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Soil fertility analysis associated to land use in Western Kenya

Louis N. Gachimbi and Joseph Maitima

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SUMMARY OF TASKS: Analysis of soil samples from EMMC Sites.

[1]Josheph Maitima collected soil samples from EMMC sites i.e. Angurai and Busia Township in Teso and Busia District respectively from Western Kenya. The samples represent different land use types in each site and were collected at the time when land use mapping was being done. Each sample is a composite of three sub samples collected at approximately 1 meter apart in a triangle spacing within the same land use. The samples were analysed at the National Agricultural Laboratories under the supervision and interpretation of [2]Louis Gachimbi.

The purpose for soil analysis in EMMC is to determine fertility levels by examining chemical and physical characteristics of the soils. A focus is to be made on the chemical and physical properties that are particularly affected by land use.

Terms of Reference for Soil analysis were therefore to:

1. Prepare and process 7 sets of soil samples from Angurai (two sets), Busia, Kamuli, Iganga, Soroti and Tororo sites for laboratory analysis.
2. Supervise laboratory analysis of the complete standard soil fertility measures including soil organic carbon, N, P, K (all macro-nutrients), exchangeable acidity, micro-nutrients and or any other soil nutrient found necessary. Ensuring that high quality standards are applied in the analysis of samples in KARI Laboratory to ensure quality results.
3. To conduct data analysis and interpretation of the results in each of the 7 sets of samples.
4. To write a technical report on the soil fertility status represented by each sample with reference to the land use from which the sample was collected.
5. Prepare a database of soil analysis results arranged per site and per land use.
6. Present both digital and hard copy, a technical report on soil analysis in Kenyan sites and a second technical report on soil analysis in Uganda sites.
7. Present in a digital format a database of soil analysis from all the study sites.

[1]Joseph Maitima
International Livestock Research Institute
P.O. Box 30709, Nairobi.
e-mail: j.maitima@cgiar.org

[2]Louis Gachimbi
Kenya Agricultural Research Institute
P.O. Box 14733, Nairobi.
e-mail: inmasp@skyweb.co.ke

EXECUTIVE SUMMARY

A total of 112 samples were collected from Busia Township and Angurai sites in Busia and Teso Districts respectively. These comprised 25 from Busia and 87 from Angurai in two sampling dates, 2002 and 2004 to determine soil fertility change over the two year period. In order to assess the soil fertility from the sites, and in different land uses, soil chemical and texture analysis was carried out and values compared with crop recommended agronomically adequate values for specific elements. Texture for purposes of soil hydrologic behaviour was also considered in respect to soil water.

Average organic carbon in the soils was 1.39% with mean in Busia and only 64% of the farms had adequate levels of carbon. In Angurai site, mean organic carbon increased over the two year period from 1.13% to 1.41% with the number of farms with adequate (moderate) levels increasing from 13% to 35%. However, overall carbon levels were still below threshold levels during the two sampling intervals. These levels of nitrogen indicated that the soils were very low in organic matter as revealed by the analysed total nitrogen, which ranged from very low to just moderately adequate. Generally the sites showed low soil fertility status as indicated by the soil organic C, total nitrogen, available phosphorous and soil PH. Exchangeable potassium was adequate in the two sites although the second sampling (after two years) in Angurai showed slightly low but above threshold levels of the same.

Available phosphorous was very low to sustain optimal crop yield in both sites even after two years sampling interval (in Teso District). 96% of points in Busia and 89% of points in Angurai and 80% of points after second sampling same site had deficient levels of available phosphorous. Some farms within the sites were applied phosphate fertilizers at planting time while others received no fertilizers. Majority of soils from these sites were also found to be strongly acidic thereby limiting availability of phosphorous. In these situations, phosphorus tends to be "fixed" by the soil. The low available P levels needs to be corrected through application of 100kg/ha of triple super phosphate or compound fertilizer containing N, P and K at planting time and top dress with 80kg/ha CAN. Acidifying fertilizers like diammonium phosphate (DAP), ammonium sulphate (AS) or ammonium sulphate nitrate (ASN) should be avoided due to their acidifying reaction. Alternatively, agricultural lime need to be applied at a rate of 2t/ha one month before planting. Exchangeable potassium (me%) was on average adequate but there were a good number of sites, which were K deficient and required K replenishment for balanced crop fertilizer application. Two year sampling interval in Angurai led to an increase in the points with potassium deficiency from 24% to 29%. It is recommended that in Busia site and Angurai in Teso District, compound fertilizer containing nitrogen, phosphorous and potassium e.g. N: P: K 17:17:17 at 300kg/ha per year should be used at planting to correct N, P and K deficiencies in the soil.

All the sites in Busia and Angurai (will) will require application of 5t/ha FYM or compost on sites with crops to raise soil organic matter and hence total nitrogen. In Angurai site foliar feed containing zinc, should be sprayed on crops. On the effect of time interval on soil fertility status in Teso District, it can be concluded that farming activities at this site led to change in soil fertility status and almost coincides with the KARI-NARL recommendations that oil should be resampled after very three years.

Most of the land (60%) in Busia is under bushland/ grazing land/ grassland/fallow and least under nappier grass indicating most farmers here practice with free range grazing and limited zero grazing. Land under crops is just 36% of the land implying that farmers are slowly

adapting crop farming. The most important crops in Busia are maize (18%) and sweet potatoes (12%) followed by cassava (8%). In Angurai site during the first sampling, 83% of the land was under crop farming with the rest under bush/fallow while during the second sampling (2004), only 64% was under cultivation. Only 18% of the farms were fallow/bush for grazing. There was pure groundnut and groundnut intercropped with maize. The nitrogen fixed by groundnuts benefit the maize crop.

The %sand, %silt and %clay indicated that soils taken from these two sites had a mean textural class of sandy loam (SL) even after an interval of two years sampling in Angurai. This texture implies that the soils have been subjected to erosion and hence the low %clay range of 5.8-57.3 % clay for Angurai and 11.1-41.2 % clay for Busia. Soil texture can only change due to erosion as both water and wind erosion would take away the fine particles first leaving large particles.

1.0 INTRODUCTION

Busia and Teso Districts are located in western Kenya. The area has been under cultivation for many years. Busia and Teso Districts (Figure 1) borders Uganda on the west (Maitima *et al* 2003). Mt. Elgon is a major landmark in the area it is north of Busia town. Lake Victoria is 70 kilometers to the south of Busia. The area is relatively dry and is characterized as agroecological zones LM2, maize/beans intercrop and maize monocrop; sorghum and cassava (Jaetzold and Schmidt, 1983). Rainfall is bimodal with short rains falling between March and May and the long rains falling between October and December of every year. Subsistence agriculture is the main human activity that supports livelihoods in the region. Crops grown include cassava, cotton, maize, sorghum, sweet potatoes and a number of other annual subsistence crops grown on a small scale. Sugar cane, tobacco and pepper are grown primarily as cash crops by some farmers. In addition to cultivation, livestock keeping is practiced dealing mainly with indigenous breeds and crossbreeds. Several farmers especially close to towns have started raring exotic cattle in an effort to improve productivity and get better returns from their small plots of land.

There is intensive land cultivation in Busia study area due to a relatively high population resulting from the proximity to town. Many people in the division live in their homes in a rural set up while working in the town either in formal employment or in self-employment. Within Busia Township study area land sizes are on average 2 to 10 hectares.

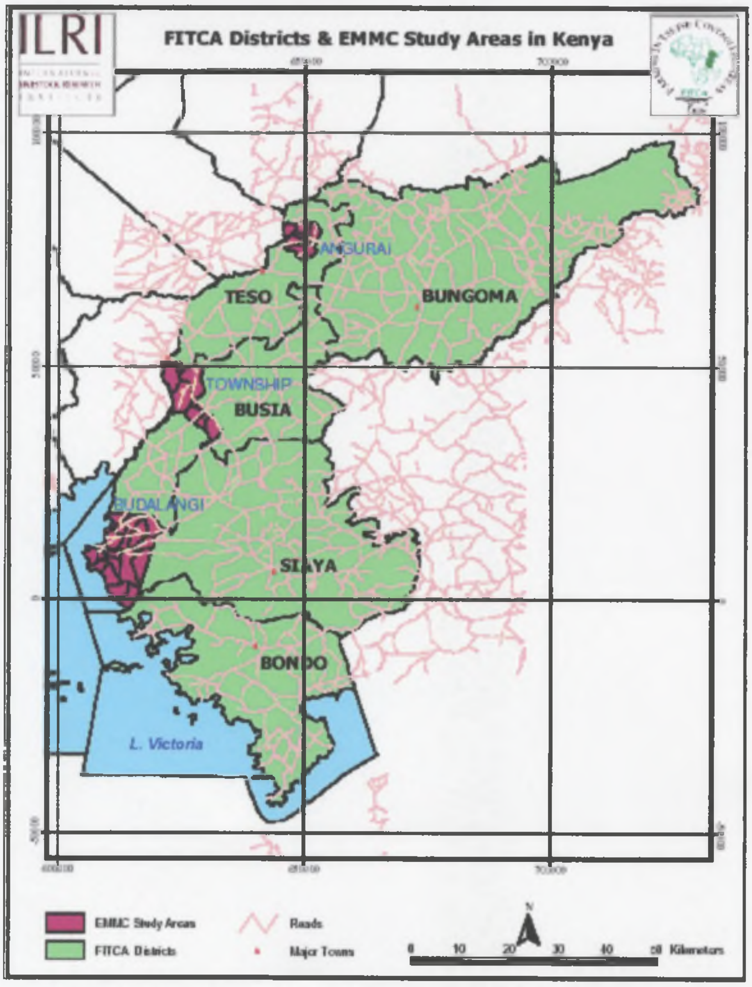

Figure 1: EMMC Study Areas in Kenya.

The population of Teso District as given in 1989 population census is 126,584. With a population growth rate of 3.5% per year, the population is projected to rise to 167, 487 in 1997 and to 192,656 in 2001 (Government of Kenya, 1997-2001). Among the four divisions of the District (i.e. Amagoro, Amukura, Angurai and Chakol), Angurai study area had the lowest population density while Amagoro had the highest population density (413 persons/km2) in 1997, projected to increase to 475 persons/km2 in 2001. Teso District's altitude ranges from 1300m a.s.l in the south to an average of 1500m in the central and northern parts (Angurai division is in the northern part of the District). The topography is undulating with hilly terrain in some parts. Numerous bushes of *Lantana camara* that grow as fallow in abandoned farmlands, roadsides and bushes along streams and river Malaba characterize Angurai area of the District. These are known tsetse habitats and are expected to reduce due to increased cultivation and grazing (GoK, 1997).

1.1 Nature of the problem

Following the 1997 cotton market depression, a decrease in livestock population and an increase in tsetse fly density have been observed in western Kenya. The question here is to find out what was the determining factor for those changes. A land use change has occurred in the more than ten years ago (Maitima *et al* 2003), which has caused an environmental imbalance which favored tsetse thriving. The woodland and the croplands have decreased and fallow has increased, causing more habitats for tsetse flies. The decrease in agricultural production can also be associated to decreased labor due high mortality rate within the population, caused by HIV/AIDS among others (GoK, 1997).

1.2 Objectives

The objective was to carry out a thorough study of the area to obtain a precise baseline data on the landscape following a multidisciplinary approach. The approach called for various types of interventions on a complex system where the tsetse habitats had proliferated. The various disciplines involved in the study include:

- Geography to support mapping.
- Socio-economics: household survey questionnaire to investigate farmers' current and past agricultural practices under tsetse challenge.
- Ecology: monitoring changes in the environment in relation to soil and vegetation.

2.0 MATERIALS AND METHODS

2.1 Study area and methods

The survey area in Busia Township and Angurai site, Teso District respectively was divided into grids and one random point generated in each grid, using the computer. Angurai site was sampled first in year 2002 and then 2004, after two years interval. The results are therefore identified as Angurai 1 (year 2002) and 2 (year 2004) to reflect the date sampled. Samples were taken from the same identified GPS points in Angurai. The objective is to determine interval of soil sampling for soil fertility replenishment recommendations to the farmers. The sample points were distributed in such a way that they represented all the types of land use in the study areas. From each random point, 2 to 3 soil samples were colleted from 20cm deep excavations. A half kilogram sample was collected into a plastic bag and properly labeled indicating the sample number, land use and area where it had been collected (Annex 1). First hand visual description of the sample was done using appropriate form.

Erosion indicators i.e. rill, ripples, deposition of soil on vegetation and on gentle slope, gully, nutrient deficiency, bare and barren spots, pedestals were recorded at each sample collection site. Soil was then analysed for chemical and physical composition. All soil samples were analysed at the National Agricultural Laboratories using routine laboratory soil analytical methods as published by Hinga *et al* (1980). Soil samples taken for routine analysis are first prepared for the analysis through air drying, breaking up of aggregates by careful pounding with pestle and mortar and sieving through 2mm sieve. Only soil that passes the sieve is analysed. The analytical methods were as follows: -

Texture: No chemical treatments to remove cementing agents. 50g soil is shaken overnight with sodium hexametaphosphate/sodium carbonate. Measurement of silt and clay (0-0.05 mm particle size) and clay (0-0.002 mm particle size) with a pipette ASTM 152H is done after 40 seconds and 2 hours respectively. Silt fraction (0.002 – 0.05 mm) is obtained by difference and sand fraction (0.05-2mm) is the rest fraction (Hinga *et al* 1980). The textural triangle was used to indicate the soil textural class.

2.1.1 PH and electrical conductivity (EC)

PH and EC were determined in a 1:1 and 2:5 soil-water suspensions respectively. EC was done for soils with PH>7.0 PH of the soil suspension was read using glass-calomel electrode while the EC was read using EC meter.

2.1.2 Organic carbon (%) and total nitrogen (%)

Soil organic carbon was done according to method of Walkley and Black (1934). 5 g of finely ground soil (less than 0.5mm) was reacted with 10ml. In potassium dichromate in a 500 ml wide-mouthed conical flask with additional of 15 ml conc. H_2SO_4. After 30 minutes, the digest was back titrated using 0.5 N ammonium ferrous sulphate using diphenylamine indicator. % Organic carbon was calculated from the used dichromate (Walkley and Black 1934). The C/N ratio was done by dividing % C by %N.

Total Nitrogen (%N) in the soil passing 2mm sieve size was done using semi-micro Kjeldal method according to Walkely and Black (1934). The principle used was that organic C bound Nitrogen in the soil is converted into ammonium nitrogen when the soil is digested in con. H_2SO_4 in presence of suitable catalyst at high temperatures. Ammonium gas is liberated from the formed ammonium nitrogen by reaction with sodium hydroxide. The liberated ammonium is captured in a dilute acid from where %N in the soil can be calculated.

2.1.3 "Mass analysis" for available nutrients.

The less than 2mm ground soil is used for the analysis of P, K, Ca, Mg, Na, Mn nutrients in the soil. The soil was extracted using dilute mineral acid (0.1NHCl + 0.025NH_2SO_4) in a soil extractant ratio of 1:5 for 1 hour. Determination of Ca, K, and Na was done by flame photometer after an anion resin treatment for Ca. magnesium (Mg) and Manganese were determined from the extract by reading directly from the Atomic absorption spectrophotometer. P was done calorimetrically using the yellow colour of vanadomoly-bdophoshoric yellow complex (Mehlich *et al* 1964)

2.1.4 P- Olsen (for soils with PH above 7.0)

Soils passing 2mm sieve are extracted using $0.5NaHCO_3$ PH 8.5 for ½ hour a soil-extractant ratio of 1:5 to the soil extract, a reagent mixture of H_2SO_4, ammonium molybdate, ascorbic acid and anti mony potassium/titrate solution. The colour intensity is measured with a spectrophotometer or a colorimeter. The colour intensity is proportional to the P concentration in the extract and hence the soil (Watanbe and Olsen 1965).

2.1.5 Analysis for trace elements Fe, Zn, Mn and Cu.

The trace elements Iron, Zinc and Copper were extracted from the finely ground (>2mm) by dilute HCl (0.1NHCl) as described in Hinga *et al* (1980). The soils are extracted for 1 hour at soil: extract ratio of 1:10. After certifying, the extracts are filtered using filter paper 1. Fe, Zn, Mn and Cu concentrations are read from AAS with specific lamps for each element. The results are given in PPM.

3.0 RESULTS AND DISCUSSIONS

3.1 Soil fertility

A total of 112 samples were collected from Busia Township and Angurai sites in Busia and Teso Districts respectively. These comprised 25 from Busia and 87 from Angurai in two sampling dates, 2002 and 2004 to determine soil fertility change over the two year period. In order to assess the soil fertility from the sites, and in different land uses, only soil chemical analysis most considered and analysed elements and PH compared with crop recommended argonomically adequate values for specific elements. Texture although very important aspects as regards soil hydrologic behaviour is considered in respect to soil water holding capacity in another section in this report. The classes of nutrients availability used in evaluating nutrient availability were those developed by Mehlich *et al* (1964) and modified by Hinga *et al* (1980) while working in Kenya. This classification was adopted because it had been shown to relate well to crop fertilizer responses in Kenya (FURP 1994). The classification of soil textural class was based on textural triangle (Hinga *et al* 1980)

Table 1: Classes of soil fertility status of P, K, Ca, Mn, Mg, Fe, Zn and Cu.

Nutrient	Deficiency level	Adequate level	Excessive or reactionary level	Remarks
Sodium me%	Seldom applies	0.0-2.0	>2.0	Salinity/sodicity possible
Potassium %	<0.2	0.2-1.5	>1.5	
Calcium %	<2.0	2.0-15.0	>15	In calcareous soils
Magnesium %	<1.0	1.0-3.0	>30	
Manganese %	<0.11	0.11-2.0	>2	Excessive in very acid soils or in poorly drained soils
Phosphorous (ppm) (Mehlich)	<20	20-80	>80	
Phosphorous (Olsen)	<5	5-10	>10	Calcareous soils
Fe ppm	<10	>10		
Zn ppm	<5	>5		
Cu ppm	<1.0	>1.0		

Source: Mehlich et al 1964

Table 2: Classification of soil PH

PH	Rating
Below 4.5	Extremely acid
4.5 - 4.9	Strongly acid
5.0 – 5.9	Moderately acid or medium acidity
6.0 – 6.4	Slightly acid
6.5 – 6.9	Near neutral
7.0 – 7.4	Slightly alkaline
7.5 – 8.4	Moderately alkaline
8.5 – 8.9	Strongly alkaline
Above 9.0	Extremely alkaline

Source: Hinga et al 1980

3.2 Variability of soil fertility within Busia and Teso sites in Kenya

Generally the sites showed low soil fertility status as indicated by the soil organic C, total nitrogen, available phosphorous and soil PH. Exchangeable potassium was adequate in the two sites although the second sampling (after two years) in Angurai showed slightly low but above threshold levels of the same. Average organic carbon in the soils was 1.39% with mean range from 0.83% to 3.22% in Busia (Table 3) and only 64% of the farms had adequate levels of carbon. In Angurai site, mean organic carbon increased over the two year period (Angurai 1and 2) from 1.13% to 1.41% with the number of farms with adequate (moderate) levels increasing from 13% to 35%. However, overall carbon levels were still below threshold levels during the two sampling intervals. Mean total nitrogen is low in Angurai 1 (0.13%) and Angurai 2 (0.14%) but slightly higher in Busia (0.25%) though the range is wide. This is due to high bush/fallow in Busia site. Total soil nitrogen ranged from 0.06% to 0.49% with mean total nitrogen ranging from 0.13% to 0.25% (Table 4).

These levels of organic carbon and nitrogen indicated that the soils were very low in organic matter as revealed by the analysed total nitrogen, which ranged from very low to just moderately adequate. Although the soil organic carbon as shown by the C/N ratio is of high quality in terms of mineralization, it is not adequate and should be raised by the application of at least 5t/ha farmyard manure or compost to provide adequate nitrogen for crops from mineralization since 94% of points during second sampling (Angurai 2) and 91% of points during first sampling (Angurai 1) in Teso District and 60% of points in Busia (Table 4) were deficient in total nitrogen. They were also low in organic matter and hence the necessary correction needed.

Table 3: Average soil organic carbon (C, %) levels in two sites in Kenya

	No. of farms	Percentage of farms with observed organic carbon level (%)					
		C<0.5 (deficient)	0.5<C<1.5 (low)	1.5<C<3.0 (moderate)	Mean	SD	Range
Busia	25	0	36	64	1.64	0.47	0.83-3.22
Angurai 1	38	3	84	13	1.13	0.14	0.48-2.32
Angurai 2	49	2	63	35	1.41	0.59	0.41-3.0

***N/B:** Organic carbon critical level = 2%*

Table 4: Average soil nitrogen levels in two sites

	No. of farms	Percentage of farms with observed nitrogen level (N, %)						
		N<0.05 (deficient)	0.05<N<0.12 (low)	0.12<N<0.25 (moderate)	N>0.25 (adequate)	Mean	SD	Range
Busia	25	0	0	60	40	0.25	0.07	0.16-0.49
Angurai 1	38	5	34	55	5	0.13	0.06	0.04-0.3
Angurai 2	49	0	43	51	6	0.14	0.06	0.06-0.39

N/B: Nitrogen critical level = 0.2%

Available phosphorous was very low in both sites even after two years sampling interval (Table 5). 96% of points in Busia and 89% of points in Angurai 1 and 80% of points after second sampling had deficient levels of available phosphorous. Mean available P ranged from 8.33 ppm to 13.97 ppm with a range of 2 to 131 ppm. This broad range meant that some farms within the sites were applied phosphate fertilizers at planting time while others received no fertilizers. Majority of soils from these sites were also found to be strongly acidic. 88%, 88.5% (average) of farms in Busia and Angurai in Teso respectively had PH below 6. In these situations, phosphorus tends to be "fixed" by the soil. The low available P levels needs to be corrected through application of triple super phosphate or compound fertilizer containing N, P and K. Acidifying fertilizers like diammonium phosphate (DAP), ammonium sulphate (AS) or ammonium sulphate nitrate (ASN) should be avoided due to their acidifying reaction. Alternatively, agricultural lime need to be applied at a rate of 1t/ha one month before planting.

Table 5: Average soil phosphorous (Mehlich) levels in two sites in Kenya

	No. of farms	Percentage of farms with observed phosphorus (P, ppm)					
		P<20 (Deficient)	20<P<80 (Adequate)	P>80 (Excessive)	Mean	SD	Range
Busia	25	96	4	0	8.33	6.08	3-029
Angurai 1	38	89	8	3	13.97	25.74	2-131
Angurai 2	49	98	2	0	4.49	7.61	1-51

N/B: Phosphorous critical level = 20 ppm.

Exchangeable potassium (me%) was on average adequate as shown by the mean range (0.20-0.41% me%) but there were a good number of sites, which were K deficient (Table 6) and required K replenishment for balanced crop fertilizer application. Two year sampling interval in Angurai lead to an increase in the points with potassium deficiency from 24% to 29%. It is recommended that in Busia and Angurai in Teso District, compound fertilizer containing nitrogen, phosphorous and potassium e.g. N: P: K 17:17:17 at 300kg/ha per year should be used at planting to correct N, P and K deficiencies in the soil. These observations on K collaborate the results and recommendation by Kanyanjua and Buresh (1999) on their work on K deficiencies in Western Kenya.

Table 6: Average soil potassium (exchangeable) levels in two sites in Kenya.

	No. of farms	Percentage of farms with observed potassium (%) level					
		K<0.2 (Deficient)	0.2<K<1.5 (Adequate)	K>1.5 (Excessive)	Mean	SD	Range
Busia	25	40	60	0	0.41	0.36	0.06-1.43
Angurai 1	38	24	76	0	0.39	0.21	0.14-0.92
Angurai 2	49	29	71	0	0.29	0.15	0.06-0.7

N/B: Potassium critical level = 0.2me%.

Trace elements iron and copper were generally adequate in Busia but deficient in Angurai site, Teso District (Table 7-9). There were pockets of iron and zinc deficiency in both Busia and Angurai sites. Copper was adequate in Busia site. These elements i.e. copper, iron and zinc should be selectively corrected through the use of folia sprays on those farms where they are deficient. It was noted that zinc deficiency in Angurai site (Teso) did not change with time as points with zinc and iron problems remained the same during the two year period (Table 8). The trace element deficiency may be attributed to soil parent materials, clay mineralogy and soil texture (FAO, 1972).

Table 7: Average soil copper (Cu, ppm) levels in two sites in Kenya.

	No. of farms	Percentage of farms with observed copper level (ppm)				
		Cu<1.0 (deficient)	Cu>1.0 (adequate)	Mean	SD	Range
Busia	25	0	100	4.44	1.31	2.2-8.35
Angurai 1	38	34	66	1.42	0.85	0.14-3.63
Angurai 2	49	80	20	0.8	0.64	0.03-2.93

Table 8: Average soil zinc (Zn, ppm) levels in two sites in Kenya

	No. of farms	Percentage of farms with observed zinc level (ppm)				
		Zn<5.0 (deficient)	Zn>5.0 (adequate)	Mean	SD	Range
Busia	25	48	52	6.49	3.9	1.7-15.9
Angurai 1	38	97	3	2.99	1.01	1.75-6.61
Angurai 2	49	96	4	1.1	1.91	0.01-11.7

Table 9: Average soil iron (Fe, ppm) levels in two sites in Kenya

	No. of farms	Percentage of farms with observed iron level (ppm)				
		Fe<10 (deficient)	Fe>10 (adequate)	Mean	SD	Range
Busia	25	16	84	21.85	33	1.64-177
Angurai 1	38	5	95	17.9	9.27	9.5-44.6
Angurai 2	49	4	96	26.1	11.81	7.13-75

3.3 Soil PH in Busia and Teso Districts

In Kenya, many soils in the humid and sub-humid regions that cover about 13% of the total land area have an acid reaction (FURP, 1987, Hoekstra and Corbett, 1995). These areas have high population densities and contribute significantly to the Kenyan economy, through cash and food crops and dairy production. Low PH soil have a number of nutritional problems that include (i) poor nutrient availability, particularly P, Ca, Mg and Mo, (ii) toxic levels of H^+, Al^+ and Mn^{2+}, (iii) low activity of micro organisms responsible for humification and (iv) low effective cation exchange capacity (Kamprath, 1984). Under natural conditions, PH of a soil depends on soil parent material, amount of leaching and whether peat has developed on top of an originally mineral soil as a guide to fertilizer and other amendments recommendations.

The soil PH in the two sites is shown in Table 10. The results indicated that most (64%) soils from Busia site were very acidic (PH 4.0- 5.0) and will require liming to correct acidity to the optimum PH range (5.5 -6.5) required by most crops (Mehlich *et al* 1964) which are medium acid tolerant. Over 52% of the points sampled during the first sampling (Angurai 1) were acidic to strongly acidic and this increased to 78% after 2 years interval (Angurai 2) in Teso District possibly due to use of acidifying fertilizers. The soils require liming to correct soil acidity depending on crop to be grown (Hinga *et al* 1980, FAO, 1983, Mehlich *et al* 1964). Annex 1 shows the acid tolerance of crops as defined and this can be used as a guide to whether any liming is required for some particular crops.

Table 10: Average pH levels in two sites in Kenya

	No. of farms	Percentage of farms with observed pH level							
		PH<4.5 (Extremely acidic)	4.5<pH<5.0 (strongly acidic)	5.0<pH<6.0 (moderately acidic)	6.0<pH<6.5 (slightly acidic)	6.5<pH< (near neutral)	Mean	SD	Range
Busia	25	32	32	24	4	8	4.88	0.72	4.08-6.91
Angurai 1	38	18	34	45	3	0	4.93	0.46	4.16-6.48
Angurai 2	49	33	45	16	2	4	4.8	0.66	3.75-7.27

3.4 Liming of acid soils in Busia and Teso Districts

The extent to which liming in Kenya has been adopted is not well documented but informal discussions has shown low use of lime due to lack of knowledge, its bulky nature, and unpleasant application methods as a result of its dusty nature. Farmyard manure (FYM) application is however, a widely adopted practice of reducing soil Ph in subsistence farming in Kenya. According to a survey done in the Kenyan highlands, Karanja *et al* (1997) found that over 95% of the small holder farmers use FYM. Farmyard manure is applied in food crops either as an alternative or supplement to chemical fertilizers. While this is the only means of neutralising soil pH and subsequently soil fertility use of FYM, in other areas is low due to quality while in other cases FYM is insufficient. Quality of FYM depends on type of livestock and quality of feeds while total amounts are determined by the number of livestock and by extension of the land size (Kanyanjua *et al*, 2002)

Liming serves the purpose of neutralizing soil acidity and to supply the nutrients calcium and often also magnesium. The levels of Hp (exchangeable acidity) together with crop tolerance to acidity are the criteria used in lime recommendations. Only those crops listed under category (c) in Annex 1 require liming fully to neutralize Hp. For crops in this group lime with 1500kg/ha of lime for each me% Hp. Crops listed under (b) are expected to grow normally in the presence of a moderate amount of Hp provided the sum of Ca plus mg are present in excess of Hp. For these crops, lime only to neutralize Hp in excess of 1 me%. Thus for a Hp of 1-3 me% use 1500kg/ha of lime. For crop group (a) only lime to provide a final Hp to base ratio of 1. Otherwise lime needed is calculated from

$$\text{Lime required (Kg/ha)} = Hp - \frac{(Hp + Na + K + Mg + Ca) \times 1000 \times 1.12}{2} \text{ kg/ha.}$$

3.5 Variability of soil fertility within land uses in Busia and Teso Districts

The macro elements NPK, organic matter and PH levels in the soils within different land uses is given special attention as this is what mainly the farmers manipulate to correct their soil fertility. The elements measured values are divided by the critical values then multiplied by 100 (Mehlich *et al* 1964) and the results plotted on the same graph (Figure 2, 3 and 4) for comparison purposes. It can be seen that potassium is in excess of the nutrient critical level (of 0.2 me% exch. K) in two land uses, i.e. bushland/grazing land/grassland/fallow and sweet potatoes in Busia site (Figure 2). The percentage threshold level in the rest of land uses i.e. cassava, maize, swamp/water source and nappier grass is below the critical level at the site. This high potassium levels is attributed to recycling of potassium via litter fall, decomposing grasses and animal droppings in the bush land/grazing land/grassland/fellow and decomposing of sweet potatoes leaves within the sweet potato land use excess stock from the parent material. Potassium is easily recycled to the soil surface because it can be washed off the vegetation to the ground. The low potassium levels in the other land uses in Busia could also be attributed to non use of fertilizers containing potassium on cassava, maize and nappier grass coupled with continuous K mining in these land uses and its removal through harvest and biomass transfer as of observed by Stoorvogel and Smaling (1990) and Gachimbi (2002) while working on nutrient flows and balances.

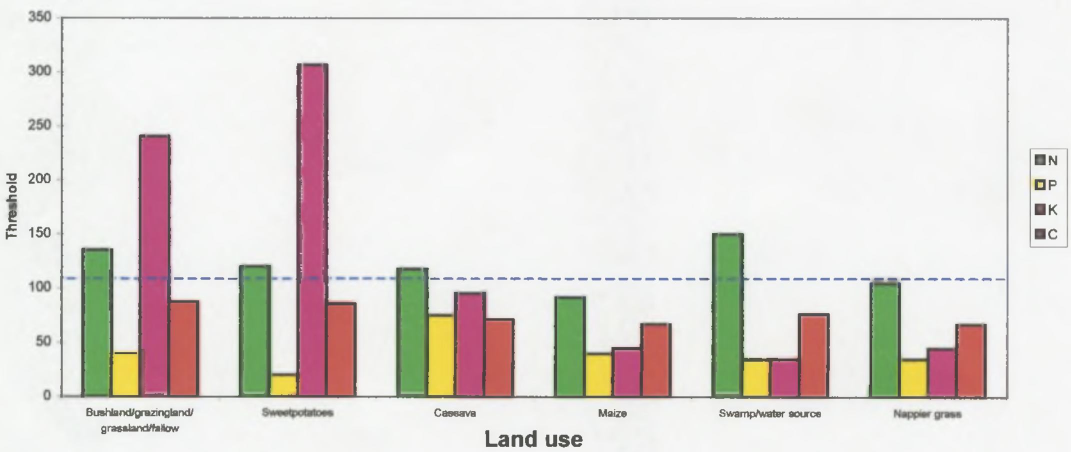

Figure 2: Variations of NPK and soil carbon in Busia township, Busia District.

The soils in western Kenya had been reported to be K deficient (Kanyanjua *et al* 1999) and K deficiencies was found to be related to soil parent material, non-use of K containing fertilizers and leaching in places of high rainfall regimes. This observation was however different in Angurai, Teso District during the first sampling and even after two years (Figure 3 and 4). In all land uses in Angurai, i.e. maize, groundnuts, groundnut/maize, finger millet, cassava, fallow/bush, tobacco and finger millet potassium was in excess of threshold levels. There was excessively greater amounts of exchangeable potassium in tobacco, finger millet and maize land uses was even higher than in other land uses. This difference was either attributed to potassium application through inputs such as manure or fertilizer containing potassium and particularly on tobacco, finger millet, maize, groundnuts and cassava or overlying potassium rich parent material. It is most likely K containing fertilizer for tobacco i.e. 15:15:6 + 4mg had been used.

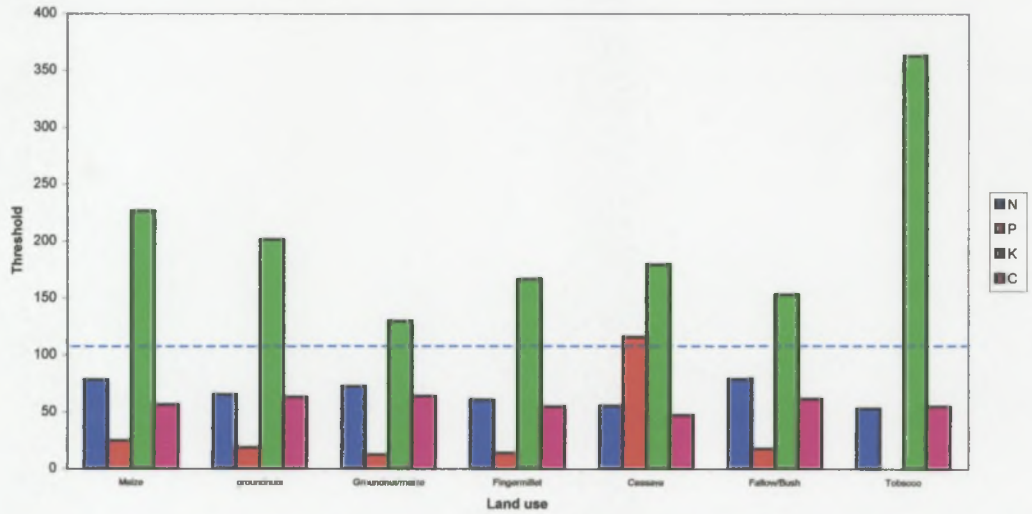

Figure 3: Variations of NPK and soil carbon in Angurai 1 (year 2002), Teso District.

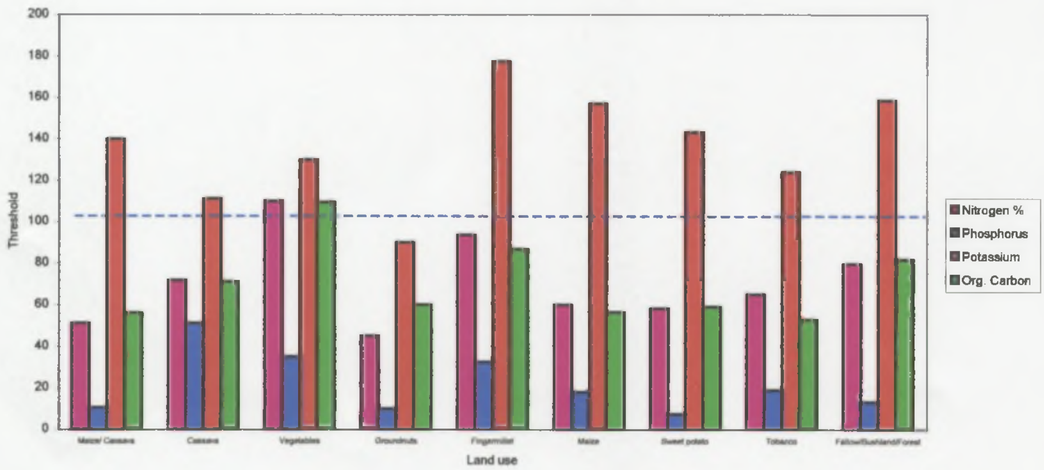

Figure 4: Variation of NPK and soil carbon with land use after two years (year 2004), Teso District.

Similarly total nitrogen in the soil was slightly above the threshold levels in all land uses in Busia except in maize land use. This can only be attributed to decomposition of litter fall in most land uses. Maize had limited leaves fall that would decompose to add more organic nitrogen in the soil. Furthermore maize leaves have a wider C/N ratio and have very little nitrogen in addition to erosion problems. The actual organic carbon in all the land uses was however low. This was attributed to accelerated mineralization of organic matter under the prevailing hot and moist climatic regions within the areas. The same trend of low total nitrogen and organic carbon was observed in Teso District, Angurai site during the second sampling dates (Figure 4).

Available phosphorus was however, below threshold levels in all land uses in Busia and Teso Districts. This was attributed to very low soil PH, non-usage of phosphorus containing fertilizers and continuous removal through crop harvest (grains and stover). In Angurai, during the first sampling available P within the land uses was again below the threshold levels except in cassava land use. It was speculated that may be, some phosphate fertilizer was applied before cassava was planted or parent rock was rich in phosphorous. The rest of the available P trends can be explained by low PH and non-usage of P- fertilizers and continuous removal via crop harvest. Soil phosphorus at PH below 5.5 is precipated by iron and aluminium and is not extracted by dilute acids used for available P analysis nor is it available to the plants.

3.6 Variability of soil pH, N, P, K and soil organic carbon with land uses in Busia and Teso Districts

The results of NPK, PH and soil organic carbon for Busia and Angurai sites are shown in Figure 5, 6 and 7 for the two sites and sampling after 2 years in Angurai site. The results indicated a low soil PH (4.3-5.1) within the bushland/grazing and grassland/fallow, sweet potatoes and swamp/water source. This was attributed to organic substances exudated within the Ah-horizons and plenty of OH^- ions within the swamp land use although not enough to make the PH alkaline due to redox reactions in swamps/water source and parent material in the area (Figure 5). PH was very low under cassava, maize and nappier grassland uses and will require corrections through lime application. In Angurai (Figure 6) the soil PH was lowest under groundnut/maize (PH 4.7), finger millet (PH 4.8), cassava (PH 4.8) and fallow/bush (PH 4.8) and highest in tobacco (PH 5.3) and finger millet (PH 5.6). The PH levels are not optimal for the crops grown within the land uses. Maize crop is medium acid tolerance (PH 5.3-6.0) and is currently is being grown on soil with PH of around 5. Some finger millet is also being grown on soil PH 4.8 while it will require PH between 5.3-6.0.

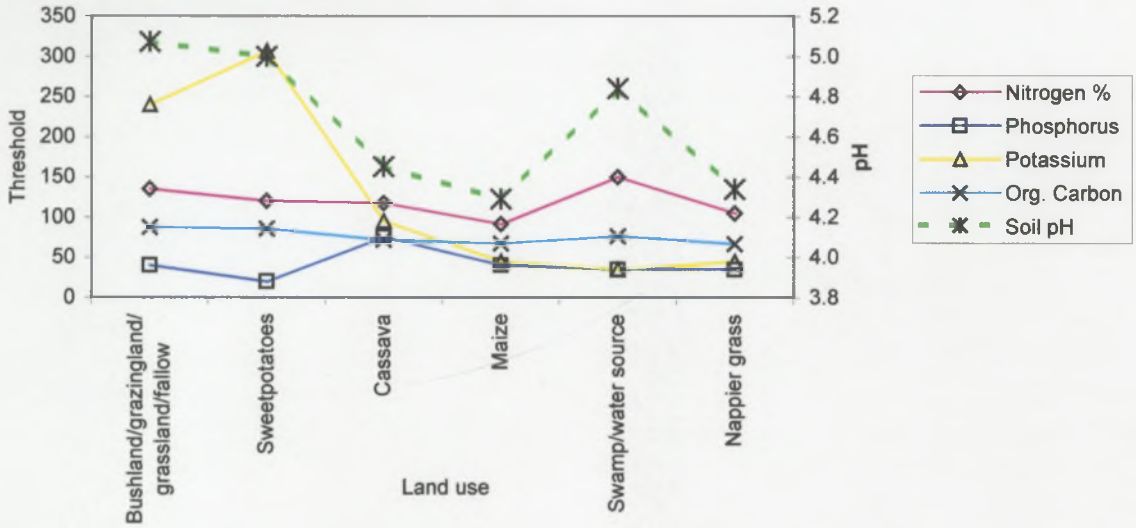

Figure 5: Variations of NPK soil C and pH across land uses in Busia Township, Busia District.

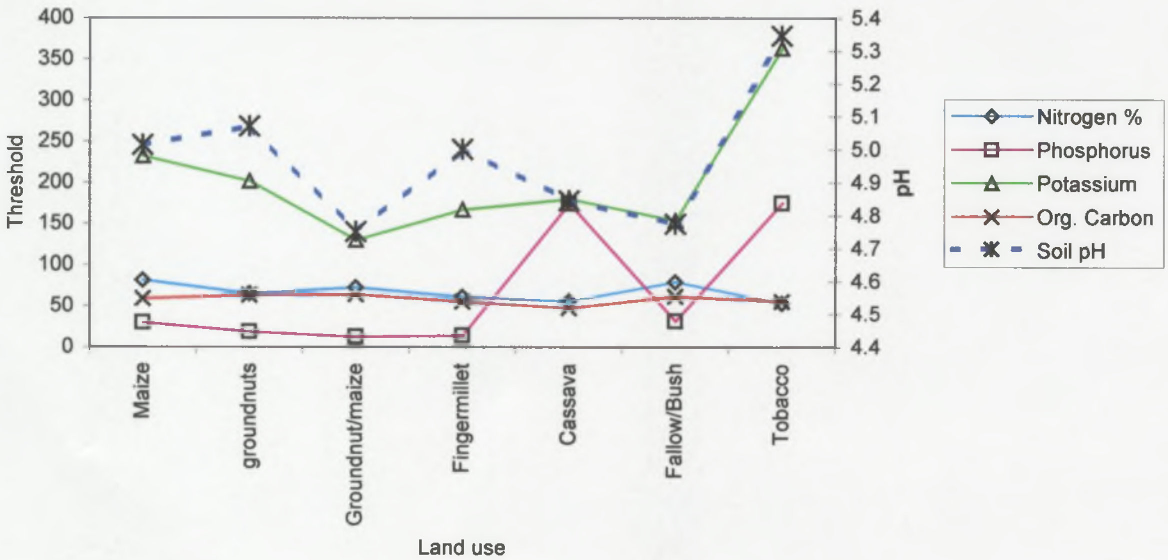

Figure 6: Variations of NPK and C and pH across land uses in Angurai 1, Teso District.

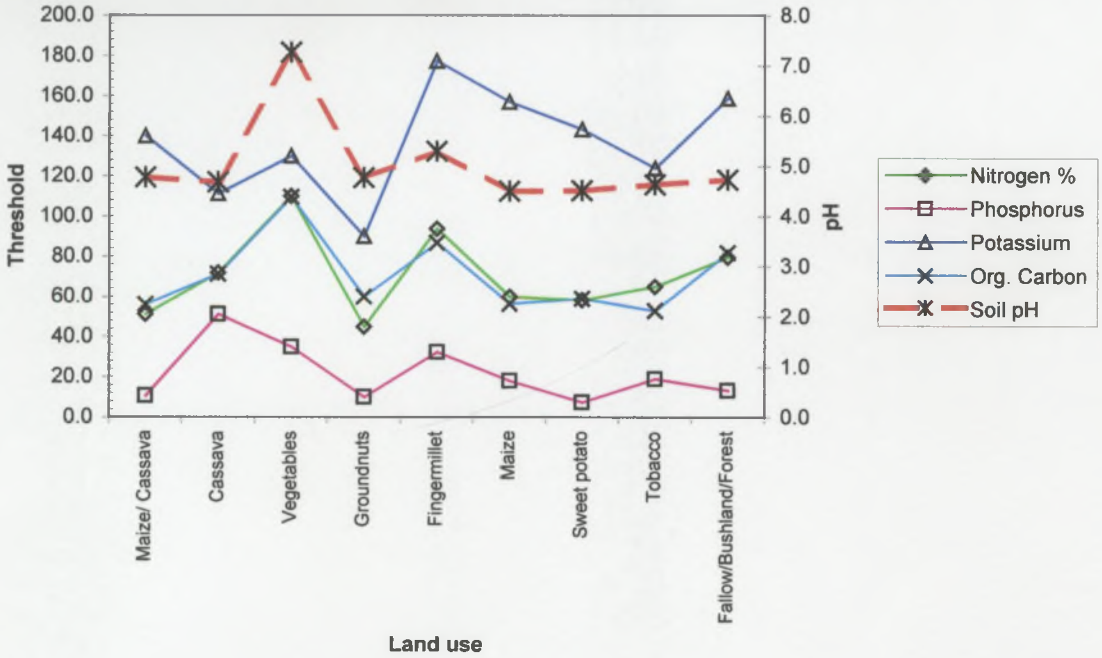

Figure 7: Variations of NPK and soil C and pH across land uses in Angurai 2, Teso District.

To get optimal PH, lime has to be applied and inco-operated into the soil three weeks before planting to correct the PH. In general most of the soil pH within some land uses is just below the optimal PH required by the crops planted and if some lime is not applied low yields will be realized. The differences in fertility status and pH over the two year period in Angurai site could be explained by change in land use over the two year period (Table 11). There was 2% overall change in land use in Angurai. That period saw a reduction in groundnuts, cassava, groundnut/maize, finger millet and an increase of tobacco, vegetables, sweet potatoes and fallow/bush cover. This itself could contribute due to FYM and acidifying fertilizers applied in tobacco fields.

Table 11: Percent land use change from 2002 to 2004 in Teso District.

Land use	**Year 2002** (Angurai 1)	**Year 2004** (Angurai 2)	**+ or – ve change**
Maize/cassava	0	8	+8
Maize	18	14	-4
Cassava	24	16	-8
Groundnuts	11	2	-9
Groundnut/maize	5	0	-5
Finger millet	17	8	-9
Sweet potatoes	0	6	+6
Fallow/bushland/forest	17	34	+15
Tobacco	8	10	+2
Vegetables	0	2	+2

In Busia Township, land use distribution is shown in (Figure 8). Most of the land (60%) in Busia is under bushland/ grazing land/ grassland/fallow and least under nappier grass indicating most farmers here are pastoralists with free range grazing and limited zero grazing. Land under crops is just 36% of the land meaning farmers are slowly adapting crop farming. The most important crops in Busia are maize (18%) and sweet potatoes (12%) followed by cassava (8%). In Angurai site during the first sampling, 83% of the land was under crop farming with the rest under bush/fallow while during the second sampling (2004), only 64% was under cultivation. Only 18% of the farms were fallow/bush for grazing. The most important crop grown in Angurai is cassava (24%) followed by maize (18%) and finger millet (17%). There was pure groundnut and groundnut intercropped with maize. The nitrogen fixed by groundnuts benefit the maize crop.

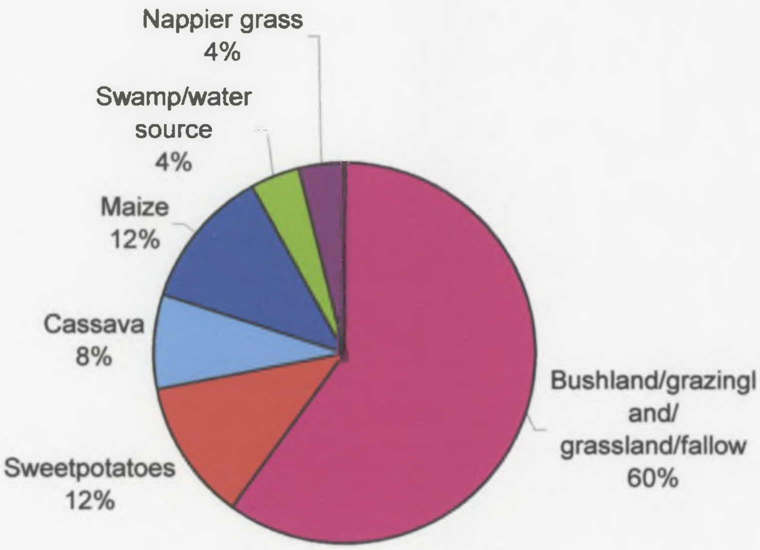

Figure 8: Distribution of land uses in Busia Township, Busia District.

Overall, in Teso District, only potassium is adequate in agronomic terms (Mehlich *et al* 1964) in all the land uses with the nutrients N, P and carbon being very low even after two years interval (Figure 9). In Busia, nitrogen is above threshold level but most significantly adequate is potassium which is at least 200% above threshold level. This is however not the case in Busia where N and K is adequate. This is possibly due to large sizes of grazing land/bush (60%) in Busia unlike in Teso where fallow/bush contributed only 18% in year 2002 and 34% in year 2004.

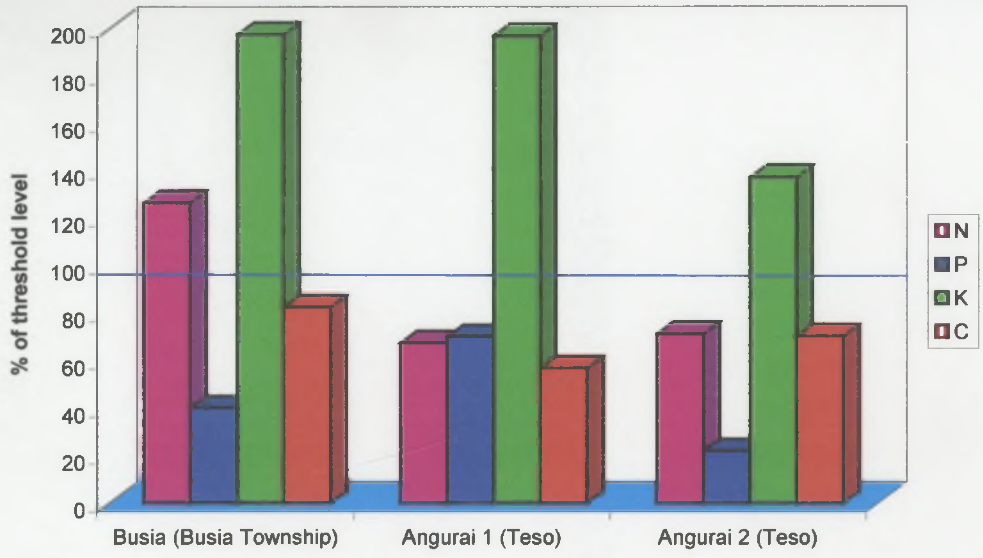

Figure 9: Overall variability of NPK and soil carbon in tsetse infested Busia and Teso Districts.

3.7 Soil fertility status and frequency of sampling at Angurai, Teso District.

Incidentally, soil sampling for fertility assessment at Angurai in Teso District was done at an interval of two years from the same sample point. It was felt important to compare the soil fertility of both sites as these sites were just in one place with only difference occurring on sampling dates i.e. August 2002 and June 2004. Table 12 shows that sampling two years latter led to an increase in percent organic carbon as indicated by the change in mean % organic carbon by 29%. There was some accumulation of organic carbon in the soil via vegetation addition as litter and subsequently the level of total nitrogen recorded (22%).

Table 12: Percent threshold level variation from 2002 to 2004 Angurai, Teso District.

Land use	**PH**			**N (%)**			**P (%)**			**K (%)**			**Organic carbon (%)**		
	2002	2004	Change	2002	2004	% change	2002	2004	% change	2002	2004	% change	2002	2004	% change
Maize	5.01	4.5	-0.51	78	50	-28	125	18	-107	227	150	-77	57	55	-2
Maize/groundnuts	4.75	4.78	+0.03	73			20			130			64		
Maize/cassava		4.73			50			10.7			140			56	
Cassava	4.84	4.7	-0.14	56	50	-6	170	51.5	-118.5	179	100	-79	48	70	+22
Vegetables		7.3			100			35			150			110	
Groundnuts	5.07	4.8	-0.27	65	50	-15	23	6	-17	201	100	-101	63	50	-13
Finger millet	5.58	5.3	-0.28	53	100	+47	50	32.5	-15.5	325	200	-125	81	85	+4
Sweet potatoes		4.5			150			7.5			150			60	
Tobacco	5.34	4.6	-0.74	53	50	-3	170	19	-51	363	100	-263	55	55	0
Fallow/bushland/ forest	4.77	4.7	-0.07	75	100	+25	30	13.5	-8.5	154	150	-4	62	80	+18
Total			-1.70			+20			-317.5			-649			+29

The number of farms deficient in available P after two years interval (Table 5 and 12) increased by 9% (89-98%) while those adequate in P also decreased in Angurai after two years by 6%. The number of farms deficient in K (<0.2me%) increased from 24% to 29% and those with adequate K (0.2<K<1.5) decreased from 76% to 71%. This meant that the farms had been cropped with crops year in year out without any fertilizer containing K added. The litter fall were either of low K quality or supplied less than what the harvested plant parts contained. Potassium is major element and is taken in large quantities from the soil by plants. It is also easily recycled via litter fall but can easily develop a partial negative balance if is not replenished. (Gachimbi 2002, Smaling *et al* 1990).

Trace element copper remained unchanged although the mean percentage was different. This was again the same for iron. The farms with zinc deficiency decreased slightly and those with adequate zinc also increased slightly. This small change does not reflect any use of zinc folia feed or application of zinc sulphate in the soil. It means the crop that was planted within the two year interval was taking up zinc in a soil deficient in this element. It can be seen from table 10 that soil PH changed after two-year interval in soil sampling as can be seen by changes of PH in soil from Angurai 2, which was sampled 2 years after Angurai. The number of extremely acid increased from 18% to 33% and the number of soils with strongly acidic reaction also increased by 11%. The percentage soils with near neutral acidic reaction also decreased by 4% from zero.

This means that some soil amendments that led to some acid neutralization must have been added to the soil. This could be inform of manure or compost as its decomposition leads to production of ammonium ions (NH_4+) which can be ammoniafied under prevailing temperature regumes within Teso District (FURP, 1987). Conversion of NH_4+ to NH_3 gas will raise the soil PH, as ammonia gas is strong base in presence of water molecules. This could have been responsible for this change in soil PH. This is supported by the observation that organic carbon% and total nitrogen did increase at Angurai as shown in table 3-4. On the effect of time interval on soil fertility status in Teso District, it can be concluded that farming activities at this site led to change in soil fertility status and almost coincides with the KARI-NARL recommendations that soil should be resampled after very three years (Gathua *et al* 2000)

4.0 SOIL TEXTURE

The term texture refers to the size range of particles in the soil i.e. whether the particles of which a particular soil is composed are mainly large, small or some intermediate size or range of sizes. Texture is a natural attribute of the soil and is used to characterise its physical behaviour. The textural fractions consist of sand, silt and clay particles. Sand is soil particles ranging in diameter from 2000µM down to 50µM (USDA classification). Silt particles have diameter 50µM-2µM while the clay is the smallest sized fraction whose particle size range from 2µM downward and is the colloidal fraction. It is the decisive fraction, which has the most influence on soil behaviour. The composition of sand, silt and clay in the soil gives its textural class, which tells more on soil hydrologic behaviour (Hillel 1980). Its susceptibility to erosion and capacity to hold moisture and nutrients. In order to assess the soil physical make up, soil texture for all the sites and even in different land uses were done.

4.1 Variability of soil texture with sites in Angurai, Teso and Busia respectively.

The soil texture for Angurai and Busia sites is as shown in (Table 13). The %sand, %silt and %clay indicated that soils taken from these two sites had a mean textural class of sandy loam (SL) even after an interval of two years sampling in Angurai. This texture implies that (Hillel 1980) the soils have been subjected to erosion and hence the low %clay range (5.8-57.3 % clay for Angurai and 11.1-41.2 % clay for Busia) as is also reported by Larcroix *et al* (2003). They recorded moderate sheet wash in 20% of maize plots and 10% soil accumulation around vegetation stamps. There was also a severe soil erosion in finger millet (18%), cassava (8%) and maize/groundnut (25%) (Wijngarden and Engelen, 1985). Because of the very low clay percentage of these sites the soils are so porous such that they cannot hold much water for a longer period and cannot be manipulated for water holding like in rice growing on vertisols. These soils will hold much water on saturation to field capacity but loose it on drying due to their high porosity.

Table 13: Mean percent soil texture and textural class

Site	No. of points	% Sand			% Silt			% Clay			Textural class
		Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	
Busia	25	34.8	11.2	21.3-63.5	26.9	8.7	15.7-61.6	38.3	11.8	2.6-57.3	SL
Angurai 1	38	65.0	9.7	47.7-81.1	11.9	3.9	5.9-27.0	23.1	8.1	11.1-41.2	SL
Angurai 2	49	62.0	9.9	44.3-87.8	12.0	4.5	2.2-22.7	26.0	8.9	5.8-44	SL

The soils easily available water is calculated as the difference in moisture content at P.f 2.3 and P.f. 3.7. The Pf 2.3 is the force at which the soil holds water at field capacity and is equivalent to 0.2 bar normally used by Kenya Soil Survey when conducting soil moisture characterization (Braun and Kibe 1978). The P.f 3.7 is the force at which the soil holds the water at a limit such that there is uninhibited plant growth. The difference between P.f 2.3 and Pf 3.7 will give easily available soil moisture. For this case if regressions equation M.C. (Moisture Capacity) P.f 2.3 = 0.54 x clay% + 3.1 and M.C P.f 3.7 = 0.49 x clay% - 0.7 are used to calculate the easily available moisture for soils in Angurai and Busia. It gave easily available moisture of 3.81 and 3.82 respectively. Their easily available moisture is within reported values (Table 14) for sandy loam texture soil class of 5mm as shown in table below.

Table 14: Amount of water (1mm) stored per 10cm soil for different textural classes.

Texture	Easily available moisture	Total available moisture
S/LS	4	5
SL	5	6
SCL/L	6	8
SC/CL	8	10
C	10	13

Source: (Braun and Kibe 1978)

The total available moisture is calculated from the difference in soil moisture at P.f 2.3 and P.f. 4.2. P.f 4.2 corresponds to 15 bar force holding the water on the soil particles and at this force plant will be highly restricted in accessing soil moisture and would wilt. The soil textural class may only be changed through erosion or soil physical removal from one place to another. However, soil structure maybe changed by addition of farmyard manure or through clay illuviation to lower layers of the profile.

4.2 Texture with land use: Busia and Angurai sites.

The average textural class of soils sampled from Angurai 1 and 2 was sandy loam (SL), sandy clay (SC) and sandy clay loam (SCL) as observed from the range of distribution of soil particle sizes. However, texture varied with land uses (Table 15-16) ranging from sandy loam, loam sandy, clay loam to clay after two years interval. However, in Busia texture ranged from loam under cassava, clay loam under bushland/grazing/grass/fallow, clay under nappier grass, maize and sweet potatoes (Table 17). Soil texture can only change due to erosion as both water and wind erosion would take away the fine particles first leaving large particles. Erosion has increased the amount of clay leading to textural change from original sandy loam to sandy clay loam and sandy clay in Angurai within a period of two years. This observation indicates that erosion is playing a key role in soil texture in Busia and Angurai sites. This is true and can be seen in the levels of increasing clay content under some land uses and as reported elsewhere in this report.

Table 15: Mean soil texture in various land uses in Angurai 1, Teso District.

Land use	% Sand	% Silt	% Clay	Class
Maize	67.7	12.9	19.4	SL
Groundnuts	51.9	12.8	35.3	SC
Groundnuts/maize	70.2	9.2	20.4	SCL
Finger millet	62.2	12.1	25.7	SCL
Cassava	69.3	11.1	19.6	SL
Fallow/bush	62.5	13.1	24.5	SCL
Tobacco	65.2	11.6	23.2	SCL

Table 16: Mean soil texture in various land uses in Angurai 2, Teso District.

Land use	%Sand	%Silt	%Clay	Class
Maize/ Cassava	63.9	8.4	27.7	SCL
Maize	65.3	10.1	24.6	SL
Cassava	61.5	13.3	25.2	SL
Vegetables	47.7	20.2	32.1	SCL
Groundnuts	56.0	8.6	35.4	SCL
Finger millet	64.9	9.6	25.5	SL
Sweet potato	58.2	14.5	27.4	SL
Tobacco	66.3	11.6	22.1	SL
Fallow/Bushland/ Forest	60.3	13.1	26.6	SL

Table 17: Mean soil texture in various land uses in Busia Township, Busia District.

Land use	% Sand	% Silt	% Clay	Class
Bushland/grazing/grasslands/fallow	34.8	25.1	40.1	CL
Sweet potatoes	29.3	30.2	40.5	C
Cassava	42.3	40.9	16.8	L
Maize	26.9	26.9	46.2	C
Swamp/water source	63.5	18.6	17.8	SL
Nappier grass	31.4	24.2	44.4	C

The observed change in soil texture under different land uses in Busia and Angurai is highly welcome. The levels of soil %clay are within workable range and the soils have increased water-holding capacity. Their easily available moisture assessed from the difference in water in 10cm soil at Pf 2.3, "the soil field capacity and Pf 3.7, the soil moisture content at which plants have no restriction or hindrance in absorbing water on the soil surface" will have increased from theoretically 5mm to 10mm as the soil texture finally changes to clay texture as observed by Braun and Kibe (1978), and total available moisture of 6 to 13mm as got by difference between Pf 2.3 and Pf 4.2 which is the permanent wilting point. The problem with texture particularly in Busia is decreased infiltration and can be enhanced by addition of manure or composts in those soils to modify the structure and increase infiltration so that water will not flood the area.

5.0 RECOMMENDATIONS

In Busia site, the soil PH where maize, nappier grass and cassava are grown is not optimal for these crops unless soil amendments are made. These crops are medium acid tolerant and will thrive well on a soil PH range of 5.3 - 6.0. In all these land uses with these crops, the soil PH is well below 4.5 and lime application at 2t/ha will raise the PH to the required range. The lime should be applied 3 weeks to 1 month and incorporated into the soil to allow reaction before planting. The soils should be retested after three years. Sweet potatoes are acid tolerant and this land use will not require any soil PH correction. The same recommendation will apply to maize land use in Angurai where the maize is being grown on soil PH below 5.0. For this land uses, apply lime at 1t/ha to raise the soil PH. Apply similar amount of lime to groundnut/maize land use. Finger millet and cassava are not demanding in terms of soil fertility and will yield at those conditions since their fertility corrections may not be economical.

All the sites in Busia and Angurai will require application of 5t/ha FYM or compost on sites with crops to raise soil organic matter and hence total nitrogen. All land uses in Busia and Angurai under crops will require further application of 100kg/ha of triple super phosphate at planting and top-dress cereals with 80kg/ha of CAN. Except on finger millet and cassava land uses. In Angurai spray containing zinc, should be sprayed on crops. The land uses in these two sites are typical to land uses in ASALs of Eastern Kenya and other drought tolerant crops like pigeon peas, green grams and cowpeas should be introduced in these places. On the effect of time interval on soil fertility status in Teso District, it can be concluded that farming activities at this site led to change in soil fertility status and almost coincides with the KARI-NARL recommendations that oil should be resampled after very three years (Gathua *et al* 2000)

6.0 ACKNOWLEDGEMENT

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8.0 ANNEXES

Annex 1: Soil samples number, land use/cover and other details from different sites in Kenya.

Annex 1(a): Soil samples number (in parenthesis), land use/cover and date of sampling for Angurai 1 site, Teso District Kenya (38 samples)

No. 19 (1483)	No. 55 (1502)
Land cover = Groundnuts	LC= Finger millet
Date = 02/0/02	Date 06/8/02
No. 15 (1484)	No. 34 (1503)
LC = Maize	LC = Finger millet
Date = 30/7/02	Date 05/08/02
No. 18 (1485)	No. 9 (1504)
LC = Maize	LC = Cassava
Date =5/7/02	Date 30/7/02
No. 5 (1486)	No. 48 (1505)
LC = Fallow	LC = Fallow
Date =30/7/02	Date 6/8/02
No. 35 (1487)	No. 39 (1506)
LC = fallow	LC = Tobacco
Date = 5/8/02	Date 5/8/02
No. 20 (1488)	No. 32 (1507)
LC = Fallow	LC = Cassava
Date 02/8/02	Date 5/8/02
No. 54 (1489)	No. 51 (1508)
LC = Cassava	LC = Maize
Date 06/8/02	Date 6/8/02
No. 6 (1490)	No. 17 (1509)
LC = Fallow	LC = Maize
Date 30/7/02	Date 02/8/02
No. 1 (1491)	No. 37 (1510)
LC = Cassava	LC = Groundnuts
Date 30/7/02	Date 5/8/02
No. 12 (1492)	No. 7 (1511)
LC = Cassava	LC = Finger millet
Date 30/7/02	Date 30/7/02
No. 53 (1493)	No. 41 (1512)
LC = Groundnuts	LC = Finger millet/maize
Date 30/7/02	Date 5/8/02
No. 4 (1494)	No. 61 (1513)
LC = Tobacco	LC = Groundnuts/maize
Date 30/7/03	Date 07/8/02
No. 25 (1495)	No. 38 (1514)
LC = Cassava	LC = Fallow
Date 5/8/02	Date 5/8/02
No. 14 (1496)	No. 3 (1515)
LC = Tobacco	LC = Maize
Date 30/7/02	Date 3/7/02

No. 18 (1497)	No. 47 (1516)
LC = Cassava	LC= Cassava
Date 02/8/02	Date 06/8/02
No. 40 (1498)	No. 54 (1517)
LC = Cassava	LC = Maize
Date 5/8/02	Date 07/8/02
No. 23 (1499)	No. 26 (1518)
LC = Maize	LC = Finger millet
Date 5/8/02	Date 5/8/02
No. 27 (1500)	No. 46 (1519)
LC = Groundnuts	LC = Finger millet
Date 5/8/02	Date 6/8/02
No. 42 (1501)	No. 31 (1520)
LC = Groundnuts	LC = Fallow
Date 5/8/02	Date 5/8/02

Annex 1(b): Soil sample number, land use/cover and other notes for Angurai 2, Teso District Kenya (44 samples)

Lab No.		Lab No.	
2425	T1	2447	Cultivation
	Q 8		T 6
2426	T3		Q 3
	Q 7	2448	T 3
2427	T 1		Q 4
	Q 5	2449	T 2
2428	T 3		Q 5
	Q 1	2450	Cultivation
2429	T 1		T 4
	Q 1		Q 2
2430	T 2	2451	Cultivation
	Q 2		T 5
2431	T 3		Q 1
	Q 5	2452	T 2
2431	T 3		Q 3
	Q 5	2453	T 3
2432	Cultivation		Q 6
	T 6	2454	Cultivation
	Q 8		T 4
2433	Cultivation		Q 7
	T 6	2455	Cultivation
	Q 8		T 5
2434	Cultivation		Q 3
	T 6	2456	T 2
	Q 4		Q 6
2435	T 2	2457	T 2
	Q 4		Q 1
2436	T 4	2458	T 3

	Q 1		Q 3
2437	Cultivation	2459	T 1
	T 5		Q 4
	Q 2	2460	T 1
2438	Cultivation		Q 6
	T 6	2461	Cultivation
	Q 2		T 6
2439	Cultivation		Q 2
	T 4	2462	T 1
	Q 3		Q 3
2440	T 1	2463	T 3
	Q 7		Q 8
2441	Cultivation	2464	Cultivation
	T 6		T 4
	Q 1		Q 5
2442	T 3	2465	T 1
	Q 2		Q 1
2443	Cultivation	2466	Cultivation
	T 4		T 6
	Q 4		Q 6
2444	T 2	2467	Cultivation
	Q 7		T 6
2445	T 2		Q 6
	Q 8	2468	Cultivation
2446	Cultivation		T 4
	T 4		Q 8
	Q 6		

Annex 1(c): Soil sample number (in parenthesis), land use/cover and date of sampling Busia Township, Busia District, Kenya.

BTS 021 (1521)	BTS 008 (1534)
PLT2TQ 25QO	PLT 6 TQ1SQ1
Fallow/Bush	Bushland
Date 14/3/03	
	BTS 005 (1535)
BTS 002 (1522)	PLT 5 TQ1
PLT 7 TQ 1SQ3&4	Grass cover (tall grass)
Closed bushland	Cotton grass
BTS 017	BTS 022 (1536)
PLT 3TQOSQO	PLT 2 TQ 45Q0
Cassava	BTS025 (1537)
	Grass
BT 003 (1524)	PLT1 TQ05Q2
PLT 5TQ25Q4	Maize + Sorghum
Woodland bushed	BTS 018 (1538)
	PLT3 TQ05Q0
	Sweet potatoes

BT 020 (1525)	BTS 007 (1539)
PLT 2 TQ 12 5Q2	PLT6 TQ15Q2
Shrub/Bush	Open grazing area
BTS 019 (1526)	
PLT 2 TQ15Q1	BTS 015 (1540)
Sweet potatoes	PLT3 TQ1 SQ1
BTS 016 (1527)	Open grass grazing
PLT 3 TQ03SQ3	
Bushland	BTS 011 (1541)
	PLT6 TQ05Q0
BTS 023 (1528)	Maize plantation
PLT 1 TQ0SQ0	
Fallow near chief's house	BTS 013 (1542)
	PLT4 TQ15SQ4
BTS 024 (1529)	Open herbaceous dominant
PLT1 TQ0SQ0	
Maize farm at chief's house	BTS 014 (1543)
	PLT4 TQ05Q0
BT 004 (1530)	Nappier grass
PLT 5TQ16Q3	
Open grazing area	BTS 009 (1544)
	PLT 6TQ3
BTS 012 (1531)	Swamp, water source/spring
PLT 4 TQ15Q1	
Bushland	BTS 001 (1545)
	SQ2
BT 006 (1532)	Open grazing area
PLT5 TQ 1	
Cassava planted	BTS 010
	PLT6 TQ05Q0
BTS 017 (1523)	Cassava
PLT7 TQ15Q3 and 4	
Cassava	BTS 010 (1533)
	PLT6TQ05Q0
	Cassava

Annex 2: Division of crops into ranges of acidity tolerance

Crop	Acidity group
Cereals	
Barley, wheat	b-c
Oats, grasses,	b
Maize, millet, sorghum	b
Rice	b
Vegetables	
Onions, spinach	c
Carrots, cabbages, Cauliflower	c
Chillies, sweet potatoes	a-b
Kales, tomatoes	b-c
English potatoes	a
Legumes	
Beans	b-c
Peas	b
Lucerne	c
Fruits and nuts	
Citrus, groundnuts	b
Bananas, pineapple	b
Plantation crops	
Cotton, coffee (mature)	b
Sisal, pyrethrum	b-c
Sugarcane	b
Tea (mature)	a-b
Tobacco (cigarette)	b
Root crops	
Cassava	b
Oil seeds	
Sunflower	c
Coconuts palm	b-c

a – highly acid tolerant - PH less than 5.3
b – medium acid tolerant- PH between 5.3 and 6.0
c – not acid tolerant – PH greater than 6.0

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