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SOILS AND VEGETATION OF KWAMARIMBA AND NORTH LONGUZA FOREST RESERVES, BOMBWERA DIVISION, MUHEZA DISTRICT, TANGA

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Agricultural Research Institute, Mlingano

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Detailed soil survey Report, 1996

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East Usambara Catchment Forest Project Technical Paper 25

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SUMMARY

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

Kwamarimba and Longuza Forest Reserves covering an area of about 810 and 360 ha respectively are located on Kwamarimba and Longuza hills that extends from Zigi river to the east and west, in Bombwera division, Muheza District. The climate is characterised by bi-modal rainfall pattern with long and short rain seasons from March to May and October to December respectively.

Both forests are gazetted as forest reserves. The study area is divided into three major physiographic units summit and upper slope, mid-slope and lower slopes. Slope gradient of the study area ranges from 8 to 50 % at an elevation between 100 to 300 m above sea level. The soils are formed from metamorphic rocks of the Usagaran system. The rocks are dominantly gneiss. In some of the plots the soils are formed from quartzite parent material.

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

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

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

1. INTRODUCTION

This report presents the results of detailed soil and vegetation survey at a scale of 1:10,000 of Kwamarimba Forest Reserve (810 ha) and Longuza Forest Reserve (360 ha) located at Bombwera Division, Muheza District, in Tanga Region. The area is found within coordinates 38°40'E and 38°45'E and 5°00' and 5°05'S at about 35 km from Muheza town and about 2 km from Kiwanda village. Marimba and Longuza Forest Reseves are part of the East Usambara forests that are gazetted as catchment forests.

The survey was carried out by the National Soil Service (NSS) at the request of East Usambara Catchment Forest Project (EUCFP).

The objectives of the study were:

1. To give general soils distribution and assess the fertility status; and
2. To map out forest in terms of dominant tree species.

The fieldwork was carried out in December 1995 by two NSS Soil Surveyors messrs J.M. Shaka and A. Msangi. Vegetation classification is based on vegetation survey conducted by Mr A.S. Mdolwa, a TAFORI botanist from the Amani Botanical Garden, Muheza. Messrs Shaka and Msangi were also responsible for the production of the final report. Soil samples collected during fieldwork were analyzed by the NSS Central Laboratory under supervision of Mr. C.T. Shawa.

2 THE ENVIRONMENT

2.1 Climate

Climate is one of the prime determinants that affect a type of vegetation to be found in a given area. However, only rainfall data is available and relevant for Kwamarimba and Longuza Forest Reserves. Table 1 provides 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 in the study area is bi-modal with long (masika) and short (vuli) rainy seasons. The short rains occur between September to December while the long rains start in March and ends in June. The long rains are more reliable and often results in more than 50% of the annual precipitation.

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

Kwamarimba and Longuza Forest Reserve are situated on Kwamarimba and Longuza range of hills respectively separated by Zigi river. To the east of Zigi river Kwamarimba Forest Reserve is located while to the west there is Longuza Forest Reserve. The Forests comprise of series of hills that are separated by narrow or V- shaped valley bottoms with no water springs originating from them. Most of the springs are seasonal.

The area is divided into units based mainly on the slope gradient. Major physiographic units include summit and upper slopes, mid-slopes and lower slopes. The study area is situated at an elevation ranging from 100 to 300 m above sea level. Slope gradient is variable. It ranges from 8 to 50 %.

The East Usambara in general and Kwamarimba and Longuza hills in particular are characterised by Metamorphic rocks of the Usagaran system (Precambian Basement). The rocks are dominantly gneiss with intermediate mineralogical composition. The rocks have approximately equal quantities of light minerals (quartz and feldspar) and dark minerals (pyroxene and hornblende). Locally amphibolites occur (Geological Survey of Tanzania, 1965). In places the dominant parent material include quartsite.

2.3 Land-use and vegetation

A large part of Kwamarimba Forest Reserve is under dense and mature forest while on the otherhand Longuza forest reserve is disturbed as the results of recent commercial timber harvest. Furthermore the forest is currently being disturbed due to the fact that presently the local communities are still grazing their cattle in the forest. Generally 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, grazing and settlement.

Other parts of the forests `highly disturbed` such that often the natural vegetation types are absent. These are forests that are regenerated from the formerly cultivated lands. 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 52 and 18 auger hole observations for Kwamarimba and Longuza Forest Reserves respectively were made to a depth of 150 cm where possible. The augerings were described according to FAO (1977) guidelines for soil profile descriptions. Soil colours were named according to the Munsell notation (Munsell colour Charts Inc., 1973).

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

For vegetation identification and classification, in each of the sample plot all trees with Diameter at Breast Height (DBH) greater than 10 cm were counted followed by individual tree identification and botanical classification.

Soil samples for standard soil fertility analysis were collected from two depths 0-25 cm and 25-50 cm. The soils were then analyzed according to the Internationally accepted method in use at NSS.

4 SOILS AND VEGETATION

4.1 General soils condition.

The soils in the study area are generally shallow to very deep, dominantly well drained, clay loam to clay, dark reddish brown to dark red or red. In places the soils have rock outcrops or even rocky without surface stoniness. The slope gradients for the study area ranges from 8 to 50 % and due to the slope gradient the soils are very prone to severe erosion if vegetation cover is removed.

The chemical data presented in Table 2 and 3 shows that generally the soils in the area are very strongly acid or strongly acid to neutral. The soils are non-saline. Organic carbon and total nitrogen are variable in the study area. In some of the mapping units the level of organic carbon and total nitrogen varies from medium to high or very high. In some of the plots organic carbon are even very high. This clearly show that the amount of organic matter in the soils within the study area is high or very high especially in the topsoil and the organic matter is of good quality as indicated by the C/N ratio.

Available phosphorus in all plots is low while exchangeable bases vary from medium to high. The level of exchangeable calcium is dominantly very high. It seems that the parent material from which the soils are formed is rich in calcium while poor in phosphorus.

4.2 General vegetation conditions

The type of vegetation in the area are dominantly dense forest with minimum disturbances but in some of the plots the vegetation are disturbed such that the vegetation are either slightly dense or open forest with or without tree dominance.

Dominantly occuring tree species in the study area are 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, Lecaniodiscus fraxinifolius, Markhamia lutea, Cussonia zimmermanii, *Pandanus rabaiensis Julbernadia magnistipulata, Combretum schumannii, Diospyros kabuyeana, Diospyros natalensis, Vincentella passargei, Fernandoa magnifica, Antiaris toxicaria, Dombeya shupangae, Stereospermum kunthianum, Ricinodendron heudelotii, Xylopia parviflora, Millicia excelsa, Cynometra fischeri, Cynometra webberi, Dialium holtsii, Markhamia lutea, and Bombax rhodognaphalon.*

Table 2. Analytical data for representative plots in Marimba Forest Reserve.

PLOT NO/ DEPTH	PARTICLE SIZE ANALYSIS <2	2-20	20-50	50-2000	pH 1:2.5 H2O	KCl	ORG C ---- % ----	TOTAL N	C/N	AVAILABLE P BRAY I mg/kg	CEC	EXCHANGEABLE BASES Ca	Mg	K	Na
												Cmolc/kg			
1a	30	26	28	16	6.20	5.50	3.62	0.33	11	1.78	16.70	7.90	3.40	0.42	0.09
1b	32	16	12	40	5.70	4.40	0.93	0.11	8	0.88	10.50	3.20	2.40	0.09	0.09
2a	26	16	8	50	6.20	5.60	4.94	0.39	13	5.64	26.30	10.30	5.80	0.99	0.06
2b	50	10	4	36	5.30	4.00	1.00	0.12	8	0.95	22.50	9.00	2.60	0.43	0.09
3a	32	10	12	46	6.10	5.40	4.44	0.40	11	2.22	18.80	8.60	3.60	0.69	0.05
3b	36	10	6	48	6.00	5.20	2.40	0.23	10	1.36	14.60	5.60	3.20	0.58	0.06
4a	24	16	8	52	6.30	5.70	3.60	0.39	9	2.74	14.30	7.50	2.90	0.55	0.03
4b	48	6	6	40	5.70	4.40	1.40	0.13	11	0.40	11.00	4.40	1.70	0.13	0.05
7a	20	10	10	60	6.00	5.20	2.43	0.20	12	4.80	16.70	6.70	3.70	0.58	0.03
7b	34	14	6	46	5.00	3.80	0.81	0.10	8	3.18	12.40	4.30	3.30	0.42	0.05
8a	28	14	8	50	6.00	5.30	3.28	0.28	12	4.35	17.20	8.10	2.80	0.73	0.04
8b	48	6	6	40	5.40	4.20	1.33	0.16	8	0.94	19.40	5.50	3.10	0.25	0.09
9a	36	14	8	42	6.10	5.40	3.91	0.37	11	1.84	13.60	6.70	2.60	0.59	0.05
13a	48	10	4	38	5.90	5.30	4.33	0.33	13	3.78	16.60	6.20	4.10	0.43	0.04
13b	60	4	4	32	5.90	5.00	1.06	0.11	10	1.20	14.60	5.90	3.20	0.18	0.04
14a	36	8	4	52	5.70	5.20	2.50	0.19	13	2.15	19.60	6.40	2.20	0.21	0.02
14b	54	4	4	38	4.70	3.80	1.43	0.12	12	0.89	15.80	3.30	1.30	0.05	0.01
15a	34	16	4	46	5.10	4.60	6.48	0.36	18	4.82	28.30	8.40	2.20	0.14	0.03
15b	36	4	6	54	5.10	4.40	1.39	0.14	10	0.97	12.50	3.00	1.90	0.09	0.01
39a	40	12	12	36	4.70	4.10	4.95	0.40	12	9.56	30.40	4.40	2.70	0.49	0.02
39b	52	4	4	40	4.30	3.60	0.76	0.10	8	1.58	9.60	1.00	0.30	0.13	0.01
40a	40	12	4	44	5.80	5.20	3.12	0.33	9	3.62	14.60	4.90	3.30	0.57	0.04
40b	60	8	4	28	4.70	3.90	0.57	0.06	10	6.02	12.30	2.20	0.70	0.28	0.01
41a	52	4	6	38	5.90	4.90	0.70	0.08	9	0.49	11.30	6.60	3.70	0.48	0.02
41b	28	8	6	58	6.80	6.30	4.26	0.34	13	3.54	19.70	8.70	4.90	0.56	0.03
42a	52	18	6	24	6.00	5.30	6.47	0.53	12	1.98	23.60	9.10	7.80	0.96	0.05
42b	72	14	6	8	5.10	4.30	2.20	0.22	10	Tr	13.40	4.20	0.90	0.32	0.06
43a	30	10	4	56	6.30	5.80	3.90	0.36	11	2.07	18.30	9.30	3.60	0.76	0.04
43b	58	4	4	34	6.10	5.00	0.67	0.07	10	0.65	10.60	4.40	2.20	0.12	0.09
16a	48	10	4	38	5.80	5.00	2.73	0.23	12	1.98	18.20	7.40	3.30	0.58	0.03
16b	62	8	4	26	5.70	4.60	0.82	0.09	9	Tr	16.40	5.60	2.70	0.18	0.04
45a	60	10	4	26	5.60	4.80	2.72	0.22	12	0.03	13.80	3.90	3.80	0.28	0.03
45b	68	2	4	26	5.60	4.80	0.84	0.09	9	Tr	10.50	3.00	1.20	0.29	0.03
46a	38	12	8	42	6.00	5.30	3.39	0.27	13	1.10	19.80	8.60	5.00	0.66	0.09
46b	52	8	8	32	6.00	4.80	0.84	0.10	8	0.10	17.70	7.90	5.10	0.18	0.12
47a	38	8	8	46	6.10	5.20	2.89	0.26	11	3.16	23.40	9.90	6.60	0.47	0.09
47b	46	6	4	44	5.80	4.40	0.78	0.08	10	0.63	14.20	8.30	6.80	0.18	0.18

Table 2 continued

PLOT NO/ DEPTH	PARTICLE SIZE ANALYSIS <2	2-20	20-50	50-2000	pH 1:2.5 H2O	KCl	ORG C ---- % ----	TOTAL N	C/N	AVAILABLE P BRAY I mg/kg	CEC	EXCHANGEABLE BASES Ca	Mg	K	Na
												Cmolc/kg			
48a	50	18	4	28	6.30	5.80	5.44	0.44	12	1.52	22.10	10.40	5.20	0.91	0.08
48b	74	8	2	16	5.30	4.70	0.97	0.11	9	1.04	15.30	4.60	2.10	0.46	0.05
49a	56	10	4	30	4.70	3.90	2.90	0.23	12	2.53	17.50	2.50	1.50	0.36	0.02
49b	74	6	4	16	4.50	3.70	1.08	0.11	10	0.16	14.50	2.60	1.40	0.13	0.01
50a	48	10	6	36	6.00	5.40	4.10	0.35	12	0.93	18.80	8.50	3.70	0.53	0.05
50b	66	6	4	24	5.90	5.00	0.84	0.10	8	0.10	10.20	4.10	2.50	0.11	0.05
17a	34	12	8	46	5.90	5.20	4.47	0.38	12	2.20	24.20	10.20	4.30	0.93	0.05
17b	50	8	4	38	6.00	5.20	1.49	0.17	9	0.34	12.80	5.00	3.40	0.31	0.09
18a	42	8	6	44	5.30	4.90	2.59	0.19	14	4.13	23.20	4.80	2.70	0.61	0.05
18b	62	6	4	28	4.70	4.90	0.68	0.07	10	0.31	17.70	3.80	1.90	0.07	0.04
35a	36	14	6	44	6.40	5.70	1.70	0.19	9	2.40	16.00	8.30	3.80	0.69	0.29
35b	54	4	6	36	5.90	4.70	0.66	0.08	8	0.17	9.80	3.20	2.90	0.13	0.17
36a	20	10	6	64	6.50	6.00	1.70	0.21	8	5.39	16.10	8.50	4.80	0.52	0.05
36b	26	2	10	62	6.20	4.80	0.54	0.07	8	1.65	8.60	3.80	2.30	0.07	0.05
51a	44	12	6	38	7.20	6.60	4.10	0.37	11	0.99	19.00	14.50	4.50	0.87	0.05
51b	66	8	4	22	6.60	5.60	1.14	0.13	9	Tr	8.90	4.20	3.10	0.28	0.05
52a	26	8	8	58	5.20	4.30	2.23	0.22	10	2.18	17.40	4.90	2.10	0.45	0.05
52b	34	8	8	50	5.40	4.20	0.89	0.10	9	0.14	11.70	3.40	2.10	0.19	0.06
53a	24	10	6	60	5.60	5.10	4.52	0.39	12	2.99	21.40	6.50	4.70	0.51	0.05
54a	28	8	6	58	5.90	5.10	2.78	0.28	10	5.79	23.20	9.80	4.70	0.53	0.05
54b	40	8	6	46	5.90	5.30	1.72	0.20	9	1.05	19.70	10.60	2.10	0.43	0.05
23a	38	10	4	48	6.70	6.00	3.65	0.31	12	0.24	13.50	6.70	4.40	0.84	0.05
23b	60	4	4	32	6.70	5.70	0.88	0.09	10	Tr	10.00	7.40	1.90	0.20	0.04
24a	32	6	6	56	7.10	6.70	3.16	0.27	12	0.27	15.90	11.20	4.30	0.63	0.04
24b	54	6	6	34	6.10	5.10	1.46	0.10	15	Tr	11.30	6.30	1.70	0.07	0.05
32a	34	10	4	52	7.70	7.00	3.37	0.28	12	5.74	12.10	11.00	2.60	0.91	0.03
32b	58	6	2	34	6.50	5.40	1.07	0.12	10	Tr	10.40	4.40	3.80	0.56	0.04
33a	26	8	6	60	7.20	6.50	3.57	0.31	12	3.36	18.50	13.30	5.10	0.78	0.04
33b	40	8	6	46	6.60	5.50	1.32	0.13	10	0.51	10.90	6.80	1.80	0.47	0.05
34a	48	14	6	32	6.20	5.30	3.34	0.31	11	1.03	14.50	5.70	5.20	0.08	0.05
34b	60	12	4	24	5.40	4.40	2.03	0.18	11	1.06	13.40	2.90	2.70	0.35	0.08

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

Table 3. Analytical data for representative plots in Longuza Forest Reserve

PLOT NO/ DEPTH	PARTICLE SIZE ANALYSIS <2	2-20	20-50	50-2000	pH 1:2.5 H2O	KCl	ORG C ---- % ----	TOTAL N	C/N	AVAILABLE P BRAY I mg/kg	CEC	EXCHANGEABLE BASES Ca	Mg	K	Na
												Cmolc/kg			
1a	32	14	8	46	5.20	4.30	2.80	0.27	10	2.82	15.70	7.90	3.30	0.49	0.05
1b	66	8	4	22	5.20	4.30	1.40	0.15	9	0.08	13.50	3.80	2.90	0.15	0.05
2a	36	16	6	42	6.20	5.20	4.20	0.41	10	1.21	14.50	5.90	4.60	1.32	0.05
2b	56	12	6	26	6.20	5.10	1.70	0.19	9	0.62	13.10	5.60	3.90	0.56	0.05
3a	34	16	6	44	6.30	5.50	2.80	0.31	9	4.95	10.80	4.60	3.40	0.41	0.05
3b	56	12	4	28	6.40	5.20	1.30	0.14	9	0.80	10.00	4.20	3.30	0.31	0.06
4a	26	18	12	44	7.10	6.00	3.20	0.28	11	3.44	8.90	5.30	2.70	1.28	0.05
4b	48	12	8	32	6.50	4.70	1.10	0.12	10	0.56	10.30	4.40	4.20	0.13	0.06
5a	58	12	8	22	4.70	2.90	4.00	0.35	11	4.27	16.80	1.10	1.00	0.35	0.03
5b	66	8	2	24	3.90	3.50	1.20	0.16	8	0.79	15.30	0.80	0.30	0.17	0.05
7a	30	14	8	48	5.50	4.70	3.90	0.41	10	4.66	12.30	4.20	2.40	0.69	0.08
7b	46	8	6	40	5.50	4.00	1.10	0.12	9	0.79	11.90	3.70	2.40	0.28	0.40
8a	46	18	8	28	6.80	6.00	4.70	0.46	10	2.39	14.10	7.50	5.30	0.66	0.06
8b	68	6	4	22	6.50	5.50	1.30	0.14	9	1.32	15.20	6.60	4.90	0.43	0.05
9a	30	14	8	48	6.20	5.30	2.90	0.33	9	1.86	13.30	5.20	4.20	0.56	0.05
9b	52	8	4	36	5.60	4.10	1.30	0.14	9	0.54	11.20	4.00	2.00	0.11	0.06
10a	28	10	8	54	6.70	6.20	4.30	0.39	11	3.02	13.40	8.10	3.30	0.83	0.10
10b	34	10	6	50	6.20	5.10	2.10	0.25	8	1.36	12.80	6.70	2.60	0.29	0.14
11a	46	12	6	36	6.60	6.00	5.50	0.51	11	3.55	19.60	10.20	6.50	0.68	0.08
11b	72	4	4	20	4.70	3.30	1.08	0.12	9	0.79	16.70	2.40	1.50	0.22	0.05
12a	26	20	8	46	5.70	4.90	3.00	0.19	16	0.86	11.30	4.00	1.90	0.34	0.08
12b	44	14	6	36	5.60	4.50	1.00	0.13	8	0.26	10.90	4.20	1.70	0.15	0.03
13a	26	12	8	54	6.50	5.80	3.80	0.36	11	1.02	12.50	6.00	4.60	0.13	0.06
13b	40	10	8	42	6.20	4.90	1.70	0.18	9	0.34	13.20	4.70	4.70	0.39	0.09
14a	38	16	6	40	6.60	5.90	2.80	0.30	9	3.09	13.40	8.30	3.30	0.83	0.09
14b	60	8	4	28	6.40	5.30	1.20	0.13	9	0.87	14.30	8.30	3.20	0.22	0.04
15a	22	12	10	56	6.10	5.30	2.40	0.20	12	3.53	10.20	3.70	3.10	0.62	0.06
15b	48	4	6	42	5.70	4.30	1.10	0.12	9	0.62	11.70	3.50	2.90	0.10	0.05
16a	30	14	8	48	5.60	4.80	4.30	0.37	12	1.97	12.50	3.20	2.40	0.79	0.09
16b	48	10	4	38	5.10	4.20	1.70	0.19	9	0.46	12.90	2.70	1.90	0.26	0.09
17a	14	16	8	62	6.10	5.30	3.20	0.36	9	0.74	6.00	2.30	1.40	0.38	0.09
18a	38	16	6	40	6.70	5.80	3.80	0.33	12	4.60	14.10	7.10	5.20	0.16	0.05
18b	48	12	4	36	6.50	5.60	1.90	0.20	10	0.34	12.60	5.80	4.00	0.84	0.05
6a	31	14	7	48	5.60	4.70	4.00	0.41		4.56	12.20	4.10	2.40	0.70	0.06
6b	46	8	6	40	5.50	4.60	1.00	0.12		0.80	12.00	3.70	2.30	0.30	0.04

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

4.3 Plots description

4.3.1 Kwamarimba Forest Reserve

4.3.1.1 Plot 1

This plot covers lower slope in the area close to Zigi river and is prone to flooding. It occurs at 100 m above sea level. Dominant slope ranges from 5 to 10 %. The soils in this mapping unit are very deep, well drained, dark reddish brown topsoil to red subsoil. The texture of the soils varies from silty clay loam in the topsoil to clay loam in the subsoil.

Chemical characteristics of the soils is that the soils are slightly acid in the topsoils and the soil reaction decreases and become medium acid in the subsoil with pH values that ranges from 6.2 to 5.7 respectively. The organic carbon are generally very high with levels around 3.62 % in the topsoil and decreases to low or very low (0.93 %) levels in the subsoil. The organic carbon inthe subsol is generally less than 0.1 %. Total nitrogen on the otherhand varies from medium in the topsoil to low in the subsoil with values 0.33 and 0.11 respectively. Based on the C/N ratios the organic matter content are of good quality implying that net mineralisation is possible. Available phosphorus are low with values ranging from 1.78 mgP/kg in the topsoil to 0.88 mgP/kg in the subsoil.
Cation exchange capacity varies from medium (16.7 Cmolc/kg) in the topsoil to low levels (10.5 Cmolc/kg) in the subsoil. The exchangeable calcium are high (12.6 Cmolc/kg) in the topsoil and decreases to low levels (3.2 Cmolc/kg) in the subsoil. The magnesium levels are generally high to medium in the topsoil and subsoil respectivelly. 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. No data on tree species are available for this plot during the reporting time.

4.3.1.2 Plot 2

This plot is located at the upper slope at 145 m above sea level. The plot has rockoutcrop especially along the drainage line. The soils in this plot are very shallow, well drained, dark red, sandy clay loam to clay soil.

The pH of the soils in this plot indicate that the soil reaction ranges from slightly acid (pH 6.2) in the topsoil to strongly acid (pH 5.3) in the subsoil. Organic carbon is very high in the topsoil (4.94 %) but decreases to low levels (1.00 %) in the subsoil. Total nitrogen on the otherhand ranges from medium (0.39 %) in the topsoil to low levels (0.12 %) in the subsoil. The organic matter found within the plot as indicated by the C/N ratio are of good quality. Available phosphorus is low. The value is generally less than 7 mgP/kg.

The ability of the soil to retain and release nutrients for plant uptake is medium over the sampling depth. The levels ranges from 26.3 to 22.5 Cmolc/kg in the topsoil and subsoil respectively. Exchangeable calcium in this plot is very high both in topsoil and subsoil. The levels ranges from 10.3 to 9.0 Cmolc/kg in topsoil and subsoil respectively. Magnessium levels ranges from high (5.8 Cmolc/kg) in the topsoil to medium levels (2.6 Cmolc/kg) in the subsoil. Potassium levels are medium in both topsoil and subsoil. The values ranges from 0.99 to 0.43 Cmolc/kg in topsoil and subsoil respectively. Exchangeable sodium is very low showing less possibility of sodicity development. Data on tree species classification could not available during the reporting time.

4.3.1.3 Plot 3

This plot is located at the middle slope at 150 m above sea level. The plot has rock outcrop spaced between 5 to 10 m apart. The soils in this plot are very shallow, well drained, dark red, sandy clay loam to clay soil.

The soil reaction in this plot is slightly acid (pH 6.0 to 6.1). Organic carbon is very high (4.44 %) in the topsoil which decreases to medium (2.40 %) levels in the subsoil. Total nitrogen on the otherhand is dominantly of medium levels in both topsoil and subsoil. The values ranges from 0.4 to 0.23 % in topsoil and subsoil respectively. Carbon to nitrogen ratio indicate good quality organic matter with dominantly low levels of the available phosphorus.

The cation exchange capacity, the parameter which indicate the ability of the soil to retain and supply nutrients for plant uptake is medium. The levels varies from 18.8 in the topsoil to 14.6 Cmolc/kg in the subsoil. Exchangeable calcium are very high throughout the sampling depth (8.6 to 5.7 Cmolc/kg). Magnessium levels are dominantly high (3.6 to 3.2 Cmolc/kg) in topsoil and subsoi respectively. Exchangeable potassium on the otherhand is medium (0.69 and 0.58 Cmolc/kg) in topsoil and subsoil repectively. Sodium levels are generally very low with levels less than 0.1 Cmolc/kg. Data on tree species found in this plot could not be available by the time this report was compiled.

4.3.1.4 Plot 4

This plot is locates at middle slope at 145 to 150 m above sea level. Dominant slope gradient ranges from 17 to 20 %. The soils in this plot are deep to very deep, well drained, dark red to red, sandy clay loam to clay soils.

The pH of the soils ranges from slightly acid (pH 6.3) in the topsoil to medium acid (pH 5.7) in the subsoil. Organic carbon varies from very high (3.6 %) in topsoil to medium levels (1.4 %) in the subsoil. Total nitrogen ranges from medium levels (0.39 %) in the topsoil to low levels (0.13 %) in the subsoil. Organic matter are of good quality with low levels of the available phosphorus.

Cation exchange capacity varies from medium levels (14.3 Cmolc/kg) in the topsoil to low levels (11.0 Cmolc/kg) in the subsoil. Exchangeable calcium are very high (7.5 Cmolc/kg) in the topsoil to high (4.4 Cmolc/kg) in the subsoil. Magnessium levels decreases with soil depth. The topsoil has medium levels (2.9 Cmolc/kg) while the subsoil has 1.7 Cmolc/kg levels of the exchangeable magnessium. Levels of potassium ranges from medium (0.55 Cmolc/kg) in the topsoil to low levels (0.13 Cmolc/kg) in the subsoil. Exchangeable sodium is very low. Tree species data on these plots was not available for reporting.

4.3.1.5 Plot 5

This plot is locates at middle slope at 135 m above sea level. Dominant slope gradient ranges from 15 to 20 %. The soils in this plot are deep to very deep, well drained, dark red to red, sandy clay loam to clay soils.

The pH of the soils ranges from slightly acid (pH 6.3) in the topsoil to medium acid (pH 5.7) in the subsoil. Organic carbon varies from very high (3.6 %) in topsoil to medium levels (1.4 %) in the subsoil. Total nitrogen ranges from medium levels (0.39 %) in the topsoil to low levels (0.13 %) in the subsoil. Organic matter are of good quality with low levels of the available phosphorus.

Cation exchange capacity varies from medium levels (14.2 Cmolc/kg) in the topsoil to low levels (11.0 Cmolc/kg) in the subsoil. Exchangeable calcium are very high (7.3 Cmolc/kg) in the topsoil to high (4.4 Cmolc/kg) in the subsoil. Magnessium levels decreases with soil depth. The topsoil has medium levels (2.9 Cmolc/kg) while the subsoil has 1.7 Cmolc/kg levels of the exchangeable

magnessium. Levels of potassium ranges from medium (0.55 Cmolc/kg) in the topsoil to low levels (0.13 Cmolc/kg) in the subsoil. Exchangeable sodium is very low.

4.3.1.6 Plot 6

This plot is located at middle slope at 140 m above sea level. Dominant slope gradient ranges from 15 to 18 %. The soils in this plot are deep to very deep, well drained, dark red to red, sandy clay loam to clay soils.

The pH of the soils ranges from slightly acid (pH 6.3) in the topsoil to medium acid (pH 5.7) in the subsoil. Organic carbon varies from very high (3.7 %) in topsoil to medium levels (1.42 %) in the subsoil. Total nitrogen ranges from medium levels (0.39 %) in the topsoil to low levels (0.13 %) in the subsoil. Organic matter are of good quality with low levels of the available phosphorus.

Cation exchange capacity varies from medium levels (14.8 Cmolc/kg) in the topsoil to low levels (11.4 Cmolc/kg) in the subsoil. Exchangeable calcium are very high (7.3 Cmolc/kg) in the topsoil to high (4.4 Cmolc/kg) in the subsoil. Magnessium levels decreases with soil depth. The topsoil has medium levels (2.9 Cmolc/kg) while the subsoil has 1.7 Cmolc/kg levels of the exchangeable magnessium. Levels of potassium ranges from medium (0.50 Cmolc/kg) in the topsoil to low levels (0.13 Cmolc/kg) in the subsoil. Exchangeable sodium is very low. Tree species data on these plots was not available for reporting.

4.3.1.7 Plot 7

Plot 7 is located at lower slope about 100 m from Zigi river and therefore subject to flooding. The elevation to which the plot occurs is at 90 to 130 m above sea level. The soils in the plot are moderately deep to deep, well drained with rock outcrop especially along the drainage line, dark red, sandy loam or sandy clay loam to clay soils.

The soils in this plot has reaction that varies from slightly acid (pH 6.0) in the topsoil to medium acid (pH 5.6) in the subsoil. Organic carbon of the soils is medium in the topsoil (2.43 %) which decreases to low levels in the subsoil (0.81 %). Total nitrogen ranges from low (0.2 %) to very low (0.1 %) in topsoil and subsoil respectively. The organic matter are of good quality. This is indicated by the C/N ratio whose value ranges from 12 to 8. Available phosphorus is generally low.

The cation exchange capacity is medium both in topsoil and subsoil. The levels varies from 16.7 to 11.4 Cmolc/kg. Calcium levels are very high (6.7 Cmolc/kg) in the topsoil to high (4.3 Cmolc/kg) in the subsoil. Exchangeable magnessium levels are dominantly high in both topsoil and subsoil. The values ranges from 3.7 in the topsoil to 3.3 Cmolc/kg in the subsoil. Exchangeable potassium is generally medium in both topsoil and subsoil. The levels are 0.58 Cmolc/kg in the topsoil and 0.42 Cmolc/kg in the subsoil respectively. The levels of sodium are generally very low.

4.3.1.8 Plot 8

The plot has slope gradient varying from 30 to 45 % at 130 m above sea level. The soils are shallow or very shallow with effective rooting depth less than 30 cm, dark reddish brown to red, sandy clay loam to clay in texture. Rock outcrops are seen at the surface.

The pH of the soils is slightly acid to medium acid, organic carbon is high in the topsoil with values of about 3.28 % and becomes medium in the subsoil (1.33 %). Total nitrogen is medium and decreases to low levels in the subsoil with respective values of 0.28 to 0.16 %.

Available phosphorus are low while the cation exchange capacity is medium. Exchangeable calcium is very high (more than 5.0 Cmolc/kg) while exchangeable magnesium is high to medium. Potassium

on the otherhand is medium to low levels in the topsoil and subsoil respectively. Sodium levels in the soil is very low. Tree species data on these plots was not available for reporting.

4.3.1.9 Plot 9

The plot is located at upper slope with slope gradient varying from 25 to 30 % at an altitude 120 to 125 m above sea level. The soils are shallow or very shallow with effective rooting depth less than 35 cm. Dominantly clay in texture. Rock outcrops are seen at the surface.

The pH of the soils is slightly acid (pH 6.1) in the topsoil. Organic carbon is high in the topsoil with values of about 3.91 %. Total nitrogen is medium (3.91 %). The carbon to nitrogen ratio show good quality organic matter. Available phosphorus are low with values less than 7mgP/kg. Cation exchange capacity is medium (13.6 Cmolc/kg). Exchangeable calcium is very high (more than 5.0 Cmolc/kg) while exchangeable magnesium is medium (2.6 Cmolc/kg). Potassium on the otherhand is medium (0.59 Cmolc/kg) in the topsoil. Sodium levels in the soil is very low.

Tree species which are dominant within the plot are *Antiaris toxicaria, Diospyros natalensis, Combretum schumannii, Lecaniodiscus fraxinifolius, Uvariodendron sp; Fernandoa magnifica, Antiaris toxicaria, Newtonia paucijuga, Acacia senegal, Maytenus acuminata, Antiaris toxicaria* and *Acacia sp.*.

4.3.1.10 Plot 10

Plot 10 is located at the middle part of the slope with dominant slope gradient ranges from 40 to 45 %. The elevation to which this plot is found is at 190 m above sea level. The soils in the plot are deep to very deep, well drained, dark red to red, clay soils.

The soils in this plot are strongly acid (pH 5.2) in both topsoil and subsoil. Organic carbon are dominantly very high (6.58 %) in topsoil and medium levels (1.35 %) in the subsoil. Total nitrogen on the otherhand ranges from medium to low levels. The value are 0.34 % in the topsoil and 0.14 % in the subsoil. The organic matter are of good quality with low levels of the available phosphorus.

Cation exchange capacity of the soils in this plot is high in the topsoil (26.3 Cmolc/kg) but decreases to medium levels (13.8 Cmolc/kg) in the subsoil. Calcium levels are very high in the topsoil (8.4 Cmolc/kg) to high (3.1 Cmolc/kg) in the subsoil. Exchangeable magnessium are dominantly medium in both topsoil and subsoil. The levels are 2.2 and 1.9 Cmolc/kg respectively. Potassium levels in this plot are very low with levels less than 0.20 Cmolc/kg. Exchangeable sodium is very low.

4.3.1.11 Plot 11

The plot is located at 220 m above sea level with 20 % slope gradient. The soils are deep to very deep, well drained, dark reddish brown to red, clayey in texture. The soils shows high intensity of weathering as there is very little horizon differentiation.

The soil reaction is very strongly acid (pH 4.8) in the topsoil which decreases to pH value of 4.5 in the subsoil. Organic carbon is very high (4.95 %) in the topsoil to high levels (2.76 %) in the subsoil. Total nitrogen medium (0.40 %) in the topsoil which decreases to low levels (0.10 %) in the subsoil. C/N ratio indicates presence of good quality organic matter with low levels of available phosphorus.

The plot has high levels of the cation exchange capacity. The CEC levels are 31.4 Cmolc/kg in the topsoil while the CEC levels in the subsoil is low to medium (9.6 Cmolc/kg). Exchangeable calcium is high (4.6 Cmolc/kg) which decreases to medium levels (1.0 Cmolc/kg) in the subsoil. Magnessium levels are medium (2.7 Cmolc/kg) in the topsoil which becomes low (0.3 Cmolc/kg) in the subsoil.

Potassium are generally medium (0.49 Cmolc/kg) in the topsoil and decreases to low (0.13 Cmolc/kg) levels in the subsoil. Exchangeable sodium are very low.

4.3.1.12 Plot 12

The plot is located at 185 to 190 m above sea level with 20 to 24 % slope gradient. The soils are deep to very deep, well drained, dark reddish brown to red, clayey in texture. The soils shows high intensity of weathering as there is very little horizon differentiation.

The soil reaction is very strongly acid (pH 4.9) in the topsoil which decreases to pH value of 4.3 in the subsoil. Organic carbon is very high (4.95 %) in the topsoil to high levels (2.76 %) in the subsoil. Total nitrogen medium (0.40 %) in the topsoil which decreases to low levels (0.10 %) in the subsoil. C/N ratio indicates presence of good quality organic matter with low levels of available phosphorus.

The plot has high levels of the cation exchange capacity. The CEC levels are 31.8 Cmolc/kg in the topsoil while the CEC levels in the subsoil is low to medium (9.3 Cmolc/kg). Exchangeable calcium is high (4.4 Cmolc/kg) which decreases to medium levels (1.3 Cmolc/kg) in the subsoil. Magnessium levels are medium (2.9 Cmolc/kg) in the topsoil which becomes low (0.4 Cmolc/kg) in the subsoil. Potassium are generally medium (0.49 Cmolc/kg) in the topsoil and decreases to low (0.11 Cmolc/kg) levels in the subsoil. Exchangeable sodium are very low.

4.3.1.13 Plot 13

The plot covers the area at 200 m above sea level with slope gradient ranging from 8 to 10 %. The soils in this plot are very deep, well drained, dark red to red and clay in texture.

The soils are medium acid with pH values of 5.9. Organic carbon is very high in the topsoil (4.33%) thereby becoming low (1.06%) in the subsoil. Total nitrogen is medium (0.33 %) in the topsoils and becomes low 0.11%) in the subsoil. Availavble phosphorus is low while the cation exchange capacity is medium with values ranging from 16.6 and 14.6 Cmolc/kg in the topsoil and subsoil respectively. Exchangeable calcium is very high with values greater than 5.0 Cmolc/kg. Magnesium levels are high in the topsoil (4.1 Cmolc/kg) but becomes medium (3.2 Cmolc/kg) in the subsoil . Exchangeable potassium is medium in the topsoil (0.43 Cmolc/kg) and low in the subsoil (0.18 Cmolc/kg). Exchangeable sodium levels are very low (0.04 Cmolc/kg).

This plot is characterised by open forest with mixed vegetation dominated mainly by grasses. Other type of the vegetation in this mapping unit include open forest with mixed types of different trees. Common tree species found in the mapping unit include *Markhamia obtusifolia, Milicia exceba, Antiaris toxicaria, Leptactina platyphylla, Trilepisium madagascariensis, Dombeya shupangae, Trichilia emetica, Fernandoa magnifica, Stereospermum kunthianum, Bridelia micrantha, Albizia gummifera and Vangueria infausta.*

4.3.1.14 Plot 14

Plot 14 is located at the middle part of the slope with dominant slope gradient of about 25 %. The elevation to which this plot is found is at 210 m above sea level. The soils in the plot are deep to very deep, well drained, dark red to red, clay soils. The soils are highly weathered as indicated by little horizon differentiation.

Soil reaction at the topsoil is medium acid (pH 5.7) which decreases to strongly acid or very strongly acid (pH 4.3). Organic carbon is medium (2.50 in the topsoil and 1.43 % in the subsoil). Total nitrogen varies from medium levels (0.19 %) in the topsoil to low levels (0.12 %) in the subsoil. The organic matter are of good quality with low levels of the available phosphorus.

The cation exchange capacity of the soil is dominantly medium in both topsoil and subsoil. The levels are 19.6 Cmolc/kg in the topsoil and 15.8 Cmolc/kg in the subsoil respectively. Exchangeable calcium is very high (6.4 Cmolc/kg) in the topsoil which decreases to high levels (3.3 Cmolc/kg) in the subsoil. Magnessium levels are very high (2.2 Cmolc/kg) in the topsoil while medium (1.3 Cmolc/kg) in the subsoil. Exchangeable potassium is low (0.21 Cmolc/kg) to very low (0.05 Cmolc/kg) in topsoil and subsoil respectively. Sodium levels are generally very low.

Tree species which are dominant within the plot include *Diospyros natalensis, Markhamia lutea, Milicia excelsa, Xylopia parviflora, Maytenus acuminata, Xylopia parviflora, Lecaniodiscus fraxinifolius, Tarnna graveolens, Zanthoxylum usambarense, Vincentella passargei, Bombax rhodognaphalon, Antiaris toxicaria, Milicia excelsa, Leptactina platyphylla and Ricinodendron heudelotii.*

4.3.1.15 Plot 15

Plot 15 is located at the middle part of the slope with dominant slope gradient ranges from 45 to 50 %. The elevation to which this plot is found is at 200 m above sea level. The soils in the plot are deep to very deep, well drained, dark red to red, clay soils.

The soils in this plot are strongly acid (pH 5.1) in both topsoil and subsoil. Organic carbon are dominantly very high (6.48 %) in topsoil and medium levels (1.39 %) in the subsoil. Total nitrogen on the otherhand ranges from medium to low levels. The value are 0.36 % in the topsoil and 0.14 % in the subsoil. The organic matter are of good quality with low levels of the available phosphorus.

Cation exchange capacity of the soils in this plot is high in the topsoil (28.3 Cmolc/kg) but decreases to medium levels (12.5 Cmolc/kg) in the subsoil. Calcium levels are very high in the topsoil (8.4 Cmolc/kg) to high (3.0 Cmolc/kg) in the subsoil. Exchangeable magnessium are dominantly medium in both topsoil and subsoil. The levels are 2.2 and 1.9 Cmolc/kg respectively. Potassium levels in this plot are very low with levels less than 0.20 Cmolc/kg. Exchangeable sodium is very low.

Dense, mature and mixed without tree dominance are the characteristics of the trees in this plot. Tree species which are dominant in the plot are *Dorstenia kameruniana, Drypetes gerrardii, Cynometra fischeri, Tricalysia, pallens, Scorodophloeus fischeri, Craibia brevicandata, Schefflerodendron usambarense, Fernandoa magnifica, Drypetes gerrardii, Angylocalyx braunii, Sericanthe ordoratuisima, Julbemadia magnistipulata, Rinorea ferruginea, Drypetes gerrardii, Craibia brevicandata, Diospyros natalensis, Diospyros natalensis, Lannea welwitschii, Morus mesozygia and Diospyros abyssinica.*

4.3.1.16 Plot 16

The plot is located at upper slope with slope gradient varying from 25 to 35 % at an altitude ranging from 125 to 130 m above sea level. The soils are shallow or very shallow with effective rooting depth less than 35 cm. The soils are clay in texture.

The pH of the soils is slightly acid (pH 6.1) in the topsoil. Organic carbon is high in the topsoil with values of about 3.91 %. Total nitrogen is medium (3.91 %). The carbon to nitrogen ratio show good quality organic matter. Available phosphorus are low with values less than 7mgP/kg. Cation exchange capacity is medium (13.6 Cmolc/kg). Exchangeable calcium is very high (more than 5.0 Cmolc/kg) while exchangeable magnesium is medium (2.6 Cmolc/kg). Potassium on the otherhand is medium (0.59 Cmolc/kg) in the topsoil. Sodium levels in the soil is very low.

The plot is characterised by dense, mature nad mixed tree species without dominance. The commonly occuring tree species within the plot include *Antiaris toxicaria, Combretum schumanii, Diospyros*

natalensis, Lecaniodiscus fraxinifolius, Uvariodendron spp; Vincentella passargei, Fernandoa magnifica, Newtonia paucijuga, Acacia senegal and Maytenus acuminata.

4.3.1.17 Plot 17

This plot is located in lower slope at the area almost near the valley at an elevation of 150 to 160 m above sea level with 15 % slope gradient. The soils are deep, well drained, dark reddish brown, clayey soils.

The soil is medium acid (pH 5.9 to 6.0). Organic carbon is very high (4.47 %) in the topsoil which decreases with soil depth to medium levels (1.49 %) in the subsoil. Total nitrogen ranges from medium levels (0.38 %) in the topsoil to low levels (0.17 %) in the subsoil. C/N ratio indicate good quality organic matter with dominantly low levels of the available phosphorus.

Cation exchange capacity of the soil is dominantly medium in both topsoil and subsoil with respective values of 24.2 12.8 Cmolc/kg. Exchangeable calcium is generally very high with levels varying from 10.2 Cmolc/kg in the topsoil to 5.0 Cmolc/kg in the subsoil. Magnessium levels are high both in topsoil and subsoil. The levels ranges from 4.3 Cmolc/kg in the topsoil to 3.4 Cmolc/kg in the subsoil. Exchangeable potassium are medium in topsoil (0.93 Cmolc/kg) which becomes low (0.31 Cmolc/kg) in the subsoil. Sodium levels are generally very low.

The plot is generally characterised by the presence of dense forest with mature trees. The tree species are mixed such that there is no tree dominance in the area. Dominant tree species include *Diospyros natalensis, Maytenus acuminata, Markhamia lutea, Brideria micrantha, Acacia senegal, Antiaris toxicaria, Mimusops sp., Leptactina platyphylla, Milicia excelsa, Terenna nigrescens, Vincentella passargei, Fernandoa magnifica, Terminalia sambesiaca, Manilkara sulcata, Celtis wightii, Diospyros squrrosa, Terenna migrescens, Mildbraedia fallax, Xylopia parviflora, Fernandoa magnifica, Zanthoxylum usambarense and Lecaniodiscus fraxinifolius.*

4.3.1.18 Plot 18

The plot found on upper slopes and summits at 185 m above sea level. Dominant slope gradient ranges from 15 to 18 %. The soils are very deep, well drained, dark reddish brown to red, clayey.

The soils are strongly acid to very strongly acid in topsoil and subsoil respectively with corresponding value of 5.3 and 4.7. Organic carbon is high (2.59 %) in the topsoil and low (0.68 %) in the subsoil. Total nitrogen on the otherhand is low to very low with levels ranging from 0.19 to 0.1 %. Available phosphorus is low with levels less than 5.0 mgP/kg.

The cation exchange capacity is medium in both topsoil and subsoil with values 23.2 and 17.7 Cmolc/kg in topsoil and subsoil respectively. Calcium levels is high (4.8 and 3.8 Cmolc/kg) in topsoil and subsoil respectively. Exchangeable magnesium on the otherhand is medium both in topsoil and subsoil (2.7 and 1.9 Cmolc/kg). Levels of exchangeable potassium is medium in the topsoil (0.61 Cmolc/kg) but becomes low or very low in the subsoil (0.1 Cmolc/kg). Exchangeable sodium is generally very low. The levels of sodium is dominantly less than 0.1 Cmolc/kg.

The plot is having dense, mature and mixed forest without tree dominance. The type of tree species found in the plot include *Diaspyros natalensis, Bridelia micrantha, Vincentella passargei, Lecaniodiscus fraxinifolius, Dialium holtzii, Nersogodonia holtzii, Fernandoa magnifica, Rotumanina manganjae, Lannea welwitschii, Antiaris toxicaria, Holarrhena pubescens, Chytranthus obliquinervis, Markhamia lutea, Xylopia passargei, Blighia spp and Trilepsium madagascariensis*.

4.3.1.19 Plot 19

Plot 19 is located at the middle part of the slope with dominant slope gradient of about 25 to 30 %. The elevation to which this plot is found is at 215 m above sea level. The soils in the plot are deep to very deep, well drained, dark red to red, clay soils. The soils are highly weathered.

Soil reaction at the topsoil is medium acid (pH 5.7) which decreases to strongly acid or very strongly acid (pH 4.3). Organic carbon is medium (2.50 in the topsoil and 1.43 % in the subsoil). Total nitrogen varies from medium levels (0.19 %) in the topsoil to low levels (0.12 %) in the subsoil. The organic matter are of good quality with low levels of the available phosphorus.

The cation exchange capacity of the soil is dominantly medium in both topsoil and subsoil. The levels are 19.6 Cmolc/kg in the topsoil and 15.8 Cmolc/kg in the subsoil respectively. Exchangeable calcium is very high (6.4 Cmolc/kg) in the topsoil which decreases to high levels (3.3 Cmolc/kg) in the subsoil. Magnessium levels are very high (2.2 Cmolc/kg) in the topsoil while medium (1.3 Cmolc/kg) in the subsoil. Exchangeable potassium is low (0.21 Cmolc/kg) to very low (0.05 Cmolc/kg) in topsoil and subsoil respectively. Sodium levels are generally very low.

The trees forms dense, mature and mixed forests such that there is no single tree species dominating. The commonly occuring tree species in the plot include *Diospyros natalensis, Markhamia lutea, Milicia excelsa, Xylopia parviflora, Maytenus acuminata, Lecaniodiscus fraxinifolius, Tarrena graveolens, Vencentella parrargei, Bombax rhodognaphalon, Antiaris toxicaria, Leptactina platyphylla and Ricinodndron hendelotii.*

4.3.1.20 Plot 20

The plot is found in lower slopes with slope gradient that varies from 20 to 30%. The altitude to which the plot is found is 160 m above sea level. The plot is generally well drained, very deep without rockoutcrop and surface stoniness. The soils in the unit are dark brown in colour that changes to red in the subsoil. The texture of the soil in this plot is dominantly clay.

The soil reaction is slightly acid in the topsoil (pH 6.3) but decreases down the profile to medium acid (5.4). Organic carbon is dominantly very high (5.44 %) in the topsoil but decreases to low levels in the subsoil. The levels of organic carbon in the subsoil is 0.97 %. Total nitrogen is medium (0.44 %) in the topsoil and decreases to low levels in the subsoil (0.11 %). The available phosphorus are low over the whole profile with values dominantly less than 7 mg P/kg.

The cation exchange capacity which determine the ability of the soils to retain and supply nutrients to plants is medium in the topsoil with levels of about 22.1 Cmol/kg. The CEC at the subsoil is also medium (15.3 Cmol/kg). The exchangeablve calcium is high to low in with values ranging from 10.4 to 4.6 Cmol/kg in topsoil and subsoil respectively. Exchangeable magnesium is high in topsoil and medium in subsoil. The values varies from 5.2 to 2.1 Cmol/kg in topsoil and subsoil respectively. Potassium on the other hand is dominantly medium with K values that ranges from 0.91 and 0.46 in topsoil and subsoil respectively. Sodium levels are very low with values dominantly less than 0.10 Cmok/kg. Phosphorus levels are low.

Characteristically the plot is having dense and mature trees that are mixed such that there is no no tree dominance. Commonly occuring tree species in the plot however *include Julbernadia magnistipulata, Terminalia sambesiaca, Kigelia africana, Leptactina platyphylla, Markhamia lutea, Xylopia parviflora, Ricinodendron heudelotii, Dialium holtzii, Rothmannia manganjae, Lecaniodiscum fraxinifolius, Lettonwianthus stellatus, Diospyros squarrosa, Dracaena steudneri, Dialium holtzii, Diospyros natalensis, Julbernadia magnistipulata, Sterculia appendiculceta, Ricinodendron heudelotii, Grewia goetzeana, Scorodophleus fischeri, Dracaena steudneri, Teclea simplicifolia,*

Diospyros natalensis, Combretum schumannii, Pterocarpus tinctorius, Celtis africana, Grewia bicolor and Brypetes usambarica.

4.3.1.21 Plot 21

This plot is situated at the lower part of the slope with dominant slope gradient ranging from 35 to 40 %. The elevation to which the plot occurs is at 170 m. The soils in this plot are moderately deep with effective rooting depth of 50cm, well drained, dark red to red, clay loam to clay soils.

The pH of the soils indicate that the soil reaction of the soils in this plot varies from slithly acid to neutral. Organic carbon is very high in the topsoil (3.65 %) but decreases to low levels (0.9 %) in the subsoil. Total nitrogen on the otherhand varies from medium (0.31 %) in the topsoil to low levels (0.1 %) in the subsoil. The carbon to nitrogen ratio ranges from 10 to 12 which indicate good quality organic matter. The levels of the available phosphorus is dominantly low.

The capacity of the soils to retain and supply nutrients for plant uptake is medium. The value varies from 13.5 to 10.7 Cmolc/kg in the topsoil and subsoil respectively. Exchangeable calcium is very high in both topsoil and subsoil. The levels varies from 7.4 to 6.3 Cmolc/kg. Magnessium levels on the otherhand ranges from high (4.4 Cmolc/kg) in the topsoil to medium (1.9 Cmolc/kg) in the subsoil. Exchangeable potassium is high (0.84 Cmolc/kg) in the topsoil which decreases to low levels (0.2 Cmolc/kg) in the subsoil. Sodium levels are generally very low with dominantly values less than 0.1 Cmolc/kg.

The plot forms an open forest that formerly has been encroached and colonised. Dominant tree species include *Ficus valischoudae, Trichilia emetica, Dombeya shupangae, Blighia unijugata, Albizia gummifera, Stereospermum kunthianum, Cussonia zimmermannii, Albizia versicolor, Trichilia emetica, Annona senegalensis, Ficus sycomoms, and Lannea schweinfurthii*.

4.3.1.22 Plot 22

Located at 245 to 250 m above sea level, this plot occurs at upper part of the slope with 45-50 % slope gradient. The plot is one of the steepest parts in the study area. The soils in this plot are moderately deep, well drained, dark red to red clay soils.

The pH of the soils indicate that the soil reaction of the soils in this plot varies from slithly acid to neutral. Organic carbon is very high in the topsoil (3.65 %) but decreases to low levels (0.9 %) in the subsoil. Total nitrogen on the otherhand varies from medium (0.31 %) in the topsoil to low levels (0.1 %) in the subsoil. The carbon to nitrogen ratio ranges from 10 to 12 which indicate good quality organic matter. The levels of the available phosphorus is dominantly low.

The capacity of the soils to retain and supply nutrients for plant uptake is medium. The value varies from 13.5 to 10.7 Cmolc/kg in the topsoil and subsoil respectively. Exchangeable calcium is very high in both topsoil and subsoil. The levels varies from 7.3 to 6.2 Cmolc/kg. Magnessium levels on the otherhand ranges from high (4.4 Cmolc/kg) in the topsoil to medium (1.9 Cmolc/kg) in the subsoil. Exchangeable potassium is high (0.84 Cmolc/kg) in the topsoil which decreases to low levels (0.2 Cmolc/kg) in the subsoil. Sodium levels are generally very low with dominantly values less than 0.1 Cmolc/kg.

Commonly occuring tree species in this plot include *Nersogodonia holstii, Scorodophleus fischeri, Cynometra webberi, Manilkara sulcata, Lannea welwitschii, Combretum schumannii, Drypetes gerrardii, Julbernadia magnistipulata, Diospyros natalensis, Celtis africana, Diospyros natalensis, Drypetes usambarica, Celtis africana, Gyrocarpus americanus, Fernandoa magnifica, Vincentella passargei, Craibia brevicaudata, Lecaniodiscus fraxinifolius, Lannea welwitschii, Drypetes gerrardii,*

Rinorea ferruginea, Dorstenia wameruniana, Dorstenia kameruniana, Cynometra sp., Mkilua fragrans and *Craibia brevicaudata.*

4.3.1.23 Plot 23

Plot 23 is found at 230 m above sea level at an area with 25 % slope gradient in the mid slope. The soils are are very deep with 110 m effective rooting depth, well drained, dark reddish brown to red, clay soil.

The pH of the soils indicate that the soil reaction of the soils in this plot varies from slithly acid to neutral. Organic carbon is very high in the topsoil (3.65 %) but decreases to low levels (0.9 %) in the subsoil. Total nitrogen on the otherhand varies from medium (0.31 %) in the topsoil to low levels (0.1 %) in the subsoil. The carbon to nitrogen ratio ranges from 10 to 12 which indicate good quality organic matter. The levels of the available phosphorus is dominantly low.

The capacity of the soils to retain and supply nutrients for plant uptake is medium. The value varies from 13.5 to 10.7 Cmolc/kg in the topsoil and subsoil respectively. Exchangeable calcium is very high in both topsoil and subsoil. The levels varies from 7.4 to 6.3 Cmolc/kg. Magnessium levels on the otherhand ranges from high (4.4 Cmolc/kg) in the topsoil to medium (1.9 Cmolc/kg) in the subsoil. Exchangeable potassium is high (0.84 Cmolc/kg) in the topsoil which decreases to low levels (0.2 Cmolc/kg) in the subsoil. Sodium levels are generally very low with dominantly values less than 0.1 Cmolc/kg.

Vegetation forms open forest that mainly make woodland with generally poor cover. Tree species which are dominant include *Trichilia emetica, Annona senegalensis, Dombeya shupangae, Annona senegalensis, Vangueria infausta, Lannea schweinfurthii, Milicia excelsa, Grewia bicolor, Bridelia micrantha, Trichilia emetica and Bridelia micrantha.*

4.3.1.24 Plot 24

This plot is located in the lower part of the slope at 30 % slope gradient. The elevation to which the plot is situated is at 220 m above sea level. The soils are deep to very deep with effective rooting depth of 105 m, well drained, slightly compacted, dark red to red, clay soil.

The soils in this plot are slightly acid to neutral. pH ranges from 7.1 in the topsoil to 6.3 in the subsoil. Organic carbon varies from high (3.16 %) in the topsoil to medium (1.5 %) in the subsoil. Total nitrogen is medium (0.3 %) in the topsoil while in the subsoil the levels of the total nitrogen is low (0.1 %) in the subsoil. The carbon to nitrogen ratio varies from 12 in the topsoil to 15 in the subsoil. This indicate good quality organic matter in the topsoil while moderate quality of the orgnic matter are found in the subsoil. Available phosphorus is generally low.

Medium levels of cation exchange capacity is found in both topsoil and subsoil. It ranges from 15.9 Cmolc/kg in the topsoil to 11.3 Cmolc/kg in the subsoil. Calcium levels are very high ranging from 11.2 to 6.3 Cmolc/kg in topsoil and subsoil respectivelly. Exchangeable magnessium ranges from high (4.3 Cmolc/kg) in the topsoil to medium levels (1.7 Cmolc/kg) in the subsoil. Potassium levels are medium (0.63 Cmolc/kg) in the topsoil to low or very low levels (0.1 Cmol/kg) in the subsoil. Exchangeable sodium is very low.

These tree species forms an open forest that characteristically make woodland with grasses. This plot is mainly at the edge of the forest. Dominant tree species within the plot include *Stereospermum kunthianum, Annona senegalensis, Dombeya shupangae, Bridelia micrantha, Antiaris toxicaria, Cussonia zimmermannii, Albizia gumifera, Trichilia emetica, Diospyros natalensis, Lannea schweinfurthii, Millettia stuhlmannii, Albizia gumifera, Markhamia lutea, Pterocarpus mildbraedii, Albizia gumifera and Bridelia micrantha.*

4.3.1.25 Plot 27

The plot is located at 210 m above sea level with 20 to 25 % slope gradient. The soils are deep, well drained, dark reddish brown to red and clay in texture. The soils shows high intensity of weathering as there is very little horizon differentiation.

The soils reaction is medium acid (pH 5.8) in the topsoil which slightly decreases with soil depth to very strongly acid (pH 4.7) in the subsoil. Organic carbon is high (3.12 %) but significantly decreases to low levels (0. 57 %) in the subsoil. Total nitrogen is medium (0.33 %) at the topsoil which becomes very low at the subsoil. The levels are 0.06 % at the subsoil. Organic matter are of good quality. Available phosphorus is low with levels varying from 3.6 mgP/kg in the topsoil to 6.0 mgP/kg in the subsoil.

The cation exchange capacity is medium in both topsoil (14.6 Cmolc/kg) and subsoil (12.3 Cmolc/kg) with high levels of exchangeable calcium. The levels of calcium are 4.9 Cmolc/kg in the topsoil to 2.2 Cmolc/kg in the subsoil. Magnessium levels are medium to high (3.3 Cmolc/kg) in the topsoil which decreases to low levels (0.7 Cmolc/kg) in the subsoil. Exchangeable potassium is generally is medium (0.57 Cmolc/k) to low (0.28 Cmolc/kg) in topsoil and subsoil respectively. Sodium levels are dominantly very low with values less than 0.1 Cmolc/kg.

The tree species in this plot forms dense, mature forest that is dominated by *Cynometra spp. and Pandanus sp*. Other commonly occuring tree species in the area include *Cynometra webberi, Manilkara sansibarensis, Markhamia lutea, Pandanus stuhlmannii, Manilkara sulcata, Cynometra fischeri, Pandanus stuhlmannii, Albizia gummifera and Afzelia quanzensis.*

4.3.1.26 Plot 28

Plot 28 is located in the lower slope with dominant slope gradient of about 15 to 20 %. The elevation to which the plot occurs is at 155 m above sea level. The soils in the plot are moderately deep to deep, well drained, dark reddish brown, clayey soil.

The soil reaction is neutral in both topsoil and subsoil. The pH levels is 7.2 to 6.6 in topsoil and subsoil respectively. Organic carbon on the otherhand is very high (4.10 %) in the topsoil to medium levels (1.14 %) in the subsoil. Total nitrogen is medium to low with values ranging from 0.37 in the topsoil to 0.13 % in the subsoil. C/N ratio indicates good quality organic matter with generally low levels of the available phosphorus.

The cation exchange capacity of the soils in this plot ranges from medium (19.0 Cmolc/kg) in the topsoil to low levels (8.9 Cmolc/kg) in the subsoil. Calcium levels are high in the topsoil but decreases to low or medium levels in the subsoil. The levels of calcium varies from 14.5 to 4.2 Cmolc/kg in topsoil and subsoil respectively. Magnessium levels on the otherhand is dominantly high in both topsoil and subsoil. The value ranges from 4.5 to 3.1 Cmolc/kg.

Exchangeable potassium is dominantly medium in the topsoil to low in the subsoil with respective value of 0.87 to 0.28 Cmolc/kg. Generally the exchangeable sodium is very low.

Dominant tree species which forms an open, mature and mixed forest include *Maytenus acuminata, Platypterocarpus tanganyikensis, Markhamia lutea, Diospyros squarrosa, Maytenus acuminata, Acacia senegal, Diospyros natalensis, Cussonia zimmermannii, Lecaniodiscus fraxinifolius, Antiaris toxicaria, Sorindeia madagascariensis and Dombeya shupangae.*

4.3.1.27 Plot 29

Plot 29 is located in the lower slope with dominant slope gradient of about 10 to 15 %. The elevation to which the plot occurs is at 150 m above sea level. The soils in the plot are moderately deep to deep, well drained, dark reddish brown, clayey soil.

The soil reaction is neutral in both topsoil and subsoil. The pH levels is 7.2 to 6.6 in topsoil and subsoil respectively. Organic carbon on the otherhand is very high (4.10 %) in the topsoil to medium levels (1.14 %) in the subsoil. Total nitrogen is medium to low with values ranging from 0.37 in the topsoil to 0.13 % in the subsoil. C/N ratio indicates good quality organic matter with generally low levels of the available phosphorus.

The cation exchange capacity of the soils in this plot ranges from medium (19.0 Cmolc/kg) in the topsoil to low levels (8.9 Cmolc/kg) in the subsoil. Calcium levels are high in the topsoil but decreases to low or medium levels in the subsoil. The levels of calcium varies from 14.5 to 4.2 Cmolc/kg in topsoil and subsoil respectively. Magnessium levels on the otherhand is dominantly high in both topsoil and subsoil. The value ranges from 4.5 to 3.1 Cmolc/kg. Exchangeable potassium is dominantly medium in the topsoil to low in the subsoil with respective value of 0.87 to 0.28 Cmolc/kg. Generally the exchangeable sodium is very low.

The plot is dominated by *Grewia bicolor, Dialium holtzii, Lecaniodiscus fraxinifolius, Markhamia sulcata, Antiaris toxicaria, Vincentella passargei, Dombeya shupangae, and Stereospermum kunthianum.* The trees in this plot forms an open forest that is usually occupied by climbers, bamboo and grasses.

4.3.1.28 Plot 30

This plot is located at the lower part of the slope with dominantly 36 % slope gradient. It is found at 195 m above sea level. The soils in the plot are moderately deep, well drained, dark red to red, clay soils.

The soil reaction is medium acid (pH 5.9). The organic carbon is high in the topsoil (2.78 %) but decreases to medium levels (1.72 %) in the subsoil. Total nitrogen on the otherhand is medium in both topsoil and subsoil. The levels varies from 0.28 to 0.20 %. Organic matter are of good quality. Available phosphorus is low.

The ability of the soils to retain and supply nutrients for plant uptake is medium in both topsoil and subsoil. The levels are 23.2 and 19.7 Cmolc/kg in topsoil and subsoil respectively. The calcium levels are very high (10.6 to 9.8 Cmolc/kg) while the levels of the exchangeable magnessium is high to medium in topsoil and subsoil. The levels are 4.7 and 2.1 Cmolc/kg respectively. Potassium levels are medium both in topsoil and subsoil (0.53 and 0.43 Cmolc/kg respectively).
Available phosphorus and exchangeable sodium levels are low to very low respectively.

The plot is characterised by dense forest whose trees are mature. The tree species are mixed such that there is no dominance. Commonly occuring tree species in the plot include *Xylopia parviflora, Julbernardia magnistipulata, Diospyros natalensis, Fernandoa magnifica, Rinorea ferruginea, Cynometra webberi, Brackenridgea zanguebarica, Diospyros natalensis, Zenkerella egregia and Gyrocarpus americanus. Other dominant tree species in the plot include Nersogodonia holstii, Mkilua fragrans, Cola greenwayi, Lecaniodiscus fraxinifolius, Scorodophleus fischeri, Rinorea usambarensis, Schefflerodendron zanguebarica, Cynometra webberi, Pandanus stuhlmannii and Craibia brevicaudata.*

4.3.1.29 Plot 31

This plot is located at the lower part of the slope with dominantly 35 % slope gradient. It is found at 200 m above sea level. The soils in the plot are moderately deep, well drained, dark red to red, clay soils.

Soils chemical characteristics are similar to that in plot 54. The plot is having dense forest whose trees are mature. The tree species are mixed such that there is no tree dominance. The commonly occuring tree species in this plot include *Julbernardia magnistipulata, Manilkara sulcata, Newtonia paucijuga, Xylopia parviflora, Dialium holtzii, Scorodophleus fischeri, Diospyros natalensis, Cynometra webberi, Dorstenia kameruniana (syn.craterogyne kameruniana), Vepris nobilis, Drypetes usambarica, Craibia brevicaudata, Drypetes usambarica and Manilkara sulcata.*

4.3.1.30 Plot 32

This plot is located at lower slope with dominant 30 % slope gradient. It is found at 160 m above sea level. The soils are are shallow with 40 cm effective rooting depth. The texture is dominantly clay. The soils are slightly compacted with very thin topsoil with very thin litter at the surface.

The soils in this plot have reaction that varies from mildly alkaline (pH 7.7) in the topsoil to slightly acid (pH 6.5) in the subsoil. Organic carbon ranges from high (3.4 %) in the topsoil to low levels (1.1 %) in the subsoil. Total nitrogen on the otherhand varies from medium levels (0.28 %) in the topsoil to low levels (0.12 %) in the subsoil. The carbon to nitrogen ratio varies from 12 to 10. This indicates good quality type of the organic matter with low levels of the available phosphorus.

Cation exchange capacity of the soils is dominantly medium in the topsoil (12.1 Cmolc/kg) but decreases to low levels (10.4 Cmolc/kg) in the subsoil. Calcium levels are dominantly very high both in topsoil and subsoil. The values ranges from 11.0 to 4.4 Cmolc/kg in topsoil and subsoil respectivelly. Magnessium levels are high (3.8 Cmolc/kg) in the topsoil to medium levels (2.6 Cmolc/kg) in the subsoil. Potassium is high both in topsoil and subsoil. The levels are 0.9 Cmolc/kg in the topsoil to 0.56 Cmolc/kg in the subsoil. Sodium levels are dominantly very low.

The plot is characterised by open forest found at the forest edge forming mainly grassland. However the Dominating tree species include *Steganotaenia araliacea, Trilepsium madagascariensis, Markhamia lutea, Sorindeia madagascariensis, Albizia glaberrima, Tarrena nigrescens, Antiaris toxicaria, Manilkara sulcata, Trichilia emetica and Ficus sycomorus.*

4.3.1.31 Plot 33

This plot is located at middle part of the slope. It occurs at 170 m above sea level with 30 % slope gradient. The soils are shallow to moderately deep with 40 to 50 cm effective rooting depth. They are well drained, dark reddish brown to red, clay soils without rock outcrop.

The soil reaction is neutral (pH 7.2)in the topsoil and (pH 6.6) in subsoil. Organic carbon varies from very high (3.5 %) in the topsoil to medium levels (1.3 %) in the subsoil. Total nitrogen in this plot varies from medium to low levels in the topsoil and subsoil respectivelly. The values are 0.3 and 0.13 %. Organic matter are of good quality. This is indicated by the C/N ratio which is at the magnitude of 12 and 10. Available phosphorus is very low.

The cation exchange capacity varies from medium (18.5 Cmolc/kg) in the topsoil to low levels (10.9 Cmolc/kg) in the subsoil. Calcium levels are very high (13.3 to 6.8 Cmolc/kg) while the exchangeable magnessium is high (5.1 Cmolc/kg) in the topsoil to medium levels (1.8 Cmolc/kg) in the subsoil. Potassium levels are high (0.8 Cmolc/kg in topsoil and 0.5 Cmolc/kg in subsoil). Exchangeable sodium is very low.

Tree species occuring in the plot include *Lonchocarpus bussei, Stereospermum kunthianum, Dombeya shupangae, Annona senegalensis and Steganotaenia araliacea*. Generally the plot is characterised by open forest that forms mainly woodland without tree dominance.

4.3.1.32 Plot 34

Plot 34 is found at the upper part of the slope at about 180 m above sea level. The dominant slope gradies is 15 %. The soils in this plot are very shallow. The effect depth is dominantly less than 30 cm below which the hardrock is observed, well drained, clay soils.

The soil reaction is slightly acid (pH 6.2) in the topsoil to medium acid or strongly acid (pH 5.4) in the subsoil. Organic carbon is high (3.3 %) in the topsoil and medium (2.0 %) in the subsoil. Total nitrogen is medium in the topsoil (0.3 %) to low levels (0.18 %) in the subsoil. C/N ratio is dominantly 11 indicating good quality organic matter. Available phosphorus is very low.

Medium level of cation exchange capacity is found in this plot. The values ranges from 14.5 to 13.4 Cmolc/kg in topsoil and subsoil respectivelly. Exchangeable calcium varies from very high (5.7 Cmolc/kg) in topsoil to high levels (2.9 Cmolc/kg) in the subsoil. Magnessium levels are high (5.2 Cmolc/kg) to medium levels (2.4 Cmolc/kg) in the subsoil. Potassium are low to very low with values ranging from 0.35 to 0.1 Cmolc/kg in topsoil and subsoil respectivelly.

The area is characterised by dense and mature without dominance. The commonly occuring tree species include *Dracaena steudneri, scorodophleus fischeri, Rytigynia flavida (syn.R.schumannii), Drypetes usambarica, Julbernardia magnistipulata, Diospyros natalensis, Drypetes usambarica, Pterocarpus tinctorius, Vincentella passargei, Acacia senegal, Celtis philippensis (c.wightii), Dialium holtzii, Pterocarpus mildbraedii, Euclea sp. Diospyros squarrosa, Julbernardia magnistipulata, Dorstenia kameruniana, Trilepsium madagascariensis, Dorstenia kameruniana and Rothmania manganjae.*

4.3.1.33 Plot 35

The plot is situated at an elevation of 165 m above sea level. The dominant slope ranges from 20 to 30 %. The soils are moderately deep with rock fragments observed at 70 cm from the surface, well drained, dark red to red, clay soils.

Soil chemical characteristics are similar to that in plot 49. However major differences interms of the dominant tree species occuring in the plot. The plot is having dense, mature and mixed tree without dominance. The commonly occuring tree species within this plot include *Vincentella passargei, Celtis mildbraedii, Diospyros natalensis, Euclea sp., Celtis wightii, Chytranthus obliquinervis, Grewia bicolor, Diospyros mespiliformis and Markhamia lutea. Others are Lettowianthus stellantus, Celtis wightii, Ziziphus mucronata, Diospyros squarrosa, Tricalysia myrtifolia, Lecaniodiscus fraxinifolius, Mildbraedia fallax, Maytenus acuminata and Dialium holtzii.*

4.3.1.34 Plot 36

The plot is situated at an elevation of 160 m above sea level. The dominant slope ranges from 20 to 25 %. The soils are moderately deep with rock fragments observed at 70 cm from the surface, well drained, red soils.

The soils are very strongly acid with pH values ranging from 4.7 in the topsoil to 4.5 in the subsoil. Organic carbon ranges from high (2.90 %) in the topsoil to low (1.1 %) in the subsoil. Total nitrogen is dominantly low or medium in both topsoil and subsoil. The levels varies from 0.23 to 0.10 % in

topsoil and subsoil respectively. The ratio of carbon to nitrogen indicates that the organic matter are of good quality with low levels of available phosphorus.

The cation exchange capcity is of medium levels. It varies from 17.5 in the topsoil to 14.5 Cmolc/kg in the subsoil. Exchangeable calcium is dominantly medium (2.5 %) while the exchangeable magnessium is commonly medium levels. It ranges from 1.5 to 1.4 Cmolc/kg in the topsoil and subsoil respectively. The levels of the exchangeable potassium is low over the sampling depth. It ranges from 0.36 in the topsoil to 0.13 Cmolc/kg in the subsoil.

The forest in this plot is dense, mature and mixed without dominance. Within the plot the following are common tree species namely *Markhamia lutea, Ricinodendron heudelotii, Celtis mildbraedii, Celtis wightii, Lannea welwitschii, Mildbraedia fallax, Sericanthe odoratissima, Diospyros sp., Celtis africana, Rinorea ferruginea, Sericanthe adoratissima, Antiaris toxicaria, Milicia excelsa, Lettowianthus stellatus, Acacia sp., Ziziphus mucronata, Grewia bicolor, Pteleopsis myrtifolia, Harrisonia abyssinica and Elaeis guineensis.*

4.3.1.35 Plot 37

The plot is located at between 200 and 210 m above sea level with 15 to 20 % slope gradient. The soils are very deep with effective rooting depth greater than 150 cm, well drained, dark reddish brown to red, heavy clays. The soils shows high intensity of weathering.

The soil reaction is medium acid both in topsoil and subsoil. pH varies from 5.9 to 5.8 in topsoil and subsoil respectively. Organic carbon varies from very high (3.70 %) in the topsoil to medium levels (2.26 %) in the subsoil. Total nitrogen is medium (0.34 %) in the topsoil which decreases to low levels (0.1 %) in the subsoil. The ratio of carbon to nitrogen indicates that the organic matter are of good quality with generally low levels of available phosphorus.

Cation exchange capacity is of medium levels both in topsoil and subsoil. The levels varies from 19.7 Cmolc/kg in the topsoil to 11.3 Cmolc/kg in the subsoil. Exchangeable calcium is dominantly very high. The values ranges from 8.7 Cmolc/kg in the topsoil to 6.6 Cmolc/kg in the subsoil. Magnessium levels are high in both topsoil and subsoil (4.9 to 3.7 Cmolc/kg). Exchangeable potassium is dominantly medium in both topsoil and subsoil. The levels ranges from 0.48 to 0.56 Cmolc/kg in topsoil and subsoil respectively. Sodium levels are generally low.

The plot is characterised by dense, mature and mixed without tree dominance. However the commonly occuring tree species within the plot include *Antiaris toxicaria, Cola usambarensis, Lecaniodiscus fraxinifolius, Blighia unijugata, Chytranthus obliquinervis, Acacia senegal, Xylopia parviflora, Diospyros natalensis, Celtis africana and Grewia goetziana.* Others include *Fernandoa magnifica, Pteleopsis myrtifolia, Lannea welwetschii, Blighia unijugata, Grewia bicolor, Dialium holtzii, Celtis philippensis (syn.C. wightii), Pterocarpus mildbraedii, Bombax rhodognaphalon and Ziziphus mucronata.*

4.3.1.36 Plot 38

The plot is located at 210 m above sea level with 20 to 25 % slope gradient. The soils are very deep with effective rooting depth greater than 150 cm, well drained, dark reddish brown to red, heavy clays. The soils shows high intensity of weathering.

The soil reaction is slightly acid (pH 6.3 to 6.1) in topsoil and subsoil respectively. Organic carbon ranges from very high (3.9 %) in topsoil to low levels (0.67 %) in the subsoil. Total nitrogen is medium (0.36 %) in the topsoil but becomes low (0.1 %) in the subsoil. Organic matter are of good quality with low levels of the available phosphorus.

The ability of the soils to retain and supply nutrients for plant uptake is of medium levels. In the topsoil the level is 18.3 Cmolc/kg while that in subsoil is 10.6 Cmolc/kg. Exchangeable calcium is very high (9.3 Cmolc/kg) in topsoil. In the subsoil the values are high (4.4 Cmolc/kg) in the subsoil. Magnessium levels are high (3.6 Cmolc/kg) in topsoil which the levels in the subsoil are medium (2.9 Cmolc/kg). Exchangeable potassium on the otherhand is medium (0.76 Cmolc/kg) in the topsoil to low or very low levels (0.12 Cmolc/kg) in the subsoil. Exchangeable sodium is generally very low.

The area is having dense, mature and mixed without tree dominance. Commonly occuring tree species include *Dialium holtzii, Rytigynia flavida, Diospyros natalensis, Pterocarpus tinctorious, Markhamia lutea, Grewia bicolor, Diospyros squarrosa, Sterculia appendiculata, Cola usambarensis, Cola greenwayi, Drypetes usambarensis, Fernandoa magnifica, Terminalia sambesiaca, Grewia goetziana, Antiaris toxicaria, Mildbraedia fallax, Drypetes usambarica, Dialium holtzii, Rinorea ferruginea and Bridelia micrantha.*

4.3.1.37 Plot 39

The plot is located at 230 m above sea level with 25 % slope gradient. The soils are deep to very deep, well drained, dark reddish brown to red, clayey in texture. The soils shows high intensity of weathering as there is very little horizon differentiation.

The soil reaction is very strongly acid (pH 4.7) in the topsoil which decreases to pH value of 4.3 in the subsoil. Organic carbon is very high (4.95 %) in the topsoil to high levels (2.76 %) in the subsoil. Total nitrogen medium (0.40 %) in the topsoil which decreases to low levels (0.10 %) in the subsoil. C/N ratio indicates presence of good quality organic matter with low levels of available phosphorus.

The plot has high levels of the cation exchange capacity. The CEC levels are 30.4 Cmolc/kg in the topsoil while the CEC levels in the subsoil is low to medium (9.6 Cmolc/kg). Exchangeable calcium is high (4.4 Cmolc/kg) which decreases to medium levels (1.0 Cmolc/kg) in the subsoil. Magnessium levels are medium (2.7 Cmolc/kg) in the topsoil which becomes low (0.3 Cmolc/kg) in the subsoil. Potassium are generally medium (0.49 Cmolc/kg) in the topsoil and decreases to low (0.13 Cmolc/kg) levels in the subsoil. Exchangeable sodium are very low.

The plot is characterised by dense forest, mature tree that are mixed without dominance. However the commonly occuring tree species found in this plot include *Jubernadia magnistipulata, Scorodophleus fischeri, Pterocarpus tinctorius, Celtis mildbraedii, Pterocarpus mildbraedii, Schefflerodendron usambarense, Xylopia parviflora, Flacourtia indica, Pterocarpus mildbraedii, Rinorea angustifolia, Schefflerodendron usambarense, Pterocarpus tinctorius, Dorstenia kameruniana, Nersogodonia holstii, Cynometra brachyrhachis, Dalbergia boehmii, Sericanthe odoratissima, Craibia brevicaudata, Dorstenia kameruniana, Drypetes gerrardii and Bombax rhodognaphalon.*

4.3.1.38 Plot 40

The plot is located at 215 m above sea level with 20 to 25 % slope gradient. The soils are deep, well drained, dark reddish brown to red, clayey in texture.

The soils reaction is medium acid (pH 5.8) in the topsoil which slightly decreases with soil depth to very strongly acid (pH 4.7) in the subsoil. Organic carbon is high (3.12 %) but significantly decreases to low levels (0. 57 %) in the subsoil. Total nitrogen is medium (0.33 %) at the topsoil which becomes very low at the subsoil. The levels are 0.06 % at the subsoil. Organic matter are of good quality implying net mineralisation. Available phosphorus is low with levels varying from 3.6 mgP/kg in the topsoil to 6.0 mgP/kg in the subsoil.

The cation exchange capacity is medium in both topsoil (14.6 Cmolc/kg) and subsoil (12.3 Cmolc/kg) with high levels of exchangeable calcium. The levels of calcium are 4.9 Cmolc/kg in the topsoil to 2.2 Cmolc/kg in the subsoil. Magnessium levels are medium to high (3.3 Cmolc/kg) in the topsoil which decreases to low levels (0.7 Cmolc/kg) in the subsoil. Exchangeable potassium is generally is medium (0.57 Cmolc/k) to low (0.28 Cmolc/kg) in topsoil and subsoil respectively. Sodium levels are dominantly very low with values less than 0.1 Cmolc/kg.

Within the plot the vegetation forms dense forest with mature tree. The trees are mixed without dominance. The commonly occuring tree species in this plot include *Gyrocarpus americanus, Scorodophleus fischeri, Pterocarpus mildbraedii, Julbernadia magnistipulata, Dialium holtzii, Vincentella passargei, Fernandoa magnifica, Mildbraedia fallax, Chytranthus obliquinervis, Acacia sp., Chrysophyllum sp. and Dalbergia boehmii.*

4.3.1.39 Plot 41

The plot is located at 210 m above sea level with 18 to 20 % slope gradient. The soils are very deep with effective rooting depth greater than 150 m, well drained, dark reddish brown to red, heavy clays. The soil reaction is medium acid both in topsoil and subsoil. pH varies from 5.9 to 5.8 in topsoil and subsoil respectively. Organic carbon varies from very high (3.70 %) in the topsoil to medium levels (2.26 %) in the subsoil. Total nitrogen is medium (0.34 %) in the topsoil which decreases to low levels (0.1 %) in the subsoil. The ratio of carbon to nitrogen indicates that the organic matter are of good quality with generally low levels of available phosphorus.

Cation exchange capacity is of medium levels both in topsoil and subsoil. The levels varies from 19.7 Cmolc/kg in the topsoil to 11.3 Cmolc/kg in the subsoil. Exchangeable calcium is dominantly very high. The values ranges from 8.7 Cmolc/kg in the topsoil to 6.6 Cmolc/kg in the subsoil. Magnessium levels are high in both topsoil and subsoil (4.9 to 3.7 Cmolc/kg). Exchangeable potassium is dominantly medium in both topsoil and subsoil. The levels ranges from 0.48 to 0.56 Cmolc/kg in topsoil and subsoil respectively. Sodium levels are generally low.

The plot is characterised by open forest which forms mainly grassland (Bamboo grassy and climbers). Common tree species within the plot include *Rothmania manganjae, Milicia excelsa, Grewia goetziana, Diospyros natalensis, Mildbraedia fallax, Newtonia paucijuga, Mildbraedia fallax, Diospyros squarrosa, Bridelia micrantha, Rytigynia flavida, Rothmania manganjae, Albizia gluberrima, Markhamia lutea, Dombeya shapangae, Ricinodendron heudelotii, Tricalysia mayrtifolia, Synsepalum msolo and Fernandoa magnifica.*

4.3.1.40 Plot 42

The plot is located at 140 m above sea level with 8 to 10 % slope gradient. The soils are very deep with effective rooting depth greater than 100 m, well drained, dark reddish brown to red, heavy clays. Rockoutcrops are very common in this plot.

The pH of the soils varies from medium acid (pH 6.0) in the topsoil to strongly acid (pH 5.1) in the subsoil. Organic carbon are very high (6.5 %) in the topsoil which decreases to medium levels (2.2 %) in the subsoil. Total nitrogen is high (0.53 %) in the topsoil which becomes medium (0.22 %) in the subsoil. Organic matter are of good quality. This is indicated by the C/N ratio whose values ranges from 10 to 12 with generally low levels of the available phosphorus.

The cation exchange capacity is dominantly medium in both topsoil and subsoil. The levels are 23.6 Cmolc/kg in the topsoil while in the subsoil the levels are 13.4 Cmolc/kg. Calcium levels are very high to high (9.1 to 4.2 Cmolc/kg) in topsoil and subsoil respectively. Magnessium levels are very high to high in both topsoil and subsoil The levels are 7.8 and 3.9 Cmolc/kg respectivelly. Potassium levels are medium while the exchangeable sodium is very low.

Dense forest with mature tree that are mixed without dominance are the vegetation characteristics in this plot. Dominant tree species in the plot include *Lecaniodiscus fraxinifolius, Bombax rhodognaphalon, Rothmania manganjae, Grewia bicolor, Xylopia parviflora, Diospyros natalensis, Antiaris toxicaria, Uvariodendron sp., Grewia bicolor, Bridelia melanthesoides, Nersogodonia holstii, Millettia stuhlmannii, Bridelia melanthesoides, Vincentella passargei, Dialium holtzii, Diospyros squarrosa and Terminalia sambesiaca.*

4.3.1.41 Plot 43

The plot is located at mid-slope of about 25 to 30 % slope gradient. The plot is located at 180 to 195 m above sea level. The soils in this plot are deep, well drained, dark brown and sandy clay loam to clay in texture.

The soil reaction is slightly acid (pH 6.3 to 6.1) in topsoil and subsoil respectively. Organic carbon ranges from very high (3.9 %) in topsoil to low levels (0.67 %) in the subsoil. Total nitrogen is medium (0.36 %) in the topsoil but becomes low (0.1 %) in the subsoil. Organic matter are of good quality with low levels of the available phosphorus.

The ability of the soils to retain and supply nutrients for plant uptake is of medium levels. In the topsoil the level is 18.3 Cmolc/kg while that in subsoil is 10.6 Cmolc/kg. Exchangeable calcium is very high (9.3 Cmolc/kg) in topsoil. In the subsoil the values are high (4.4 Cmolc/kg) in the subsoil. Magnessium levels are high (3.6 Cmolc/kg) in topsoil which the levels in the subsoil are medium (2.9 Cmolc/kg). Exchangeable potassium on the otherhand is medium (0.76 Cmolc/kg) in the topsoil to low or very low levels (0.12 Cmolc/kg) in the subsoil. Exchangeable sodium is generally very low.

Characteristically the plot is having dense forest with mature trees that are mixed such that there is no tree dominance. The commonly occuring tree species in the plot include *Combretum schumannii, Maytenus undata, Albizia zimmermannii, Soriendia madagascariensis, Markhamia lutea, Leptactina platyphylla, Grewia goetziana, Dialium holtzii, Acacia senegal, Vincentella passargei, Newtonia paucijuga, Grewia bicolor, Chrysophyllum sp., Xylopa parviflora, Diospyros natalensis, Cola greenwayi, Diospyros squarrosa, Zanthoxyllum usambarensis, Maytenus undata, Millettia oblata, Lannea schweinfurthii, Mystroxylon holstii, Albizia zimmermannii, Markhamia lutea and Lecaniodiscus fraxinifolius.*

4.3.1.42 Plot 44

The plot is located at 150 m above sea level with 10 to 15 % slope gradient. The soils are very deep with effective rooting depth greater than 100 m, well drained, dark reddish brown to red, heavy clays. The pH of the soils varies from medium acid (pH 6.0) in the topsoil to strongly acid (pH 5.1) in the subsoil. Organic carbon are very high (6.5 %) in the topsoil which decreases to medium levels (2.2 %) in the subsoil. Total nitrogen is high (0.53 %) in the topsoil which becomes medium (0.22 %) in the subsoil. Organic matter are of good quality. This is indicated by the C/N ratio whose values ranges from 10 to 12 with generally low levels of the available phosphorus.

The cation exchange capacity is dominantly medium in both topsoil and subsoil. The levels are 23.6 Cmolc/kg in the topsoil while in the subsoil the levels are 13.4 Cmolc/kg. Calcium levels are very high to high (9.1 to 4.2 Cmolc/kg) in topsoil and subsoil respectively. Magnessium levels are very high to high in both topsoil and subsoil The levels are 7.8 and 3.9 Cmolc/kg respectivelly. Potassium levels are medium while the exchangeable sodium is very low.

The plot is characterised by dense forest with mature trees that are mixed without dominance. However the tree species commonly occuring in plot 44 include *Lecaniodiscus fraxinifolius,*

Scorodophleus fischeri, Dorstenia kameruniana, Cynometra webberi, Euphorbia candelabrum, Dracaena steudneri, Diospyros squarrosa, Afzelia quanzensis, Acacia senegal, Pterocarpus tinctarius, Terminalia sambesiaca, Antiaris toxicaria, Diospyrous natalensis and *Sterculia appendiculata.*

4.3.1.43 Plot 45

This mapping unit covers the lower slope. With dominant slope of 40 % and occurs at altitude 170 m above sea level. The soils in this mapping unit are moderately deep, well drained, dark brown and clay in texture. Rotten rock and some rock fragments occur at 50 cm from surface.

The soil reaction of the soils is medium acid with pH values that ranges from 5.6 to 6.0. The total nitrogen in the topsoil is low with levels around 0.22 % but it decreases to very low levels in the subsoil with values of about 0.09 %. The organic carbon of the soils found in this mapping unit is high (3.2 %) in the topsoil and decreases to low levels (1.1 %) in the subsoils. The C/N ratio which gives more information on the availability of the nitrogen and hence showing the quality of the organic matter are of good quality. The levels ranges from 9 to 11.

The available phosphorus are low with levels ranging from 2.36 to 2.29 mgP/kg. The exchangeable calcium on the other hand are very high with levels that varies from 13.92 in the topsoil to 8.08 Cmolc/kg. Exchangeable magnesium are dominantly high ranging from 5.79 in the topsoil to 4.48 Cmolc/kg in the subsoil. Potassium levels are high in the topsoil (1.84 Cmolc/kg) and decreases to very low levels in the subsoil. The exchangeable sodium are generally very low with levels less than 0.1 Cmolc/kg.

The plot has characteristic dense forest without tree dominance. Different tree species very common in the mapping unit include *Diospyros natalensis, Dombeya shupangae, Allophylus calophyllus, Ricinodendron hendelotii, Chrysophyllum spp, Anglocalyx braunii, Milicia excelsa, Combretum schumannii, Fernandoa magnifica, Leptactina platyphylla, Trilepsium madgascariensis, Antiaris toxicaria, Milicia excelsa, Bombax rhodognaphalon, Vincentella passargei, Rothmania manganjae, Xylopia parviflora, Lannea welwitschii and Lecaniodiscus fraxinifolius.*

4.3.1.44 Plot 46

The mapping unit is located on very steep slopes of about 40 to 45 % slope gradient. the altitude to which the unit is located is 220 m to 230 m above sea level. The soils in this plot are deep, well drained, dark brown and clayey in texture. At 60 cm rock fragments are present.

The soils are medium acid with pH value of about 6.0. It decreases slightly down with soil depth. Organic carbon is high in the topsoil (3.39 %) and decreases significantly to low levels in the subsoil with levels of about 0.84 %. Total nitrogen on the other hand is medium in the topsoil (0.27 %) while low (0.10 %) in the subsoil. Available phosphorus is low with values less than 7 mg P/kg. The cation exchange capacity is medium with values ranging from 19.8 to 17.7 Cmolc/kg in the topsoil and subsoil respectively. the exchangeable calcium is very high with levels ranging from 8.6 to 7.9 Cmolc/kg in the topsoil and subsoil respectively. Exchangeble magnessium is high while potassium is medium to low (0.66 and 0.18 Cmolc/kg) in the topsoil and subsoil respectively. Sodium levels in the soils are low to very low.

The unit has dense, mature and mixed forst with dominance of *Cynometra spp.* Other tree species in the mapping unit include *Commiphora zimmermannii, Afzelia quanzensis, Markhamia lutea, Euphorbia candelabrum, Manilkara obovata, Manilkara sulcata, Brackenridgea bussei and Dracaena steudneri.*

4.3.1.45 Plot 47

The plot is located on area with slope gradient of about 40 %. The elevation at which the plot occurs is at 170 m above sea level. The soils in this plot are moderately deep, well drained, dark red to red, clayey or gravely clay in texture. At 60 cm hardrock is observed.

The soils are slightly acid in the topsoil to medium acid in the subsoil with values ranging from 6.1 to 5.8 in the topsoiland subsoil respectively. Organic carbon is high in the topsoil (2.89 %) but decreases to low levels (0.78 %) in the subsoil. Total nitrogen is medium (0.26 %) in the topsoil and becomes very low in the subsoil. Available phosphorus is low. The capacity of the soil to retain and supply nutrients for plant uptake is medium thoughout with values ranging from 23.4 Cmolc/kg in the topsoil to 14.2 Cmolc/kg in the subsoil.

Exchangeable calcium is very high similarly exchangeable magenesium is high with levels varying from 6.6 to 6.8 Cmolc/kg. The exchangeable potassium is medium in the topsoil (0.47 Cmolc/kg) but decreases down the profile to low or very low levels in the subsoil. Sodium levels are generally very low.

The plot has dense, mature and mixed without tree dominance. Commonly occuring tree species in the plot are *Milletia oblata, Lecaniodiscus fraxinifolius, Markhamia lutea, Euclear spp, Manilkara sulcata, Diospyros natalensis, Sterculia appendiculata, Milletia stuhlmannii, Pandanus stuhlmannii, Vepris nobilis, Diospyros squarrosa, Cola greenwayi, Rothmannia manganjae, Vincentella passargei, Milletia stuhlmannii, Lecaniodiscus fraxinifolius, Grewia bicolor, Commiphora zimmermannii, Xylopia parviflora, Diospyros mespiliformis, Rytigynia flavida, Drypetes usambarica, Dialium holtzii, Sorindeia madagascariensis, Celtis philippensis, Tricalysis myrtifolia and manilkara sulcata.*

4.3.1.46 Plot 48

The unit is found in lower slopes of the dissected hills found in the study area. The unit have slope gradient that varies from 20 to 25 %. The altitude to which the unit is found is 150 m above sea level. The plot is generally well drained, very deep without rockoutcrop and surface stoniness. The soils in the unit are dark brown in colour that changes to red in the subsoil. The texture of the soil in this plot is dominantly clayey.

The soil reaction is slightly acid in the topsoil (pH 6.3) but decreases down the profile to medium acid (5.4). Organic carbon is dominantly very high (5.44 %) in the topsoil but decreases to low levels in the subsoil. The levels of organic carbon in the subsoil is 0.97 %. Total nitrogen is medium (0.44 %) in the topsoil and decreases to low levels in the subsoil (0.11 %). The available phosphorus are low over the whole profile with values dominantly less than 7 mg P/kg.

The cation exchange capacity which determine the ability of the soils to retain and supply nutrients to plants is medium in the topsoil with levels of about 22.1 Cmol/kg. The CEC at the subsoil is also medium (15.3 Cmol/kg). The exchangeablve calcium is high to low in with values ranging from 10.4 to 4.6 Cmol/kg in topsoil and subsoil respectively. Exchangeable magnesium is high in topsoil and medium in subsoil. The values varies from 5.2 to 2.1 Cmol/kg in topsoil and subsoil respectively. Potassium on the other hand is dominantly medium with K values that ranges from 0.91 and 0.46 in topsoil and subsoil respectively. Sodium levels are very low with values dominantly less than 0.10 Cmok/kg. Phosphorus levels are low.

The plot has dense, mature and mixed forests without dominance. Common tree species found in the mapping unit include *Lecaniodiscus fraxinifolius, Markhamia lutea, Diaspyros squarrosa, Diospyros*

natalensis, Antiaris toxicaria, Dialium holtzii, Maytenus acuminata, Fernandoa magnifica, Milicia excelsa, Lettowianthus stellatus, Acasia senegal, Nersogodonia holstii, Chrysophyllum gororngosanum, Maytenus acuminata, Vincentella passargei, Rothmannia manganjae and Cola greenwayi.

4.3.1.47 Plot 49

The plot is situated at an elevation of 160 m above sea level. The dominant slope gradient ranges from 20 to 25 %. The soils are moderately deep with rock fragments observed at 70 cm from the surface, well drained, red and clayey soils.

The soils are very strongly acid with pH values ranging from 4.7 in the topsoil to 4.5 in the subsoil. Organic carbon ranges from high (2.90 %) in the topsoil to low (1.1 %) in the subsoil. Total nitrogen is dominantly low or medium in both topsoil and subsoil. The levels varies from 0.23 to 0.10 % in topsoil and subsoil respectively. The ratio of carbon to nitrogen indicates that the organic matter are of good quality with low levels of available phosphorus.

The cation exchange capcity is of medium levels. It varies from 17.5 in the topsoil to 14.5 Cmolc/kg in the subsoil. Exchangeable calcium is dominantly medium (2.5 %) while the exchangeable magnessium is commonly medium levels. It ranges from 1.5 to 1.4 Cmolc/kg in the topsoil and subsoil respectively. The levels of the exchangeable potassium is low over the sampling depth. It ranges from 0.36 in the topsoil to 0.13 Cmolc/kg in the subsoil.

The plot is characterised by dense forest with mature trees that are mixed and show no dominance. However the commonly occuring tree species in the area include *Julbernadia magnistipulata, Vincentella passargei, Nersogodonia holstii, Pterocarpus tinctorius, Diospyros natalensis, Pterocarpus mildbraedii, Celtis mildbraedii, Acasia senegal, Lecaniodiscus fraxinifolius and Scorodophleus fischeri.*

4.3.1.48 Plot 50

This plot is located near drainage line, at the lower slope with dominantly materials formed from quartzite parent materials. The quartzite in the form of rockoutcrops are scattered all over the area with spaces between them ranging from 5 to 10 m apart. The unit is found at 450 m above sea level with slope gradient of about 35 %. The soils are shallow to moderately deep, well drained, very dusky red to dark red, sandy loam to sandy clay loam in texture.

The soil reaction as indicated by pH of the soils is medium acid with levels varying from 6.0 and 5.9 in the topsoil and subsoil respectively. Organic carbon is very high (4.10 %) in the topsoil which decreases to low levels in the subsoil (0.84 %). Total nitrogen on the otherhand is medium (0.35 %) to low (0.10 %) in the topsoil and subsoil. Available phosphorus is low with values ranging fgrom 0.93 to 0.10 mgP/kg in the topsoil and subsoil respectively.

The cation exchange capacity is medium (18.8 to 10.2 Cmolc/kg) in topsoil and subsoil respectively. The exchangeable calcium is very high in the topsoil and becomes high in the subsoil with respectively values of 8.5 and 4.5 Cmolc/kg. Exchangeable magnessium is high in the topsoil (3.7 Cmolc/kg) and also high in the subsoil (2.5 Cmolc/kg).

Potassium levels are medium in the topsoil (0.53 Cmolc/kg) to low in the subsoil (0.11 Cmolc/kg). Exchangeable sodium is dominantly very low (0.05 Cmolc/kg).

The vegetation in the mapping unit is characterised by dense forest that are mature and mixed with mainly climbers, grasses without tree dominance. Common tree species in the mapping unit are *Terminalia sambesiaca, Milicia excelsa, Markhamia lutea, Diospyros natalensis, Vincentella*

passargei, Newtonia paucijuga, Combretum schumannii, Bridelia melanthesoides, Zanthoxylum usambarense, Chytranthus obliquinervis and Julbernadia magnistipulata

4.3.1.49 Plot 51

Plot 51 is located in the lower slope in the area close to the valley bottom with dominant slope gradient of about 15 %. The elevation to which the plot occurs is at 150 m above sea level. The soils in the plot are moderately deep to deep, well drained, dark reddish brown, clayey soil.

The soil reaction is neutral in both topsoil and subsoil. The pH levels is 7.2 to 6.6 in topsoil and subsoil respectively. Organic carbon on the otherhand is very high (4.10 %) in the topsoil to medium levels (1.14 %) in the subsoil. Total nitrogen is medium to low with values ranging from 0.37 in the topsoil to 0.13 % in the subsoil. C/N ratio indicates good quality organic matter with generally low levels of the available phosphorus.

The cation exchange capacity of the soils in this plot ranges from medium (19.0 Cmolc/kg) in the topsoil to low levels (8.9 Cmolc/kg) in the subsoil. Calcium levels are high in the topsoil but decreases to low or medium levels in the subsoil. The levels of calcium varies from 14.5 to 4.2 Cmolc/kg in topsoil and subsoil respectively. Magnessium levels on the otherhand is dominantly high in both topsoil and subsoil. The value ranges from 4.5 to 3.1 Cmolc/kg. Exchangeable potassium is dominantly medium in the topsoil to low in the subsoil with respective value of 0.87 to 0.28 Cmolc/kg. Generally the exchangeable sodium is very low.

Vegetation types in the plot include slightly dense (open) and mature forest. The dominating tree species include *Diospyros sp.*. Other tree species in the plot are *Diospyros mespiliformis, Celtis philippensis (syn.C. wightii), Vincentella passargei, Celtis africana, Diospyros natalensis, Celtis africana, Ricinodendron heudelotii, Fernandoa magnifica, Xylopia parviflora, Celtis gomphophylla, Drypetes gerrardii, Scorodophleus fischeri, Combretum schumannii, Lannea welwitschii, Lecaniodiscus fraxinifolius and Cola greenwayi,*

4.3.1.50 Plot 52

The plot is found on the summits and upper slopes with dominant slope gradient ranging from 45 to 48 % at altitude varying from 250 to 270 m above sea level. The soils are very shallow with effective rooting depth less than 20 cm, well drained, dark red, sandy clay loam to clay soils. Within the plot rockoutcrops spaced at 10 and 15 m apart are observed.

The soil reaction as determined by pH of the soils is strongly acid in both topsoil and subsoil with pH values varying slightly from 5.2 and 5.4. The organic carbon is medium (2.23 %) in the topsoil which decreases to low levels in the subsoil with levels of about 0.89 %. Total nitrogen is as well medium in the topsoil and low in the subsoil with levels varying from 0.22 and 0.1 % respectivelly. The organic matter is generally of good quality. Available phosphorus is low with dominantly values less tha 3 mgP/kg.

The ability of the soil to supply and retain the nutrent, CEC, varies from medium levels in the topsoil to low levels in the subsoil. The corresponding values are 17.4 and 11.7 Cmolc/kg in the topsoil and subsoil. Exchangeable calcium is high in both topsoil and subsoil (4.9 and 3.4 Cmolc/kg). Exchangeable magnesium is medium (2.1 Cmolc/kg) while the exchangeable potassium ranges from medium (0.45 Cmolc/kg) in the topsoil to low or very low levels (0.19 Cmolc/kg) in the subsoil. The exchangeable sodium is very low.

The forest structure include slightly dense forests, mature, mixed with dominance of *Millettia oblata*. Other tree species common in this mapping unit include *Manilkara sulcata, Drypetes usambarica, Milletta oblata, Pandanus stuhlmannii, Bridelia micrantha, Manilkara obovata, Euphobia*

candelabrum, Terminalia sambesiaca, Lettowianthus stellatus, Lannea welwestchii and Brachylaena huillensis.

4.3.1.51 Plot 53

The plot has slope gradient that varies from 40 to 45 % at 245 m above sea level. The soils are deep, well drained, dark red to reddish brown, sandy clay loam in texture.

The pH of the soil is medium acid (5.6 to 6.0). Organic carbon is very high (4.52 %) while the total nitrogen is medium (0.39 %). The C/N ratio shows that the organic matter are of good quality. Low levels of exchangeable phosphorus is the characteristic of this plot. The cation Exchange Capacity is dominantly medium with levels ranging from 20.00 to 21.4 Cmolc/kg. The exchangeable calcium is very high (6.5 Cmolc/kg) while the exchangeable magnesium is high with levels ranging fron 4.7 to 5.6 Cmolc/kg. The potassium levels on the otherhand are high (0.51 Cmolc/kg) with very low levels of exchangeable sodium.

The forest structure include dense forest with mature trees that are dominated by *Cynometra fischeri, Cynometra longipedicellata, Pandanus stuhlmannii, Euphorbia candalabrum, Diospyros mespiliformis, Millettia stuhlmannii, Markhamia lutea and Lecaniodiscus fraxinifolius*

4.3.1.52 Plot 54

This plot is located at the lower part of the slope with dominantly 35 % slope gradient. It is found at 190 m above sea level. The soils in the plot are moderately deep, well drained, dark red to red, sandy clay loam to clay soils.

The soil reaction is medium acid (pH 5.9). The organic carbon is high in the topsoil (2.78 %) but decreases to medium levels (1.72 %) in the subsoil. Total nitrogen on the otherhand is medium in both topsoil and subsoil. The levels varies from 0.28 to 0.20 %. Organic matter are of good quality. Available phosphorus is low.

The ability of the soils to retain and supply nutrients for plant uptake is medium in both topsoil and subsoil. The levels are 23.2 and 19.7 Cmolc/kg in topsoil and subsoil respectively. The calcium levels are very high (10.6 to 9.8 Cmolc/kg) while the levels of the exchangeable magnessium is high to medium in topsoil and subsoil. The levels are 4.7 and 2.1 Cmolc/kg respectively. Potassium levels are medium both in topsoil and subsoil (0.53 and 0.43 Cmolc/kg respectively). Available phosphorus and exchangeable sodium levels are low to very low respectively.

The plot is characterised by the presence of dense forest with mature trees that are mixed. Dominant tree species include *Dialium holtzii, scorodophleus fischeri, Dorstenia kameruniana, Cynometra webberi, Afzelia quanzensis, Celtis africana, Celtis mildbraedii, Diospyros natalensis, Celtis mildbraedii, Lannea welwistchii, Pterocarpus mildbraedii, Manilkara sulcata, Zanthoxyllum usambarensis, Bridelia micrantha, Vitex keniensis, Julbernardia magnistipulata, Diospyros natalensis, Celtis philippensis (c.wightii), Terminalia sambesiaca, Ficus exasperata, Diospyros squarrosa, and Antiaris toxicari*a.

4.3.2 Longuza Forest Reserve

4.3.2.1 Plot 1

Plot 1 is located at upper slope with 35 % slope gradient. It is found at 210 m above sea level. The soils in this plot are moderately deep with hardrock observed at 50 cm from the surface, well drained, dark red to red, clay loam to clay without rock outcrop at the surface.

The soil reaction is strongly acid with 5.2 pH values. The organic carbon and total nitrogen generally decreases with soil depth. Organic carbon is high in the topsoil (2.8 %) which becomes medium in the subsoil (1.4 %). Total nitrogen is medium in the topsoil (0.27 %) but low in the subsoil (0.15 %). The ratio of carbon to nitrogen is of good quality. Available phosphorus is low with values less than 3 mgP/kg.

The cation exchange capacity is generally medium both in the topsoil and subsoil with levels varying from 15.7 Cmolc/kg in the topsoil and 13.5 Cmolc/kg in the subsoil respectively. The excheable bases, calcium, magnessium and potassiun generally decreases with soil depth. The calcium levels in the plot are very high in the topsoil (7.9 Cmolc/kg) to high in the subsoil (3.8 Cmolc/kg). The exchageable magnessium is high in the topsoil to medium in the subsoil with respective values of 3.3 and 2.9 Cmolc/kg. Exchangeable potassium is medium (0.49 Cmolc/kg) in the topsoil which becomes low (0.15 Cmolc/kg) in the subsoil. The exchangeable sodium is overal very low.

Dominant tree species include *Scorodophloeus fischeri, Bequartiodendron natalense, Milletia usaramensis, Euphorbia nyikae, Fernandoa magnifica, Nersogodonia holtzii, Bombax rhodognaphalon, Terminalia sambesiaca, Newtonia pauncijuga, Drypetes usambarica, Grewia microcarpa, Dombeya cincinnata, Diospyros kabuyeana, Combretum schumanii, Dalbergia lactea, Terminalia sambesiaca, Nersogodonia holtzii, Dialium holtzii, and Dracaena steudneri.*

4.3.2.2 Plot 2

This plot covers the upper part of the slope with dominant slope gradient of about 25 %. The plot is located at an altitude ranging from 230 to 245 m above sea level. The soils in this plot are shallow and in places the soils are moderately deep, well drained, dark red, clay loam to clay in texture.

The soil is slightly acid (pH 6.2) with organic carbon that varies significantly with soil depth. At the topsoil the organic carbon is very high becoming medium in the subsoil with respective values of 4.2 to 1.7 %. On the otherhand total nitrogen varies from medium to low in the topsoil and subsoil respectively. The levels in the topsoil are 0.41 % while that in the subsoil are 0.19 %. The C/N ratio which gives the indication of the quality of the organic matter ranges from 10 in the topsoil to 9 in the subsoil. This clearlyb show good quality organic matter.

Available phosphorus in the plot are low with phosphorus levels ranging from 1.21 in the topsoil to 0.62 mgP/kg in the subsoil. The cation exchange capacity, which shows the ability of the soil to retain and supply nutrients for plant uptake is medium both in topsoil and subsoil. The levels ranges from 14.5 to 13.1 Cmolc/kg in the topsoil and subsoil respectively. The exchangeable calcium is dominantly medium both in topsoil and subsoil with levels ranging from 5.9 to 5.6 Cmolc/kg. The exchageable magnessium is generally high both in the topsoil and subsoil. The levels varies from 4.6 in the topsoil to 3.9 Cmolc/kg in the subsoil. The exchangeable potassium on the otherhand is medium 1.32 and 0.56 Cmolc/kg in the topsoil and subsoil respectively.

Dominant tree species in the plot include *Milicia excelsa, Stereospermum cunthianum, Markhamia obtusifolia, Albizia gummifera, Flueggea virosa, Antiaris toxicaria, Millettia usaramensis, Fernandoa magnifica, Milicia excelsa, Grewia microcarpa, Fernandoa magnifica, Commiphora eminii and Combretum schumanii.*

4.3.2.3 Plot 3.

Plot 3 covers the lower slope, in the area close or near Zigi rivers at 170 m above sea level with dominantly 20 % slope gradient. The soils in the plot are very deep with soil depth greater than 100cm and no rockoutcrop within the plot. The texture ranges from clay loam in the topsoil to clay in the subsoil.

The soil reaction as determined by soil pH in the plot is slightly acid with levels varying from 6.3 to 6.4. The organic carbon is high in the topsoil (2.8 %) and decreases in the subsoil thereby becoming low in the subsoil (1.3 %). Total nitrogen on the otherhand is medium (0.31 %) in the topsoil but becomes low in the subsoil with levels of about 0.14 %. The quality of the organic matter as predetermined by the carbon to nitrogen ratio is of good quality. The available phosphorus on the otherhand is low with levels varying from 4.95 in the topsoil to 0.80 mgP/kg in the subsoil.

The ability of the soil to retain and supply nutrients for plant uptake, the cation exchange capacity, is medium to low in the topsoil and subsoil respectively. The respective values are 13.1 and 10.8 Cmolc/kg. The exchangeable calcium is high in both topsoil and subsoil with respective values ranging from 4.6 and 4.2 Cmolc/kg. Exchangeable magnessium is high in both topsoil and subsoil (3.4 and 3.3 Cmolc/kg). Potassium levels are medium (0.41 Cmolc/kg) in the topsoil and becomes low in the subsoil (0.31 Cmolc/kg). The exchangeable sodium is generally very low.

Dominant tree species within the plot are *Milicia excelsa, Sorindeia madagascariensis, Grewia microcarpa, Antiaris toxicaria, Sterculia appendiculata, Albizia gummifera, Allophylus rubifolius, Milicia excelsa, Fernandoa magnifica, Bridelia micrantha, Lannea stuhlmannii, Dombeya cincinnata, Ficus exasperata and Fernandoa magnifica.*

4.3.2.4 Plot 4

Plot 4 covers upper part of the slope with 35 % slope gradient at an altitude of 175 m above sea level. The soils in this plot are moderately deep with gravels and or hardrock observed at 60 cm from the surface. The soils are dark reddish brown, loamy to clay in texture.

The soil reaction is neutral in the topsoil (pH 7.1) that decreases to slightly acid (pH 6.5) in the subsoil. The organic carbon ranges form high to low in the topsoil and subsoil. The levels are 3.2 and 1.1 %. Total nitrogen is medium to low in topsoil and subsoil. In the topsoil total nitrogen is 0.28 % while in the subsoil the value is 0.12 %. With such levels of the organic carbon and total nitrogen the ratio of carbon to nitrogen is of good quality. Available phosphorus is low with levels that ranges from 3.44 in the topsoil to 0.56 mgP/kg in the subsoil.

The cation exchange capacity (CEC) is low in both topsoil and subsoil with 8.9 and 10.3 Cmolc/kg respectively. Calcium levels is very high to high in both topsoil and subsoil. The levels ranges from 5.3 and 4.4 Cmolc/kg. Exchangeable magnessium on the otherhand is high to medium (2.7 and 4.2 Cmolc/kg). Exchangeable potassium levels are high (1.28 Cmolc/kg) in the topsoil to medium in the subsoil (0.13 Cmolc/kg). The exchangeable sodium is dominantly very low.

Dominant tree species in the plot include *Stereospermum kunthianum, Dombeya cincinnata, Annona senegalensis, Lonchocarpus cappasa, Strychnos madagascariensis, and Sclerocarya caffra.*

4.3.2.5 Plot 5

Plot 5 covers the middle part of the slope at 180 m above sea level and 10 % slope gradient. The soils in this plot are deep, well drained, dark red, clay soils with presence of rockoutcrop at distances ranging from 40 to 50 m apart.

The soils in this plot are strongly acid in the topsoil to very strongly acid in the subsoil with pH values that ranges from 4.7 to 3.9 in the topsoil and subsoil respectively.Organic carbon is very high in the topsoil (4.0 %) which decreases significantly to low or medium levels in the subsoil (1.2 %). Total nitrogen on the otherhand varies from medium levels in the topsoil to low levels in the subsoil. The respective values are 0.35 and 0.16 %. The C/N ratio show that the organic matter in the plot are of good quality. The available phosphorus in the plot are generally low (4.27 in the topsoil to 0.79 mgP/kg in the subsoil).

The cation exchange capacity is medium in both topsoil and subsoil. The levels ranges from 16.8 to 15.3 Cmolc/kg. Exchangeable calcium is dominantly medium within 50 cm from the soil surface. The levels are 1.1 in the topsoil and 0.8 Cmolc/kg in the subsoil. The magnessium levels on the otherhand are low in both topsoil and subsoil (1.0 and 0.3 Cmolc/kg). Potassium levels are low to very low (0.35 to 0.17 Cmolc/kg) in topsoil and subsoil respectively. The exchangeable sodium levels is very low.

The plot has the following dominant tree species *Diospyros kabuyeana, Bombax rhodognaphalon, Julbernardia magnistipulata, Nersogodonia holtzii, Bequaertiodendron natalense, Streblus usambarensis, Dialium holtizii, Rothmannia manganjae, Craibia brevicaudata and Anglocalyx braunii.*

4.3.2.6 Plot 6

Plot number 6 is located on the middle part of the slope with 20 to 25 % slope gradient. The elevation to which the plot is located is 175 to 180 m above sea level. The soils in the plot are moderately deep with hardrock observed at 60 cm from the soil surface, well drained dark reddish brown, sandy clay loam to clay soils.

This plot has the same setting and has similar soils characteristics with plot 7 except that the dominant tree species in this plot include *Antiaris toxicaria, Mesogodonia holtzii, Celtis wightii, Pachystela msolo, Rothmannia manganjae, Fernandoa magnifica, Dialium holtzii, Xylopia parviflora, Zahna golungensis, Celtis wightii, Pterocarpus tinctorius, Streblus usambarensis, Combretum schumanii, and Bequaertiodendron natalense.*

4.3.2.7 Plot 7

Plot number 7 is located on the middle part of the slope with 20 % slope gradient. The elevation to which the plot is located is 165 m above sea level. The soils in the plot are moderately deep with hardrock observed at 50 cm from the soil surface, well drained, dark reddish brown, sandy clay loam to clay.

The soil reaction as determined by pH of the soil is strongly acid in both topsoil and subsoil. The pH values are 5.5. Organic carbon on the otherhand is very high (3.9 %) in the topsoil which decreses to low levels (1.1 %) in the subsoil. The C/N ratio show that the organic matter are of good quality and the available phosphorus is low.

The cation exchange capacity is medium (12.3 Cmolc/kg) in the topsoil to low (11.9 Cmolc/kg) in the subsoil. Calcium levels decreases slightly down with soil depth. The topsoil is having 4.2 while the subsoil is having 3.7 Cmolc/kg. Magnessium levels are constantly medium (2.4 Cmolc/kg) over the studied depth. Potassium levels on the otherhand are medium (0.69 Cmolc/kg) in the topsoil and becomes low in the subsoil with levels of about 0.28 Cmolc/kg. Exchangeable sodium is very low.

The following tree species are dominant in the plot namely *Fernandoa magnifica, Bequaertiodendron natalense, Lecaniodicus flaxinifolius, Diospyros kabuyeana, Newtonia paucijuga, Ehretia amoena,*

Antiaris toxicaria, Diospyros cf. mespiliformis, Dialium holtizii, Sclerocarya caffra, Maytenus undata and Grewia microcarpa.

4.3.2.8 Plot 8

This plot is located on the lower part of the slope with 20 % slope gradient at 190 m above sea level. The soils in this plot are moderately deep, well drained, dark red to red, clay soils. In places rock outcrops are present.

The soil reaction is neutral with pH values that ranges from 6.8 in the topsoil to 6.5 in the subsoil. Organic carbon is very high in the topsoil (4.7 %) but decreases to medium levels in the subsoil. Values in the subsoil is 1.3 %. Total nitrogen on the otherhand is medium (0.46 %) in the topsoil while low (0.14 %) in the subsoil. As determined by the C/N ratio the organic matter within this plot are of good quality. Available phosphorus are low with levels dominantly less than 3 mgP/k g.

The cation exchange capacity of the soils is medium in both topsoil and subsoil with levels ranging from 14.1 in the topsoil to 15.2 Cmolc/kg in the subsoil. Exchangeable calcium on the otherhand are medium in both topsoil and subsoil. The levels varies from 7.5 to 6.6 Cmolc/kg in topsoil and subsoil respectively. Magnesium levels are high (5.3 to 4.9 Cmolc/kg) while exchangeable potassium levels are medium (0.66 in the topsoil to 0.43 Cmolc/kg in the subsoil).

The plot is characterised by open forest with generally low canopy and poorly mixed trees. Dominant species is Markhamia spp. Other tree species include *Xyanthus speciasus, Markhamia lutea, Grewia goetzeana, Pachystela msolo, Diospyros natalensis, Antiaris toxicaria, Strychnos mitis, Dialium holtzii, Margaritaria discoidea, Trichilia emetica, Pachystela msolo, Stereospermum kunthianum, Entada pursaetha, Flueggea virosa, Ficus sp, Dombeya shupangae, Diospyros squarrosa, and Sorindeia madagascariensis.*

4.3.2.9 Plot 9

Plot number 9 is located at the middle part of the slope with 10 % slope gradient. The elevation to which the plot is found is at 185 m above sea level. The soils in the plot are moderately deep, well drained, dark reddish brown, sandy clay loam to clay.

The soil reaction is slightly acid (pH 6.2) in the topsoil to medium acid (pH 5.6) in the subsoil. Organic carbon is high in the topsoil (2.9 %) that decreases to medium levels in the subsoil (1.3 %). Total nitrogen on the otherhand is medium to low levels in topsoil and subsoil respectively. The values are 0.33 and 0.14 %. The quality of the organic matter as indicated by the carbon to nitrogen ratio is good. Available phosphorus is low with levels less than 2 mgP/kg.

The capacity of the soil to retain and supply nutrients for plant uptake is medium in both topsoil and subsoil with values ranging from 13.3 to 11.2 Cmolc/kg in topsoil and subsoil respectively. Exchangeable calcium is very high to high. The levels are 5.2 Cmolc/kg in the topsoil to 4.0 Cmolc/kg in the subsoil. Magnessium levels in the plot are high in the topsoil (4.2 Cmolc/kg) but decreases to medium levels (2.0 Cmolc/kg) in the subsoil. Potassium levels are medium in the topsoil (0.56 Cmolc/kg) which decreases to low or very low levels in the subsoil. The value in the subsoil is 0.11 Cmolc/kg.

Dominant tree species include *Grewia microcarpa, Fernandoa magnifica, Lecaniodiscus flaxinifolius, Cola microcarpa, Pterocarpus tinctorius, Race stolzii, Markhamia obtusifolia, Terminalia sambesiaca, Millettia usaramensis, Fernandoa magnifica, Grewia goetzeana, Combretum schumanii, Acacia robusta, Ehretia amoena, Leptactina platyphylla, Diospyros kabuyeana, Celtis wightii, Dialium holtzii, Diospyros kabuyeana, Margaritaria discoidoa, Olax dissitiflora, Allophylus rubifolius, Grewia calymmatosepala and Milicia excelsa.*

4.3.2.10 Plot 10

The plot is located on the middle slopes with slope gradient that ranges from 10 to 15 % at 180 to 200 m above sea level. The soils in this mapping unit are very shallow to shallow with effective rooting depth of 40 cm and sandy clay loam in texture. The soils are well drained with lot of litter at the surface.

The soil reaction is neutral in both topsoil and subsoil. The pH values are 6.7 in topsoil and 6.2 in the subsoil. The organic carbon is very high (4.3 %) in the topsoil and decreases to medium (2.1 %) levels in the subsoil. Total nitrogen is medium in both topsoil and subsoil (0.39 and 0.25 % respectively). Available phosphorus is low with levels less than 7 mgP/kg.

The cation exchange capacity is medium (13.4 to 12.8 Cmolc/kg) with very high levels of calcium that varies from 8.1 to 6.7 Cmolc/kg in topsoil and subsoil respectively. Exchangeable magenessium is high to medium (3.3 to 2.6 Cmolc/kg) with low to medium levels of potassium. The corresponding values are 0.83 Cmolc/kg in topsoil and 0.29 Cmolc/kg in subsoil. The soil unit has low levels of exchangeable sodium which values from 0.1 Cmolc/kg in the topsoil to 0.14 Cmolc/kg in subsoil.

Dominant tree species include *Albizia gummifera, Pterocarpus tinctorius, Rothmannia manganjae, Acacia rubusta, Fernandoa magnifica, Rothmannia manganjae, Cremaspora triflora, Diospyros kabuyeana, Ehretia amoena, Albizia adiantifolia, Grewia goetzeana, Ehretia amoena, Sorindeia madagascariensis, Sorindeia madagascariensis, Newtonia paucijuga, Lecaniodiscus flaxinifolius, Blighia unijugata, Acacia robusta, Albizia adiantifolia, Ficus exasperata, Sorindeia madagascariensis, Harrisonia abyssinica and Dombeya cicinnata.*

4.3.2.11 Plot 11

Plot 11 covers the middle slope with dominant slope gradient of about 30 %. The altitude to which the plot occurs is at 180 m above sea level. The soils in this plot are very deep , well drained, dark red to red and clay .

The reaction of the soils in this plot is neutral pH 6.6 in the topsoil which decreases to very strongly acid in the subsoil (4.7). Organic carbon is very high in the topsoil (5.5 %) which decreases to low levels in the subsoil. The levels in the subsoil is 1.1 %. Total nitrogen ranges from high in the topsoil to low or medium in the subsoil. The respective values in the topsoil and subsoil are 0.51 and 0.12 %. Generally organic matter are of good quality. Available phosphorus is low with levels generally less than 4.0 mgP/kg.

The level of cation exchange capacity is medium both in topsoi and subsoil. The levels ranges from 19.6 to 16.7 Cmolc/kg in topsoil and subsoil respectively. Exchangeable calcium ranges from very high (10.2 Cmolc/kg) to low (2.4 Cmolc/kg) in topsoil and subsoil respectively. Magnessium levels are very high to low in the topsoil and subsoil respectively. The corresponding values are 6.5 and 1.5 Cmolc/kg. Potassium levels in this plot are medium (0.68 Cmolc/kg) to low (0.22 Cmolc/kg) in topsoil and subsoil respectively. Wihin this plot low or very low levels of sodium are very common.

Dominant tree species include *Antiaris toxicaria, Milicia excelsa, Xylopia parvifolia, Diospyros kabuyeana, Fernandoa magnifica, Milicia excelsa, Bequartiodendron natalense, Dialium holtzii, Bequartiodendron natalense, Lecaniodiscus flaxinifolius, Pterocarpus tinctorius, Antiaris toxicaria, Sorindeia madagascariensis, Allophylus rubifolius and Rothmannia manganjae.*

4.3.2.12 Plot 12

This plot covers the upper part of the slope in the area found at an altitude of 345 m above level with 40 % slope gradient. The soils in this plot is moderately deep with hardrock observed at 60 cm from the soil surface, well drained, dark red to red, sandy clay loam to gravely clay in the subsoil. Rockoutcrop are present at 5 to 10 m apart.

The soil reaction is medium acid in both topsoil and subsoil. The levels of pH are 5.7 and 5.6 in topsoil and subsoil respectively. Organic carbon is high to low in topsoil and subsoil respectively. The levels are 3.0 % in topsoil and 1.0 % in subsoil. Total nitrogen on the otherhand is low in both topsoil and subsoil. The values ranges from 0.19 % in the topsoil to 0.13 % in the subsoil. The organic matter is of good quality with low levels of the available phosphorus that ranges from 0.86 to 0.26 mgP/kg in the topsoil and subsoil respectively.

Cation exchange capacity is low both topsoil and subsoil. The levels are 11.3 Cmolc/kg in the topsoil and 10.9 Cmolc/kg in the subsoil. Exchangeable calcium is generally high with levels ranging from 4.0 to 4.2 Cmolc/kg in topsoil and subsoil repectively. Magnessium levels are medium in both topsoil and subsoil. The levels ranges from 1.9 to 1.7 Cmolc/kg in topsoil and subsoil respectively. The amount of exchangeable potassium on the otherhand is low to very low. The critical levels of potassium in this plot ranges from 0.34 to 0.14 Cmolc/kg. Exchangeable sodium is generally very low.

The plot is characterised by open forest which are bushy. Dominant tree species include *Millettia oblata, Diospyros sp, Margaritaria discoidea, Markhamia lutea, Grewia bicolor, Manilkara sulcata, stereospermum kunthianum, Lonchocarpus bussei, Senna singueana, Lecaniodiscus fraxinifolius, Harrisonia abyssinica, Dichrostachys cinerea, Afzelia quanzensis and Cussonia zimmermannii.*

4.3.2.13 Plot 13

Plot 13 is located at 300 m above sea level on upper part of the slope with 35 % slope gradient. The soils in this plot are moderately deep with hardrock and rotten rock observed at 50 cm from the surface, well drained, dark red, gravely sandy clay loam to clay soils. In places rockoutcrop are present.

The soils in the plot are slightly acid both in topsoil and subsoil. pH levels in this plot ranges from 6.5 to 6.2 in topsoil and subsoil respectively. Organic carbon are very high in the topsoil (3.8 %) to medium levels in the subsoil (1.7 %). Total nitrogen is medium to low with respective values of 0.36 and 0.18 %. The ratio of carbon to nitrogen indicates good quality organic matter with low levels of available phosphorus. In this plot available phosphorus ranges from 1.02 mgP/kg in the topsoil to 0.34 mgP/kg in the subsoil.

In both topsoil and subsoil the cation exchange capacity is medium. The values ranges from 12.5 to 13.2 in topsoil and subsoil repectively. The exchangeable calcium is very high (6.0 Cmolc/kg) to high (4.7 Cmolc/kg) in topsoil and subsoil respectively. Magnessium levels are dominantly high (4.6 to 4.7 Cmolc/kg) while potassium levels are generally low with levels that varies from 0.13 to 0.39 Cmolc/kg in topsoil and subsoil respectively. The exchangeable sodium levels are low or very low.

This plot is characterised by open forests that has been subjected to cattle grazing. Its structure is woodland. Dominant tree species in the plot include *Piliostigma thonningii, Stereospermum kunthianum, Ormocarpum bibracteatum, Crossapteryx febrifuga, Lannea welwitschii, Dombeya shupangae, Srychnos potatorum, Annona senegalensis, Lonchocarpus bussei, Grewia bicolor, Crossopterix febrifuga and Allophyllus stachyanthus.*

4.3.2.14 Plot 14

This plot is located in the middle part of the slope at 180 m above sea level with 10 % slope gradient. The soils in the plot are deep, well drained, dark red to red, clay in texture. On the surface the plot is having rockoutcrop at a distance of 50 m apart.

The soil in the plot are slightly acid with pH values ranging from 6.6 in the topsoil to 6.4 in the subsoil. Organic carbon is high in topsoil (2.8 %) but decreases to low level (1.2 %) in the subsoil. Total nitrogen within this plot ranges from medium to low levels. The levels of total nitrogen in the topsoil is 0.30 % while that in the subsoil is 0.13 %. Good quality organic matter are present which may lead to net mineralisation. Available phosphorus is generally low with dominantly values ranging from 3.1 to 0.87 mgP/kg.

The cation exchange capacity in the plot is medium. The levels ranges from 13.4 to 14.3 Cmolc/kg in both topsoil and subsoil respectively. Very high levels of calcium are present in the plot. Exchangeable calcium in the plot are dominantly 8.3 Cmolc/kg. Magnessium levels on the otherhand are high in both topsoil and subsoil. The levels ranges from 3.3 to 3.2 Cmolc/kg. Potassium levels varies from medium to low. The levels are 0. 83 in the topsoil to 0.22 in the subsoil. Very low levels of the exchangeable sodium are very common the plot showing less chances for sodicity development.

The plot has dense forest without dominance. Dominant tree species in the plot within the study area include *Fernandoa magnifica, Drypetes usambarica, Cussonia zimmermannii, Zanha golungesis, Xylopia parviflora, Drypetes usambarica, Lecaniodiscus fraxinifolius, Diospyros squarrosa, Antiaris toxicaria and Allophylus calophyllus, Dombeya shupangae, Albizia glaberrima, Ricinodendron heudelottii, Sorindeia madagascariensis, Milicia excelsa, Diospyros natalensis, Dialium holtzii, Markhamia lutea, and Markhamia obtusifolia.*

4.3.2.15 Plot 15

The plot covers the middle slope with slope gradient varying from 15-20 % at an elevation ranging from 170 to 180 m above sea level. The soils are moderately deep to deep with effective rooting depth of about 40 to 60 cm, well drained, dark reddish brown to red,sandy clay loam to clay soils.

The pH of the soils in the topsoil varies from medium acid (5.5 to 6.1) in the topsoil to dominantly medium acid in the subsoil. Organic carbon is high (2.4 %) in the topsoil but decreases to low levels in the subsoil (1.1 %). Total nitrogen on the otherhand is medium (0.20 %) in the topsoil thereby becoming low levels in the subsoil (0.12 %). Available phosphorus is generally low in both topsoil and subsoil with P levels less than 5 mgP/kg.

Cation exchange capacity (CEC) is both low in topsoil and subsoil. The levels are (11.7 Cmolc/kg) in topsoil which becomes (10.2 Cmolc/kg) in the subsoil. Exchangeable calcium is dominantly high (3.7 Cmolc/kg) while magnessium levels are medium (2.4 Cmolc/kg). Levels of exchangeable potassium is medium (0.69 Cmolc/kg) in topsoil becoming low levels (0.28 Cmolc/kg) in the subsoil. The exchangeable sodium are very low with levels less than 0.1 Cmolc/kg.

The plot has dense forest without tree species dominance. The commonly occuring tree species in this mapping unit include *Diospyros squarrosa, Albizia schimperana, Diospyros mespiliformis, Lecaniodiscus fraxinifolius, Diospyros natalensis, Markhamia lutea, Cussonia zimmermannii, Millettia usambarensis, Rothmannia manganjae, Sorindeia madagascariensis, Stereospermum kunthianum, Dombeya cincinnata and Antiaris toxicaria.*

4.3.2.16 Plot 16

This mapping unit covers the lower slopes with slope gradient ranging from 15-20 % at an elevation between 170-200 m above sea level. The soils are very deep, well drained, dark red to red and sandy clay loam to clay in texture. In places rock outcrop are present.

pH in the topsoil ranges from medium acid to slightly acid (5.6) while in the subsoil pH is 5.1. Organic carbon is high to very high (2.8 %) in the topsoil which becomes medium in the subsoil (1.7 %). Total nitrogen is medium (0.37 %) at the topsoil while low in the subsoil (0.19 %). Available phosphorus for plant uptake is low.

Cation exchange capacity is low to medium with values ranging from 10.5 to 12.9 Cmolc/kg in both topsoil and subsoil. Calcium levels are high throughout the profile with values ranging from 3.2 to 2.7 Cmolc/kg. Magnessium levels are medium (3.4 Cmolc/kg). Exchangeable potassium levels is high (0.79 Cmolc/kg) in topsoil but decreases to medium levels (0.26 Cmolc/kg) in the subsoil. Levels of exchangeable sodium is very low.

The plot has dense, riverine forest without tree dominance. The common tree species found in this mapping unit include *Scorodophloeus fischeri, Terminalia sambesiaca, Diospyros mespiliformis, Combretum schumanii, Breonadia salicina, Pterocarpus tinctorius, Barringtonia spp, Acacia spp, Commiphora zimmermannii, Bombax rhodognaphalon, Lannea welwitschii, Craibia brevicandata, Parkia filicoidea, Albizia adianthifolia, Lecaniodiscus fraxinifolius, Nersogodonia holstii and Milletia stuhlmannii.*

4.3.2.17 Plot 17

Plot 17 is located at the lower slope at 200 m above sea level with 8 to 10 % slope gradient. The soils in this plot are shallow with hardrock or rotten rock observed at 30 cm form the surface, well drained, dark red to red, sandy loam to clay soils. The plot is generally rocky with rockoutcrop located at distances between 10 and 30 cm.

The soil reaction of the topsoil is slightly acid (pH 6.1). Organic carbon is high (3.2 %) while total nitrogen is medium (0.36 %). C/N ratio shows good quality of the organic matter with overal low levels of the available phosphorus. The plot has low levels (6.0 Cmolc/kg) of cation exchange capacity. Calcium levels are high (2.3 Cmolc/kg) with medium levels of exchangeable magnessium. The exchangeable magnessium in the plot are 1.4 Cmolc/kg. Potassium and sodium levels in the soils of this plot low to very low with 0.38 Cmolc/kg and 0.09 Cmolc/kg respectively.

The plot has dense forests alog the riverine with no dominance . However the commonly occuring tree species include *Khaya anthotheca, Barringtonia racemosa, Parkia filicoidea, Synsepalum msolo, Antiaris toxicaria, Ricinodendron heudelotii, Funtumia africana, Bombax rhodognaphalon, Fernandoa magnifica, Celtis philippensis, Sorindeia madagascariensis, Dorstenia kameruniana, Antiaris toxicaria, Scorodophloeus fischeri, Synsepalum msolo, Croton sylvaticus, Ficus usambarensis, Lannea welwitschii, Croton sylvaticus, Dialium holtzii, Sorindeia madagascariensis, Anthocleista grandiflora, and Trilepisium madagascariense.*

4.3.2.18 Plot 18

The mapping unit covers the upper part of the slope in the study area with 18 to 24 % slope gradient at 200 to 250 m above sea level. The soils within the plot are shallow, well drained, clay, dark reddish brown soils. Vegetation cover dominantly include grasses cover.

The soil reaction is neutral (pH 6.7) in the topsoil to slightly acid (pH 6.7) in subsoil. Organic carbon is very high (3.8 %) in the topsoil but becomes medium (1.7 %) in the subsoil. Total nitrogen is

medium in the topsoil (0.33 %) and low in the subsoil (0.20 %). Available phosphorus is dominantly low with levels less than 7 mg P/kg. The cation exchange capacity is medium both in topsoil and subsoil with corresponding values of 14.5 and 13.1 Cmolc/kg respectively. Exchangeable calcium is very high both in topsoil and subsoil with values greater than 5.0 Cmolc/kg. Exchangeable magnessium is also high both in topsoil and subsoil. The levels of magnessium are 4.6 and 3.9 Cmolc/kg in topsoil and subsoil resepectively. Potassium levels are high in the topsoil (1.32 Cmolc/kg) and becomes medium (0.56 Cmolc/kg) in the subsoil. The levels of exchangeable sodium is generally low with lvalues dominantly less than 0.1 Cmocl/kg.

The plot has dense forest without tree dominance. Common tree species in the mapping unit include *Dombeya shupangae, Lannea schweinfurthii, Ehretia spp, Grewia bicolor, Milletia stuhlmannii, Ximenia spp, Annona senegalensis, Markhamia lutea, Vangueria infausta and Stereospermum kunthianum*

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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	<7	7-20	>20
(Olsen) mg/kg	<5	5-10	>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	medium	high	very high
Ca (clayey soils rich in 2:1 clays) Cmolc/kg	<2.0	2.0-5.0	5.1-10.0	10.1-20.0	>20.0
Ca (loamy soils) Cmolc/kg	<0.5	0.5-2.0	2.1-4.0	4.1- 6.0	> 6.0
Ca (kaolinitic and sandy soils) Cmolc/kg	<0.2	0.2-0.5	0.6-2.5	2.6- 5.0	> 5.0

Exchangeable magnesium

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

For loamy soils a classification has to be used with figures in between the two sets presented for clayey and sandy soils.
The desired saturation level of exchangeable Mg is 10 to 15 percent; for sandy and kaolinitic soils 6 to 8 percent Mg saturation is still sufficient.
Ca/Mg ratios of 2 to 4 are favourable.

Exchangeable potassium

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

The desired saturation level of exchangeable K is 2 to 7 percent.
Favourable Mg/K ratios for most crops are in the range of 1 to 4.

Exchangeable sodium

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

ANNEX 2. GUIDE TO SOIL DEPTH CLASSIFICATION

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

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