the subsoil. The exchangeable calcium are high (4.80 Cmolc/kg) in the topsoil and decreases to medium (2.30 Cmolc/kg) in the subsoil. The magnesium levels are generally high both in topsoil and subsoil. The levels are 4.50 Cmolc/kg and 4.10 Cmolc/kg respectively. Potassium is medium (0.60 Cmolc/kg) in the topsoil to low levels (0.35 Cmolc/kg) in the subsoil. The exchangeable sodium is generally very low.

The forest is dense, mature and mixed without dominance. Also the undergrowth species of *Olyra, Acacia and Mildbraedia fallax are inclusive. The vegetation include tree species of Englerophytum natalense, Diospyros natalensis, Millettia oblata, Dialium holtzii, Ptereocarpus mildbraedia, Fernandoa magnifica, Ricinodendron hendelotii, Millettia stuhlmannii, Scorodophleus fischeri, Drypetes usambarica, Rothmannia mangajae, Celtis mildbraedia, Nersogodonia holstii and Combretum schumannii.*

4.3.39 Plot 39

The plot occupies the middle part of the slope with slope gradient 30 % at an altitude ranging from 900 to 950 m a.s.l. The soils are deep with effective depth greater than 90 cm, well drained, dark reddish brown to dark red, clay without rock outcrops.

The soils are slightly acid in the topsoil and the reaction decreases and become strongly acid in the subsoil with pH values that ranges from 6.40 to 5.00 respectively. Organic carbon is generally very high with levels around 6.80 % in the topsoil and decreases to low or very low (0.90 %) levels in the subsoil. Total nitrogen on the otherhand varies from high in the topsoil to low in the subsoil with values 0.61 % and 0.08 % respectively. The C/N ratio indicates that the plot has organic matter good quality.

Available phosphorus is low with values ranging from 6.00 mgP/kg in the topsoil to 3.10 mgP/kg in the subsoil.

Cation exchange capacity varies from medium (12.00 Cmolc/kg) in the topsoil to low levels (11.00 Cmolc/kg) in the subsoil. The levels of the exchangeable calcium is dominantly very high in both topsoil and subsoil. The levels are 13.00 Cmolc/kg and 11.00 Cmolc/kg

respectively. The magnesium levels is high (3.80 Cmolc/kg) in the topsoil to 3.20 Cmolc/kg in the subsoil. Potassium levels in the plot is medium with levels that varies from 0.7 Cmolc/kg to 0.50 Cmolc/kg in topsoil and subsoil respectively. The exchangeable sodium is generally very low.

The forest is open consisting of woodland and scrub vegetation. Also grasses of *Oplesmanus and Smilax* climber is inclusive. Tree species include *Markhamia obtusifolia, Dombeya shupangae, Sterculia quinqueloba, Lannea schweinfurthii, Pteleopsis myritifolia, Millettia oblata, Dombeya cincinnata and Brideli melanthesoides.*

4.3.40 Plot 40

The plot occupies middle part of the slope with slope gradient 40 % at an altitude approximately 1400 m a.s.l. The soils are shallow with effective depth of about 35 cm, well drained, dark reddish brown to dark red, clay loam to clay with rock outcrops. The plot is dissected with small valley.

The soil reaction is very strongly acid or strongly acid. The levels are pH 4.50 which decreases with soil depth thereby becoming more acidic in the subsoil. The organic carbon is very high with levels around 6.50 % in the topsoil and decreases to low or very low levels in the subsoil. Total nitrogen is high (0.71 %) in the topsoil and decreases with soil depth. Organic matter of good quality are found in the plot.

Available phosphorus is dominantly low with values ranging from 4.00 mgP/kg in the topsoil or less in the subsoil.

Cation exchange capacity varies from medium (14.50 Cmolc/kg) in the topsoil to low levels in the subsoil. The exchangeable calcium is very high (15.00 Cmolc/kg) in the topsoil and decreases to medium or low levels in the subsoil. Magnesium levels is high (3.60 Cmolc/kg) in the topsoil and decreases with the soil depth. Potassium is medium (0.65 Cmolc/kg). The exchangeable sodium is generally very low.

The forest under this plot is dense, mature mixed without dominance with undergrowth spp of *Sansiviera, Pandanus, Millettia(climbers) and grandidiera. Trees include Scorodophleus Fischeri, Manilkara obovata, Millettia stuhlmannii, Dialiun holtzii, Cola greenwayi, Nersogodonia holtzii, Albizia zimmermannii and Cola usambarensis.*

4.3.41 Plot 41

The plot occupies lower part of the slope with slope gradient 30 % at an altitude approximately 1100 m a.s.l. The soils are moderately deep with effective depth 70 cm, well drained, dark reddish brown and clay loam to clay. Rock outcrops were seen in small valley dissecting the plot.

The soil reaction varies from slightly acid in the topsoil (pH 6.50) to strongly acid or medium acid (pH 5.40) in the subsoil. Organic carbon are generally very high with levels around 6.00 % in the topsoil and decreases to low or very low (0.80 %) levels in the subsoil. Total nitrogen on the otherhand varies from high (0.52 %) in the topsoil to low levels (0.10 %) in the subsoil. The C/N ratio indicates that the organic matter are of good quality.

Available phosphorus is low with values ranging from 5.50 mgP/kg in the topsoil to 5.00 mgP/kg in the subsoil.

Cation exchange capacity varies from medium (18.00 Cmolc/kg) in the topsoil to low levels (7.30 Cmolc/kg) in the subsoil. The levels of the exchangeable calcium is very both high both in topsoil and subsoil. The levels are 12.00 Cmolc/kg in the topsoil and decreases to 10.10 Cmolc/kg) in the subsoil. Magnesium levels is high both in topsoil and subsoil. The values ranges from 4.20 Cmolc/kg in the topsoil to 4.00 Cmolc/kg in the subsoil. Potassium is dominantly medium with values that ranges from 0.60 Cmolc/kg in the topsoil to 0.25 Cmolc/kg in the subsoil. The exchangeable sodium is generally very low.

The forest is dense, mature mixed without dominance with undergrowth spp of *Mildbraedia and grandidae*. Tree species include *Pandanus stuhlmannii, Julbernadia magnistipulata, Bombax rhodognaphalon, Diospyros natalensis, Ricinodendron heudelotii, Chrysophyllum spp, Cleinstantus polystachus, Prunus africana, Ptereocarpus tinctorius, Nersogodonia holstii, Ziziphus mucronata, Dorstenia kameruniana, Milicia excelsa and Cynometra webberi.*

4.3.42 Plot 42

The plot is located on the middle part of the slope with slope gradient
25 % at an altitude approximately 800 m a.s.l. The soils are deep with effective depth greater than 95 cm, well drained, dark red to red, clay loam to clay without rock outcrops.

The soils are slightly acid in the topsoil and the soil reaction decreases and become strongly acid in the subsoil with pH values that ranges from 6.20 to 5.30 respectively. Organic carbon is very high with levels that ranges from 7.00 % in the topsoil and decreases to low or very low (0.90 %) levels in the subsoil. Total nitrogen varies from high in the topsoil to low or very low in the subsoil with values 0.87 % and 0.09 % respectively. Organic matter are of good quality.

Available phosphorus is low with values ranging from 3.80 mgP/kg in the topsoil to 2.15 mgP/kg in the subsoil.

Cation exchange capacity varies from medium (13.50 Cmolc/kg) in the topsoil to low levels (10.00 Cmolc/kg) in the subsoil. The exchangeable calcium ranges from very high (11.00 Cmolc/kg) in the topsoil and decreases 10 Cmolc/kg) in the subsoil. Magnesium levels is both high in topsoil and subsoil. The levels are 3.60 and 3.20 Cmolc/kg respectively. Potassium is medium low (0.35 Cmolc/kg) and decreases significantly to low levels (0.21 Cmolc/kg in the subsoil. The exchangeable sodium is generally very low.

The forest is dense, mature mixed with dominance and undergrowth species of *Olyra, Grandidiera londolphia and millettia* bushes are inclusive. Tree species include *Nersogodonia holstii, Millettia oblata, Diospyros natalensis, Dialium holtzii, Markhamia lutea, Albizia zimmermannii, Englerophytum natalense, Diospyros abyssinica, Celtis philippensis.*

4.3.43 Plot 43

The plot occupies upper part of the slope with slope gradient that ranges from 50 to 55 % at an altitude approximately 1200 m a.s.l. Rock outcrops were observed and constitute 60 - 70 % of the total plot area. The soils are shallow with effective rooting depth of 35 cm, well drained, dark reddish brown and clay soils with rock outcrops that constitute 60 to 70 % of the total area.

The soil pH ranges from strongly acid to medium acid (pH 5.50) in the topsoil. In the subsoil the soil reaction decreases further thereby becoming more acidic. The organic carbon is very high with levels around 6.00 % in the topsoil and decreases to low or very low levels in the subsoil. Total nitrogen is high (0.54 %) in the topsoil and decreases to low levels in the subsoil. The C/N ratio indicates that the organic matter are of good quality.

Available phosphorus is low with values ranging from 4.00 mgP/kg in the topsoil or less in the subsoil.

Cation exchange capacity varies from medium (16.00 Cmolc/kg) in the topsoil to low levels in the subsoil. The levels of the exchangeable calcium varies from very high (12.00 Cmolc/kg) in the topsoil and decreases to low levels in the subsoil. Magnesium levels is high (3.40 %) in the topsoil and decreases significantly with soil depth. Potassium is medium (0.50 %) the value which decreases with soil depth. The level of exchangeable sodium is very low.
The forest is dense, mixed with dominance of *Englerophytum spp*. Also undergrowth species of *Olyra, Sansiviera kirkii, Londolphia and Acacia are inclusive. Tree species include Cola greenwayi, Milicia excelsa, Rothmannia mangajae, Englerophytum natalensis, Celtis phillippensis, Antiaris toxicaria, Lecaniodiscus fraxinifolius, Blighia unijugata, Bombax rhodognaphalon, Vepris nobilis, Albizia gummifera, Diospyros natalensis, Monodora minor, Celtis africana, Combretum schumannii, Dialium holtzii and Sorindeia madagascariensis.*

4.3.44 Plot 44

The plot occupies upper part of the slope with slope gradient 45 % at an altitude approximately 1200 m a.s.l. The soils are shallow with effective rooting depth of about 25 cm, well drained, dark red to red, clay loam to clay soils with rock outcrops.

Soil chemical characteristics is that the soils are slightly acid in the topsoil and the soil reaction decreases and become medium acid in the subsoil with pH values that is around 6.30 or less. Organic carbon is very high with levels around 5.10 % in the topsoil and decreases to low or very low levels in the subsoil. Total nitrogen varies from medium levels (0.41 %) in the topsoil to low levels in the subsoil. Organic matter of good quality are found within the plot.

Available phosphorus is low with values ranging from 3.50 mgP/kg in the topsoil and further decreases with soil depth.

Cation exchange capacity varies from medium (12.40 Cmolc/kg) in the topsoil to low levels in the subsoil. The levels of the exchangeable calcium is very high (13.50 Cmolc/kg) in the topsoil and decreases to low levels in the subsoil. The magnesium levels is medium (3.00

Cmolc/kg) in the topsoil. Potassium is medium (0.40 Cmolc/kg). The levels of the exchangeable sodium is generally very low.

The forest under this plot is dene, mature mixed without dominance. The vegetation include tree species of *Markhamia lutea, Cussonia zimmermannii, Combretum schumannii, Gyrocarpus americanus, Milicia excelsa, Ptereocarpus mildbraedia, Terminalia sambesiaca, Lecaniodiscus fraxinifolius, Antiaris toxicaria, Leptactina platyphylla, Albizia glaberrima, Grewia holstiiand Millettia oblata.*

4.3.45 Plot 45

The plot is located on the upper part of the slope with slope gradient 35 % at an altitude ranging from 1200 to 1250 m a.s.l. The soils are shallow with effective rooting depth that ranges from 20 to 30 cm, well drained, dark reddish brown, clay in texture with dominantly rock outcrops.

The soil reaction is that the soils are medium acid (pH 5.60) in the topsoil and the soil reaction decreases and become strongly acid or very strongly acid in the subsoil. Organic carbon is very high with levels around 4.40 % in the topsoil and decreases to low or very low levels in the subsoil. Total nitrogen is medium (0.40 %) in the topsoil and decreases to low or very in the subsoil. Based on the C/N ratios the organic matter content are of good quality.

Available phosphorus is low with values ranging from 3.10 mgP/kg in the topsoil to even less in the subsoil.

Cation exchange capacity varies from medium (14.50 Cmolc/kg) in the topsoil to low levels in the subsoil. The exchangeable calcium is very high (8.60 Cmolc/kg) in the topsoil and decreases to low levels in the subsoil. The level of exchangeable magnesium is high (3.10 Cmolc/kg) in the topsoil but decreases with increases in soil depth. Potassium is medium (0.60 Cmolc/kg) in the topsoil to low levels in the subsoil. The level of the exchangeable sodium is low to very low.

The area is under open forest,woodland scrub or thickets with bushes. Trees species include *Ludia mauritania, Millettia oblata, Dialium holtzii, Markhamia lutea, Cola usambarensis, Grewia holstii, Milicia excelsa, Commiphora eminori, Leonicadiscus fraxinifolius, Ehretia cymosa, Bridelia miciantha, Albizia zimmermanii, Markhamia lutea, Cussonia zimmermanii, Tricalysia myrtifolia, Vincentella parsagei and Carpodiptre africana.*

4.3.46 Plot 46

The plot is located on the upper part of the slope with slope gradient 35 % at an altitude ranging from 900 to 950 m a.s.l. The soils in the plot are moderately deep to deep with effective depth 95 cm, well drained, dark red to red, clay in texture.
The plot is dominated by rock outcrops.

The soil reaction which is determined by the pH of the soils indicates that the soils varies from slightly acid or neutral in the topsoil and the soil reaction decreases and become medium acid in the subsoil with pH values that ranges from 6.60 to 6.00 respectively. The organic carbon in the plot varies from very high with levels around 4.80 % in the topsoil and

decreases to low or very low (1.00 %) levels in the subsoil. Total nitrogen varies from high in the topsoil to low in the subsoil with values 0.60 and 0.07 respectively. Good quality organic matter are found in the plot.

Available phosphorus is low with values ranging from 4.50 mgP/kg in the topsoil to 2.70 mgP/kg in the subsoil.

Cation exchange capacity varies from medium (17.50 Cmolc/kg) in the topsoil to low levels (8.80 Cmolc/kg) in the subsoil. The levels of the exchangeable calcium is very high both in topsoil and subsoil. The levels are 9.50 Cmolc/kg in the topsoil and decreases 7.30 Cmolc/kg) in the subsoil. The exchangeable magnesium is high (4.10 Cmolc/kg) in the topsoil and medium to low levels (2.80 Cmolc/kg) in the subsoil. Exchangeable potassium is medium in both topsoil and subsoil. The levels are 0.65 Cmolc/kg and 0.41 Cmolc/kg respectively. The exchangeable sodium is generally very low.

The forest under this plot is dense, mature mixed with dominance of *Millettia oblata and Scorodophleus fischeri spp*. The vegetation under the area include tree species of *Millettia oblata, Scorodophleus fischeri, Dracaena steudneri, Vepris trichocarpa, Dialium holtzii, Manilkara sulcata, Vincentella parsagei, Millettia stuhlmannii and Ludia mauritania.*

4.3.47 Plot 47

The plot is located on the middle part of the slope with slope gradient 30 % at an altitude approximately 1200 m a.s.l. The soils are moderately deep with effective depth 65 cm, well drained, dark red, clay without rock outcrops.

The soil reaction varies medium acid in the topsoil and the soil reaction decreases and become medium acid or strongly acid in the subsoil with pH values that ranges from 5.80 to 5.60 respectively. The level of organic carbon is very high (5.80 %) in the topsoil and decreases to low or very low (1.30 %) levels in the subsoil. Total nitrogen varies from high to low in the subsoil with values 0.58 % and 0.09 % respectively. Based on the C/N ratios the organic matter content are of good quality implying that net mineralisation is possible.

Available phosphorus is low with values ranging from 3.60 mgP/kg in the topsoil to 2.50 mgP/kg in the subsoil.

Cation exchange capacity varies from medium (15.00 Cmolc/kg) in the topsoil to low levels (9.20 Cmolc/kg) in the subsoil. Exchangeable calcium is very high both in topsoil and subsoil. The levels are 10.00 Cmolc/kg and 6.20 Cmolc/kg respectively while the magnesium levels are generally high in both topsoil and subsoil. The levels are 3.80 Cmolc/kg and 3.20 Cmolc/kg respectively. The level of the exchangeable potassium is high with values ranges from 0.55 Cmolc/kg and 0.40 Cmolc/kg. The level of the exchangeable sodium is dominantly low to very low in both topsoil and subsoil.

The forest is dense, mature mixed with dominance. Also undergrowth species of *Mildbraedia fallax, Grandidiera, Saba florida and sansiviera kirkii* are inclusive. Tree species include *Diospyros natalensis, Millettia oblata, Dialium holtzii, Albizia zimmermannii, Combretum schumannii, Millettia stuhlmannii, Diospyros mespiliformis, Combretum natalensis, Lecaniodiscus fraxinifolius, Markhamia lutea, Chrysophyllum sp, Scorodophleus fischeri,*

Drypetes usambarica, Nersogodonia holstii, Ludi mauritania, Monodora minor, Millicia excelsa, Dialium holtzii, Mildbraedia fallax, Cynometra webberi, Ricinodendron heudelotii, Trcalysia myrtifolia, Terminalia sambesiaca and Acacia senegal.

4.3.48 Plot 48

The plot occupies the lower part of the slope with slope gradient 15 % at an altitude approximately 800 m a.s.l. The soils are moderately deep with effective depth 60 cm, well drained, dark reddish brown to dark red without rock outcrops.

The soil pH varies from medium acid in the topsoil to strongly acid in the subsoil with pH values that ranges from 5.90 to 5.40 respectively. Organic carbon is very high with levels around 4.60 % in the topsoil and decreases to low or very low (0.0.80 %) levels in the subsoil. Total nitrogen on the otherhand varies from medium in the topsoil to low levels in the subsoil with values 0.30 and 0.06 % respectively. Based on the C/N ratios the organic matter content are of moderate to good quality.

Available phosphorus is low with values ranging from 4.15 mgP/kg in the topsoil to 3.30 mgP/kg in the subsoil.

Cation exchange capacity varies from medium (20.50 Cmolc/kg) in the topsoil to low levels (6.40 Cmolc/kg) in the subsoil. The exchangeable calcium are very high (8.50 Cmolc/kg) in the topsoil and decreases with soil depth. In the subsoil the level is 6.60 Cmolc/kg). The level of magnesium is medium in the topsoil and decreases to low level (2.80 Cmolc/kg) in the subsoil. The level of exchangeable potassium is medium in both topsoil and subsoil with values ranging from 0.55 Cmolc/kg to 0.37 Cmolc/kg. The level of exchangeable sodium varies from low to very low.

The forest is dense, mature mixed with dominance of *scorodophleus*. Also undergrowth of *grandidiera, Mildbraedia fallax, Dorstenia species and Olyra grasses* are inclusive. Tree species include *Uvariodendron, Diospyros natalensis, Lannea welwistchii, Lecaniodiscus fraxinifolius, Dorstenia kameruniana, Dialium holtzii, Ficus lutea, Scorodophleus fischeri, Ptereocarpus tinctorius, Drypetes usambarica, Dracaena steudneri, Combretum schumannii and Dorstenia kameruniana.*

4.3.49 Plot 49

The plot occupies the lower part of the slope with slope gradient 10 to 15 % at an altitude approximately 650 m a.s.l. The soils are moderately deep with effective depth 70 cm, well drained, dark red, clay loam to clay. No rock outcrops were observed in the plot.

Soil chemical characteristics is that the soils are slightly acid in the topsoil and the soil reaction decreases and become medium acid in the subsoil with pH values that ranges from 6.10 to 5.70 respectively. The level of organic carbon within the plot varies from high in the topsoil to low levels in the subsoil. The values are 4.60 % and 0.70 % respectively. Total nitrogen varies from medium in the topsoil to low in the subsoil with values 0.41 % and 0.07 % respectively. Organic matter are are of good quality.

Available phosphorus is low with values ranging from 3.80 mgP/kg in the topsoil to 1.70 mgP/kg in the subsoil.

Cation exchange capacity varies from medium (15.90 Cmolc/kg) in the topsoil to low levels (8.20 Cmolc/kg) in the subsoil. The exchangeable calcium is high both in topsoil and subsoil. The levels are 11.50 and 5.00 Cmolc/kg respectively. The level of exchangeable magnesium varies from medium to low with values that ranges from 3.50 Cmolc/kg to 2.30 Cmolc/kg respectively. The level of exchangeable potassium varies from medium to low with values that ranges from 0.44 Cmolc/kg to 0.21 Cmolc/kg in topsoil and subsoil respectively. The exchangeable sodium varies from low to very low.

The forest under this plot is dense, mature mixed without dominance. Also the undergrowth species of *Mildbraedia, Grandidiera and Olyra latifolia* are inclusive. The vegetation include tree species of *Dialium holtzii, Diospyros natalensis, Drypetes usambarica, Combretum schumannii, Lecaniodiscus fraxinifolius, Celtis mildbraedia, Ficus natalensis, Terminalia sambesiaca, Ricinodendron hendelottii, Celtis africana, Millettia oblata, Scorodophleus fischeri.*

4.3.50 Plot 50

The plot is located on the middle part of the slope with slope gradient that varies from 20 to 25 % at an altitude approximately 750 m a.s.l. No rock outcrops were observed. The soils in the plot are shallow with rooting depth 35 cm, well drained, dark red to red, clay loam to clay. Rock outcrops is not the characteristic of the plot.

The reaction of the soils in the plot as indicated by the pH of the soil is medium acid (pH 5.9) in the topsoil that decreases with the soil depth. In the subsoil the reaction becomes strongly or very strongly acid. The level organic carbon is very high with levels around 3.80 % in the topsoil and decreases to low or very low levels in the subsoil. Total nitrogen is medium in the topsoil which decreases with increase in soil depth thereby becoming low or very low. The levels are 0.38 % in the topsoil. Good quality organic matter are found in the plot.

Available phosphorus low with values ranging from 6.60 mgP/kg in the topsoil and further decreases with soil depth.

Cation exchange capacity varies from medium (15.50 Cmolc/kg) in the topsoil to low levels in the subsoil. The exchangeable calcium is very high
(9.80 Cmolc/kg) in the topsoil and decreases to low levels in the subsoil. The magnesium levels is high (3.20 Cmolc/kg) to medium or low in the topsoil and subsoil respectively. The levels of exchangeable potassium is medium (0.65 Cmolc/kg). Sodium levels varies from low to very low in topsoil and subsoil respectively.

The forest under the area is dense, mature mixed with dominance of *Scorodophleus sp*. The vegetation in the area include tree species of *Pandanus stuhlmannii, Millettia oblata, Manilkara obovata, Manilkara sulcata, Nersogodonia holstii, Cola greenwayi, Vepris trichocarpa and Scorodophleus fischeri.*

4.3.51 Plot 51

The plot is located on the middle part of the slope with slope gradient that varies from 15 to 20 % at an altitude approximately 650 m a.s.l. No rock outcrops were observed.
The soils are moderately deep with effective depth 75 cm, well drained, dark reddish brown, clay in texture without rock outcrops.

Soil chemical reaction indicates that the soils are dominantly slightly acid in both topsoil and subsoil. The values ranges from pH 6.40 in the topsoil to pH 6.10 in the subsoil. Organic carbon varies from very high (4.20 %) in the topsoil to low or very low (0.60 %) levels in the subsoil. Total nitrogen on the otherhand varies from medium in the topsoil to low in the subsoil with values 0.42 % and 0.05 % respectively.

Available phosphorus is low with values ranging from 6.20 mgP/kg in the topsoil to 2.80 mgP/kg in the subsoil.

Cation exchange capacity varies from medium (16.20 Cmolc/kg) in the topsoil to low levels (17.10 Cmolc/kg) in the subsoil. The level of the exchangeable calcium is very high (6.10 Cmolc/kg) in the topsoil and decreases to medium levels (2.40 Cmolc/kg) in the subsoil. The exchangeable magnesium ranges from high (3.80 Cmolc/kg) in the topsoil to medium levels (2.10 Cmolc/kg) in the subsoil. The level of the exchangeable potassium is dominantly medium with levels varying from 0.60 Cmolc/kg to 0.50 Cmolc/kg. The exchangeable sodium is generally very low. No

The forest under the area is dense, mature mixed without dominance. The undergrowth species of *Londoliphia kirkii, Saba flori and gradidiera bushes are inclusive.The vegetation include tree species of Morus mesozygia, Grewia holstii, Dialium holtzii, Anyglocalyx braunii, Scorodophleus fischeri, Pandanus stuhlmannii, Fernandoa magnifica, Celtis africana, Schefflerodendron usambarense, Sterculia appendiculata, Cleistanthus polystachyus.*

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.

Hyytianen, 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 H_20) 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. P (Olsen) mg/kg	<7 <5	7-20 5-10	>20 >10

Available phosphorus is determined by the Kurtz-Bray I method if the pH H_20 of the soil is less than 7.0. In soils with a pH H_20 of more than 7.0 the Olsen method is used.

Exchangeable calcium

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

Exchangeable magnesium

	very low	low	mediu m	high	very high
Mg (clayey soils) Cmolc/kg Mg (sandy soils Cmolc/kg	<0-3 <0.2	0.3-1.0 0.2-0.5	1.1-3.0 0.5-1.0	3.1-6.0 1.1-2.0	>6.0 >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 K (loamy soils) Cmolc/kg K (sandy soils) Cmolc/kg	<0.20 <0.13 <0.05	0.20-0.40 0.13-0.25 0.05-1.10	0.41-1.20 0.26-0.80 0.11-0.40	1.21-2.00 0.81-1.35 0.41-0.70	>2.00 >1.35 >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 : >120 cm

East Usambara Catchment Forest Project Technical Paper Series

(ISSN 1236-620X)

The East Usambara Catchment Forest Project Technical Papers Series consists of reports on forestry issues in the East Usambara Mountains. This series started in 199. These reports aim to make information more widely available to staff members of the East Usambara Catchment Forest Project, to the Forestry and Beekeeping Division, and to other institutions and individuals concerned and interested in the conservation of the East Usambara forests.

The reports are prepared by staff members of the East Usambara Catchment Forest Project or by other researchers, consultants and interested individuals. The views expressed in the reports are those of the author(s).

Current titles in the series are:

1. Mwihomeke, S.T. 1991. Some notes to identify and discuss coopeation in forestry research in the East Usambara mountains.
   Räsänen, P.K. 1991. Outline of a research planning programme for the East Usambara Catchment Forest Project.
2. Hyytiäinen, K. 1992. Forest management plan for Longuza teak plantations.
3. Seymour, M. 1992. Manual harvesting of *Maesopsis eminii* in the East Usamaba mountains, Tanzania.
4. Newmark, W.D. 1992. Recommendations for wildlife corridors and the extension and management of forest reserves in the East Usambara mountains, Tanzania.
5. Häkkinen, I. & Wambura, M. 1992. A Frame plan for the Amani Nature Reserve.
6. Masilingi, W.M.K. 1992. Consultancy report on the legal establishment of the Amani Nature Reserve.
7. Binagi, E.R. 1992. Consolidation of environmental education for adults: critique of FINNIDA-funded forestry projects in Tanzania. A case study of the East Usambara Catchment Forest Project.
8. Tuominen, V. 1993. Marking of the forest reserve boundaries in the East Usambara mountains.
9. Pirttilä, I. 1993. The discharge of Sigi River as an indicator of water catchment value of the East Usambara mountains in Tanzania.
10. Hyytiäinen, K. 1993. Combined seed and timber production in Longuza Teak plantations, Tanzania.
11. Kajembe, G.C. & Mwaseba, D. 1994. The extension and communication programme for the East Usambara Catchment Forest Project.
12. Hyytiäinen, K. 1995. Land use classification and mapping for the East Usambara Mountains.
13. Hall, J.B. 1995. *Maesopsis eminii* and its status in the East Usambara Mountains.
14. Heinonen, P. 1995. PSPs in East Usambara Mountains: present findings and future recommendations.
15. Munuyku, F.C.N. 1995. Report on an inventory of selected proposed forest reserves in Muheza District, Tanga Region.
16. 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.
17. 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.
18. Ellman, A.E. 1996. Handing over the stick? Report of a village forest management and farm forestry consultancy
19. 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.
20. 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.
21 Howard, P.C. 1996. Baseline biological surveys in selected East Usambara forest reserves and forests, 1995-96 - project evaluation report
22. Woodcock, K. 1995. Indigenous knowledge and forest use: two case studies from the East Usambaras, Tanzania.
23. Shaka, J.M. & A. Msangi. 1996. Soils and vegetation of Bamba Ridge Forest Reserve, Maramba Division, Muheza District, Tanga.
24. Shaka, J.M. & H. Mwanga. 1996. Soils and vegetation of Mlungui Proposed Forest Reserve, Maramba Division, Muheza District, Tanga.
25. Shaka, J.M. & A. Msangi. 1996. Soils and vegetation of Kwamarimba Forest Reserve, Bombwera Division, Muheza District, Tanga.
26. Shaka, J.M., W. Kabushemera & A. Msangi. 1997. Soils and vegetation of Kambai Forest Reserve, Bombwera Division, Muheza District, Tanga.

Suggested citation: Shaka, J.M., W. Kabushemera & A. Msangi. 1997. Soils and vegetation of Kambai Forest Reserve, Bombwera Division, Muheza District, Tanga. – East Usambara Catchment Forest Project Technical Paper No. 26. - Forestry and Beekeeping Division & Finnish Forest and Park Service & National Soil Service, Dar es Salaam & Vantaa.