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Soil fertility analysis associated to land use in Eastern Uganda

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OVERVIEW: FITCA Project

The regional project FITCA (Farming in Tsetse Controlled Areas) has a general objective to integrate tsetse control activities into the farming practices of rural communities such that the problem of trypanosomosis can be contained to the levels that are not harmful to both human and the livestock and environmentally gentle and integrated into the dynamics of rural development and are progressively handled by the farmers themselves. The project is hosted by the Inter-African Bureau for Animal Resources of the African Union (AU-IBAR) and covers areas with small scale farming in Uganda, Kenya, Tanzania and Ethiopia.

EMMC (Environmental Monitoring and Management Component) is the environmental component of FITCA. It is implemented by ILRI in collaboration with CIRAD (as member of SEMG, Scientific Environmental Monitoring Group). This regional component has been charged with the responsibility of identifying of monitoring indicators and methodologies, as well as the development of an environmental awareness among the stakeholders. It contributes to propositions of good practices and activities mitigating the impacts and rehabilitating the threatened resources likely to result directly or indirectly of tsetse control and rural development.

The FITCA EMMC project was written by Dr. Robin Reid of the International Livestock Research Institute (ILRI) a future Harvest Centre supported by CGIAR (Consultative Group for International Agricultural Research).

The present report has been prepared under the responsibility of the leading group of EMMC:

- Dr Bernard Toutain, agronomist, coordinator
- Dr Joseph Maitima, ecologist

This report and others produced by FITCA-EMMC are available in the web at the following address: www.fitca.org

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

[1]Josheph Maitima collected soil samples from all EMMC sites in Uganda. 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 (Angulai (two sets), Busia, Kamuli, Iganga, Soroti and Tororo 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.

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EXECUTIVE SUMMARY

A total of 191 soil samples were collected from different land uses in the four sites (Tororo, Iganga, Kamuli and Soroti Districts) in Uganda for soil fertility and texture analysis. Soil fertility in respect to organic carbon (organic matter), total nitrogen, available phosphorus, exchangeable potassium, and trace elements were variable but generally ranged from adequate to deficient with a lot of variations across sites and within sites. Mean organic carbon varied from very low (1.41% organic C) in Tororo to adequate (2.27% Organic C) in Iganga. The same trend was observed for total nitrogen, which also varied from very low (0.14% N) in Tororo to adequate (0.26% N) in Iganga. Only one site had adequate carbon levels with the rest (Tororo, Kamuli and Soroti) having low organic carbon levels. This was due to nitrogen fixing crops grown in Iganga (e.g. groundnut), level of inorganic fertilizers applied in coffee or maize farms and substantial bush/fallow fields (47%) in this site unlike in the other sites where no nutrients are added. Available phosphorus ranged from very low (4ppm) to luxury amounts (91 ppm) but the mean available P was low throughout the four sites (4-15ppm).

Out of the four sites, 31% and 20% of sites in Tororo and Iganga respectively had potassium deficiency 15% of the farms in the other sites had deficiency problems. Trace elements ranged from very low to luxury amounts or consumption in some sites. In Soroti and Tororo, 100% and 96% land uses respectively had deficiency in zinc levels while 42% and 40% of the points in Kamuli and Soroti respectively were deficient in iron. However, the level of copper in all the sites was almost adequate (82%) in most of the land uses except in few places. Mean soil PH in the four sites indicated that the soil reaction was ranging from strongly acidic (PH ≤4.5) to medium acidity (PH ≤6.0). The range in soil PH was from PH 3.61 to PH 7.19. Both non-acidifying and acidifying fertilizers need to be selectively used depending on the soil PH at respective sites. The soil texture analysis showed that soils sampled from the four sites had a mean textural class of sandy clay loam (SCL). At the extreme range e.g. Tororo the soils are of clay nature usually dark/black clacking clays. This implies that the soil have been slightly eroded leading to poor soil fertility problems. FYM or compost must be added to modify the soil texture and improve its water holding characteristics.

At Kamuli, Soroti, Iganga and Tororo sites, apply farmyard manure (FYM) or compost at 5t/ha to raise soil organic matter, PH and supply sufficient nitrogen to most of the crops. Apply 2t/ha of lime on maize/millet, maize and coffee at Soroti and Kamuli sites to raise the soil PH to between 5.5 and 6.5 required by most crops for optimal crop growth. It is recommended that compound fertilizer containing N: P: K 17:17:17 at 300kg/ha per year be used at planting time to correct nitrogen, phosphorous and potassium (NPK) deficiencies in the soil for common crops. For coffee, apply one debe or 10kg/tree of FYM or compost around the tree base; apply further 50g of TSP by broadcasting around the tree/year and top dress with 25kg/10tonnes CAN or ASN per year in alternate years. Apply 25kg of ASN to coffee at nursery. For maize in all sites top dress with 250kg/ha sulphate of ammonia in two portions at knee high and at flowering stage. Crop diversification noticed in most sites is recommended to utilize available nutrients and for crops to complement each other e.g. maize/groundnuts in terms of nutrients. Foliar feed containing zinc and iron is recommended for application on tree crops like coffee and bananas due to its scarcity in most sites.

1.0 INTRODUCTION

FITCA EMMC land use mapping sites in Uganda are in Kamuli, Iganga, Soroti and Tororo Districts (Figure 1). The problem of land is acute in the area at present and its going to escalate, as the young generations are the majority of the population taking up their land share to produce their own food and generate income for their own. Crops grown include bananas, maize, beans, cotton, cassava, sweet potatoes etc. Cultivation of maize as cash crop requires large farms in order to produce enough to sell because harvest per acre is usually low. Yields of most crops have been declining with time to fertility problems due to continuous cropping on same plots and low application of farm inputs.

Buyuba Busiri study site in Kamuli district is located in a relatively wetter climate that receives moderate rainfall due to its location in an area that receives conventional rainfall from lake Victoria, a major source of precipitation for the southern part of Uganda. Cotton growing had been introduced in the area but declined due to poor markets. However, there has been a recent attempt to promote production of the cash crop to benefit from new opportunities in emerging markets. According to Agro-ecological zones and farming systems in Uganda, Kamuli lies under the zone described as Banana-Robusta Coffee System, which comprises of good climate and evenly distributed rainfall on medium to high productivity soils. Vegetation is mainly forest/savanna mosaic with pastures suitable for intensive livestock development. Banana, coffee and maize are the main cash crops with root crops on the increase. Livestock is not generally integrated into the system but it can be an important source of income (World Bank 1993 and MENR, 1996).

Bubaka village in Bulamagi parish in Kugulu county study site is located in Iganga District of Uganda. Due to the site proximity to Iganga town, the population density is high at about 237 people per Km^2 and widely cultivated with the natural areas consisting of swamps and short fallows. FITCA is encouraging farmers to keep cattle for milk products as well as for animal traction. The major indicators of change expected are the conversion of existing land use and cover types to fodder crops and grazing lands in this area (Maitima *et al* 2003).

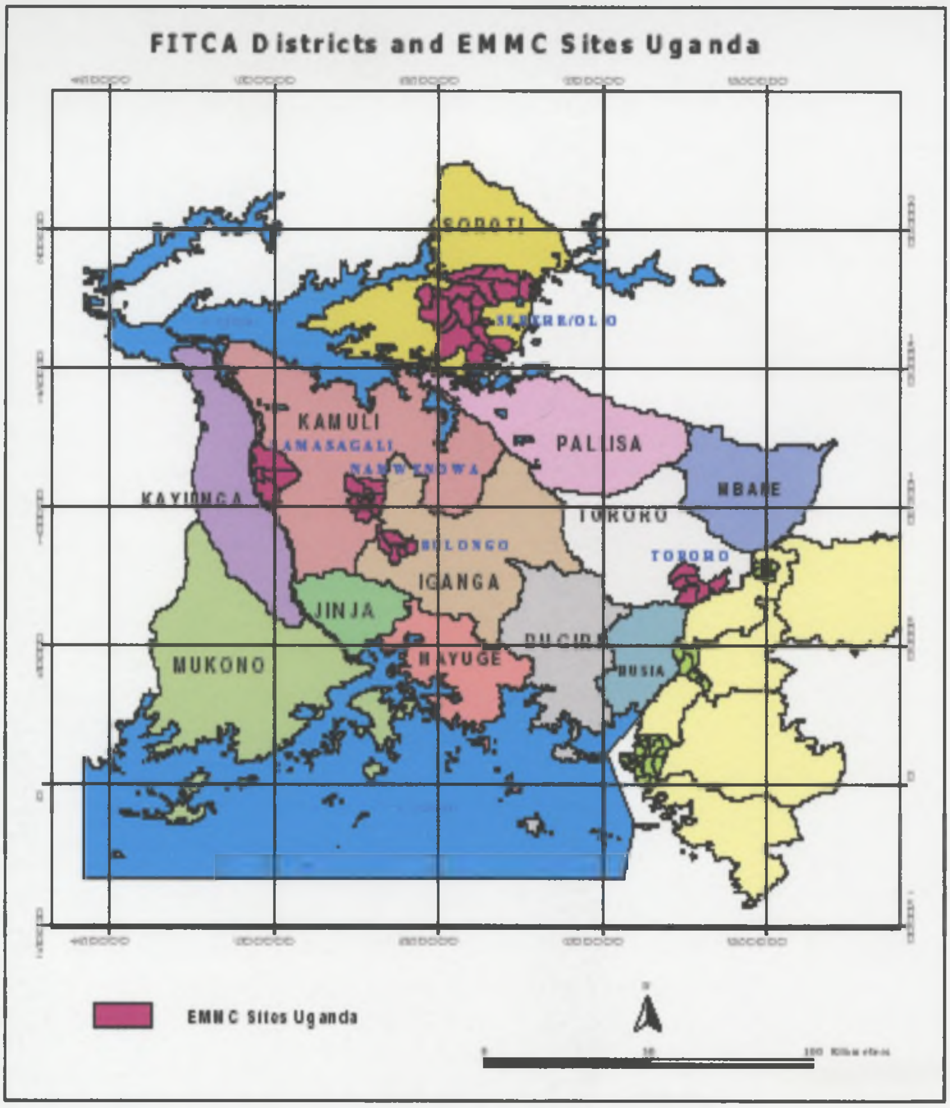

Figure 1: FITCA Districts & EMMC Study Areas in Uganda

Akoroi site is located in Soroti district in the middle of eastern Uganda in the transition between the wetter southern part of the country and the drier northern part (Figure 1). Soroti district is located in a relatively dry climate compared to the wetter southern part of eastern Uganda. The area receives little rainfall due to its distant location from lake Victoria. In the north the major occupation of people is livestock keeping and in the south people are mainly farmers growing maize, beans, millet, sorghum, cassava, cotton, rice but most farmers also keep livestock. Cotton growing had however, declined due to poor market but recently production of cash crop is increasing due to new emerging markets. The area is endowed with relatively richer vegetation compared to other areas in the district. The vegetation in the area provides a typical habitat for tsetse habitation. Tsetse and trypanosomosis problem in the area especially the human disease has been high.

1.1 Objectives

The overall objective of FITCA project is to promote farming activities in tsetse controlled areas so that land use activities would maintain the flies to low densities and the prevalence of both animal and human trypanosomosis low. Tsetse infested areas are marginal areas where ecologically productive systems operate at very narrow ranges and are very susceptible to disturbance. Most tsetse control areas especially those with animal trypanosomosis, are characterized by low and unreliable rainfall, poor vegetation cover, poor soils, and generally degraded lands. These areas have generally been neglected as low potential areas by governments and as such there are no proper guidelines on land use. Land use and settlement in these areas require an environmental monitoring in order to detect changes as they occur and a management programme to mitigate the negative impacts.

EMMC is therefore designed to fulfill this role. The initial objective of EMMC was to understand the environmental settings of FITCA project areas in the participating countries, design an approach to conduct environmental analysis in selected sites to provide baseline information for scaling up to landscape level analysis. This exercise is also aimed at providing data from which ecological constraints to agricultural production can be identified and communicated to the land users (farmers) in a format that they can understand in order to monitor and manage changes in their farms.

2.0 MATERIAL AND METHODS

2.1 Methods

The survey area in each of the four sites was divided into grids and one random point generated in each grid, using the computer. Samples were collected randomly in all of the survey area and GPS readings taken. The sample points were distributed in such a way that they covered all the land uses in each site. Each composite was made from three sub-samples collected from 20cm depth auger hole spaced at approximately 1 meter apart in a triangle spacing within the same land use. A half kg sample was collected into a plastic bag and properly labeled indicating the sample number and land use type of the area where it had been collected. A first hand visual description of the sample was done using an appropriate description 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 and reported in other reports (Maitima *et al* 2003). 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.

2.2 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.

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

Soil organic carbon was done according to method of Walkley and Black (1965). 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.

2.4 "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 1964)

2.5 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).

2.6 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 191 soil samples were collected from the four sites in Uganda. They were 71 from Iganga, 72 from Tororo, 24 from Kamuli and 20 from Soroti District (Annex 1). In order to assess the soil fertility from the sites, and in different land uses, only the soil chemical analysis is most considered and analysed elements and PH compared with crop recommended agronomic adequate values for specific elements (Table 1 and 2). Texture although very important aspects as regards soil hydrologic behaviour or erodibility is also considered in respect to soil water holding capacity in another section. 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 in soil fertility within Kamuli, Soroti, Iganga and Tororo Districts study sites.

Soil fertility in respect to organic carbon (organic matter), total nitrogen, available phosphorus, exchangeable potassium, and trace elements are variable but generally ranged from adequate to deficient with a lot of variations across sites and within sites. Mean organic carbon varied from very low (1.41% organic C) in Tororo to adequate (2.27% Organic C) in Iganga (Table 3). The same trend was observed for the mean levels of total nitrogen (Table 4), which also varied from very low (0.14% N) in Tororo to adequate (0.26% N) in Iganga. Only one site (Iganga) had adequate carbon levels with the rest (Tororo, Kamuli and Soroti) having low organic carbon levels. This was due to nitrogen fixing crops grown in Iganga (e.g. groundnut), level of inorganic fertilizers applied in coffee or maize farms and substantial bush/fallow fields (47%) in this site unlike in the other sites.

However, the sites had wide variations of %C from 1.08% in Iganga to 4.55% in the same site. Overall 20% of the farms/points were deficient in organic carbon and 5% had excess levels of the same. Overall 15% of the farms were deficient in nitrogen and the rest adequate. This is due to the dynamics with nitrogen which need to be adjusted upwards regularly. The C/N ratio also rose from 5.7 to 10.7. This implied that, the soils in the four sites in Uganda i.e. Tororo will require application of 2.5-5t/ha FYM or compost to raise the soil organic matter and nitrogen within cultivated lands. The present C/N ratios, indicated soil organic matter of high quality, i.e. unlikely to immobilize added fertilizer nitrogen.

Table 3: Average soil organic carbon (%C) levels in four sites in Uganda

	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
Kamuli	24	0	29	71	1.91	0.73	0.6-3.55
Soroti	20	0	50	50	1.82	0.63	1.28-3.43
Iganga	75	20	57	17	2.27	0.93	1.08-4.55
Tororo	72	1	67	32	1.41	0.55	0.41-3.00

N/B: Critical level organic carbon (%C) =2%

Table 4: Average soil nitrogen levels in four 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
Kamuli	24	0	4	71	25	0.24	0.14	0.12-0.69
Soroti	20	0	20	65	15	0.19	0.08	0.08-0.39
Iganga	75	0	1	63	36	0.26	0.12	0.11-0.55
Tororo	72	0	36	58	6	0.14	0.06	0.06-0.39

N/B: Nitrogen critical level = 0.2%

Available phosphorus ranged from very low (4ppm) to luxury amounts (91 ppm) but the mean available P was low throughout the four sites (4-15ppm). This meant that if the soils were used for cultivation, they would require application of phosphate fertilizers or organic nutrients and lime to avail soil P in available forms. The broad range in available P indicated use of phosphate fertilizers in some sites. PH in the four sites are moderately acidic to strongly acidic. On average only 3% of the points/land uses/farms were on optimal PH range of 6.5 to 7 required for adequate crop growth. In these circumstances phosphorous is not available to the plants as it tends to be fixed on soil clay surfaces. Other factors which lead to deficiency of phosphorus are parent material (inherent low levels of soil P), or depletion of soil P through crop harvests, erosion or grazing animals.

Table 5: Average soil phosphorus (Mehlich) levels in four sites in Uganda

	No. of farms	Percentage of farms with observed phosphorus (P, ppm)					
		P<20 (Deficient)	20<P<80 (Adequate)	P>80 (Excessive)	Mean	SD	Range
Kamuli	24	92	8	0	10.27	6.7	2-023
Soroti	20	90	5	5	12.25	19.78	4-091
Iganga	75	76	24	0	15.59	11.63	5-056
Tororo	72	99	1	0	4	6.43	1.00-41.00

N/B: Phosphorus critical level = 20ppm

Exchangeable potassium (Table 6) in the four sites ranged from very low (0.06 me%) to very high (1.98 me%). This indicated non-usage of potassium containing fertilizers on soils that are already K deficient and luxury use of K fertilizers at some sites. Out of the four sites only 31% and 20% of sites in Tororo and Iganga respectively had deficiency in potassium with the other sites having less than 15% of the farms have deficiency problems. It is recommended that compound fertilizer containing N: P: K 17:17:17 at 300kg/ha per year be used at planting time to correct these deficiencies in the soil. These observations on K collaborate with the results and recommendations by Kanyanjua and Buresh (1999) on their work on K deficiencies in Western Kenya.

Table 6: Average soil potassium (exchangeable) levels in four sites in Uganda

	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
Kamuli	24	13	83	4	0.56	0.46	0.17-1.98
Soroti	20	15	85	0	0.42	0.21	0.19-1.08
Iganga	75	20	75	5	0.63	1.5	0.08-9
Tororo	72	31	69	0	0.3	0.19	0.06-1.26

N/B: Potassium critical level= 0.2 me%

Trace elements ranged from very low to luxury amounts or consumption in some sites (Table 7-9). In Soroti and Tororo, 100% and 96% land uses respectively had deficiency in zinc levels while 42% and 40% of the points in Kamuli and Soroti respectively were deficient in iron (Table 8). However, the level of copper (Table 9) in all the sites was almost adequate (82%) in most of the land uses except in few places. These element i.e. copper, zinc and iron should be selectively corrected through the use of folia sprays on those farms where they are deficient. Trace elements anormalities can be attributed to soil parent materials, clay meralogy and soil texture (FAO, 1972).

Table 7: Average soil zinc (Zn, ppm) levels in four sites

	No. of farms	Percentage of farms with observed zinc level (ppm)				
		Zn<5.0 (deficient)	Zn>5.0 (adequate)	Mean	SD	Range
Kamuli	24	96	4	2.06	1.5	0.13-5.5
Soroti	20	100	0	1.25	0.96	0.11-3.87
Iganga	75	33	67	6.5	2.87	0.9-14.3
Tororo	72	96	4	1.1	1.75	0.01-11.7

Table 8: Average soil iron (Fe, ppm) levels in four sites

	No. of farms	Percentage of farms with observed iron level (ppm)				
		Fe<10 (deficient)	Fe>10 (adequate)	Mean	SD	Range
Kamuli	24	42	58	14.56	10.02	1.28-37.7
Soroti	20	40	60	52.12	171.25	1.84-779
Iganga	75	20	80	55.31	97.32	6.8-650
Tororo	72	3	97	28.46	13.28	7.13-75.0

Table 9: Average soil copper (Cu, ppm) levels in four sites

	No. of farms	Percentage of farms with observed copper level (ppm)				
		Cu<1.0 (deficient)	Cu>1.0 (adequate)	Mean	SD	Range
Kamuli	24	4	96	2.92	1.55	0.38-5.72
Soroti	20	0	100	3.71	5.34	1.85-26.3
Iganga	75	4	96	2.43	1.1	0.7-6.7
Tororo	72	67	33	1.02	0.99	0.03-5.03

3.3 Soil PH in the four sites in Uganda

In East Africa, many soils in the humid and sub-humid regions that cover about 13% of the total land area have an acid reaction (Kamprath, 1984, Hoekstra and Corbett, 1995). These areas have high population densities and contribute significantly to their respective economics, through cash, food crops and livestock production or 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.

Mean soil PH in the four sites (Table 10) indicated that the soil reaction was ranging from strongly acidic (PH $\leq$4.5) to medium acidity (PH $\leq$6.0). The range in soil PH was from PH 3.61 to PH 7.19. This indicated that some sites will require liming with over 2 t/ha of lime to raise the soil PH to between 5.5 and 6.5, required by most crops (FAO, 1983, Hinga *et al* 1980 and Mehlich *et al* 1964) for optimal growth. Notable is Soroti where 100% of the soil is acidic. 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. The low PH would be responsible for low available P in most sites. At extremely low PH, (PH 3.61 to PH 5.5) phosphorus is susceptible to precipitation by iron and aluminium. Both non-acidifying and acidifying fertilizers will be selectively recommended depending on the soil PH at respective sites. The results indicated that an average of 96% of the soils from four sites Tororo, Soroti, Iganga and Kamuli were extremely acidic (PH 4.5- 6.5) and will require liming to correct acidity to the optimum PH range (5.5 -6.5).

Table 10: Average pH levels in four sites

	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<7.0 (near neutral)	Mean	SD	Range
Kamuli	24	29	29	25	5	8	4.93	0.91	3.61-7.19
Soroti	20	25	40	35	0	0	4.89	0.55	4.14-5.91
Iganga	75	5	21	57	13	3	5.42	0.61	4.35-7.48
Tororo	72	31	46	19	3	1	4.7	0.63	3.70-7.27

3.4 Liming of acid soils in Uganda sites

The extent to which liming has been adopted in East Africa 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 (Buresh *et al* 1997). Farmyard manure (FYM) application is however, a widely adopted practice in subsistence farming in Kenya. The quality of FYM used depends on type of livestock and quality of feeds while total amounts are determined by the number of livestock and by extension 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 with land use in the four sites in Uganda

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 for Iganga, Soroti, Tororo and Kamuli study sites (Figure 2,3, 4 and 5) for comparison purposes. From figure 2 and 3, it can be seen that potassium in all land uses in Iganga and Soroti sites is in excess of the nutrient critical level (of 0.2 me% exch. K) i.e. in bushland/grazing land/grassland/fallow, tobacco, millet, groundnuts and sweet potatoes. 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 /fallow and decomposing of sweet potatoes leaves within the sweet potato land use. Potassium is easily recycled to the soil surface because it can be washed off the vegetation to the ground.

The percentage threshold level of N, P and carbon almost in all cases are below the critical level except in rice and groundnut land uses where organic carbon is above critical level except in rice and groundnut land uses where carbon is above critical level. The high carbon and nitrogen levels in rice land use in Soroti and Iganga District can be attributed to decomposition of rice litter and inhibited conversion of ammonium nitrogen to nitrates under these reducing conditions. The low level of N and carbon in other land uses could be due to continuous mining in these land uses and its removal through harvest and biomass transfer as observed by Stoorvogel and Smaling (1990) and Gachimbi (2002) while working on nutrient flows and balances. The variability of soil fertility in the land uses depends on the land use, level of nutrient (organic or inorganic) application, type of crop grown which is in most times based on farmers perception of soil quality in farm unit. Cassava and sweet potatoes are grown in poor quality soil while rice is grown in soils with relatively poor drainage. Groundnuts release nutrients to the soil through biological nitrogen fixation and litter fall.

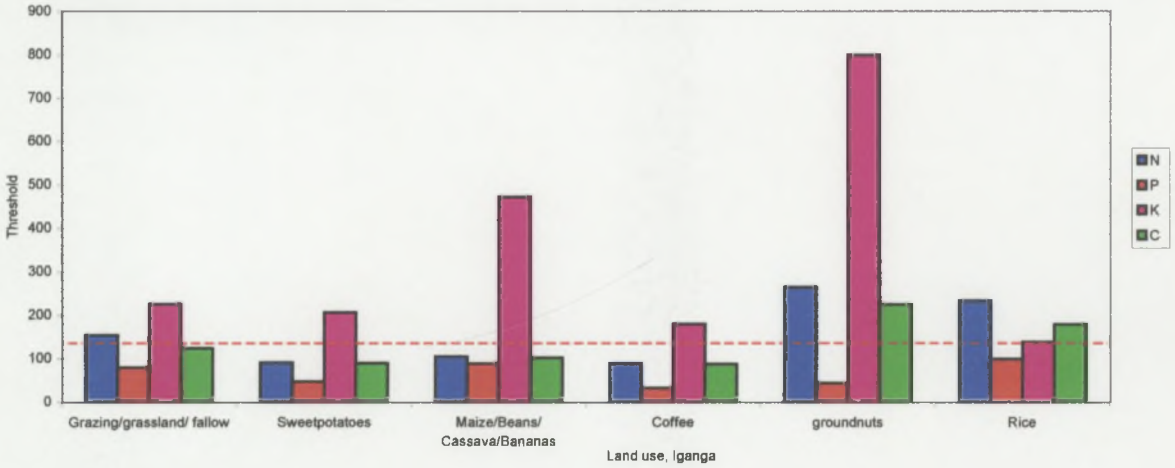

Figure 2: Variations of NPKC and soil organic carbon in Iganga, Uganda

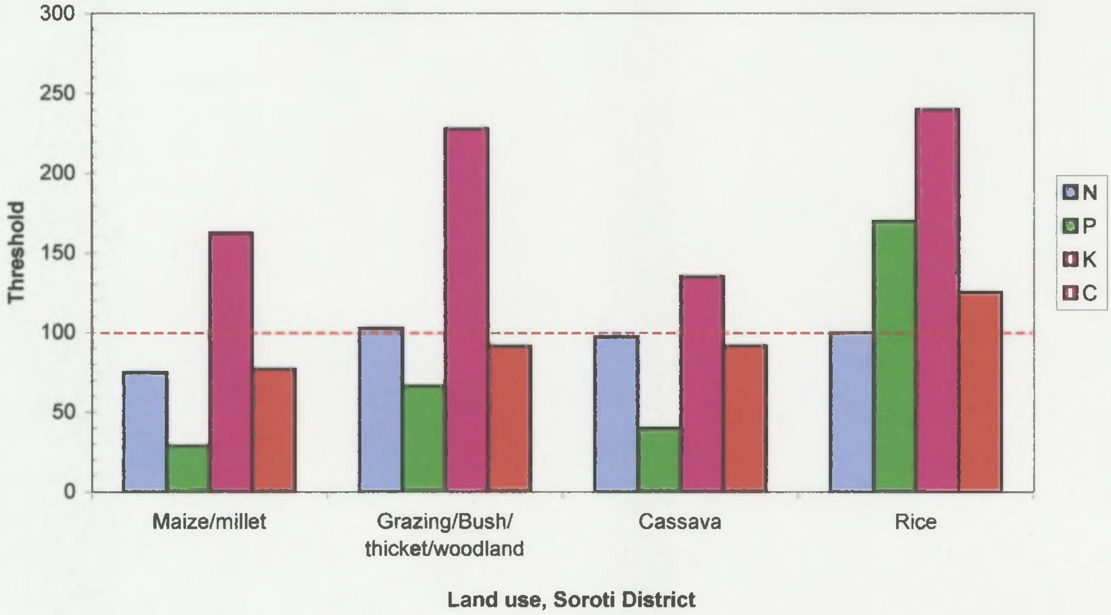

Figure 3: Variations of NPK and soil carbon in Akoroi Village, Soroti District, Uganda.

Nitrogen, phosphorous and organic carbon is overall deficient in agronomic terms (Figure 4 and 5) while potassium is adequate in all the land uses. High potassium level is due to the soil parent material and thus adequate stocks in the soil, the length of cultivation period and the crops planted which may not do not demand a lot of potassium. Nitrogen in Tororo and Kamuli Districts was more under grazing/ grassland/fallow due to decomposition of plant litter and effect of BNF. Available P was low throughout all the land uses due to non-use of P fertilizers and crop removal coupled with soil deficiencies (Table 4) as this site had very acidic soils (Table 6). Available phosphorus was however, below threshold levels in all land uses in Uganda. This was attributed to very low soil PH and non-usage of phosphorus containing fertilizers and continuous removal through crop harvest (grains and stover). In Soroti, Iganga and Tororo available P within the land uses was again below the threshold levels in all cases. 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.

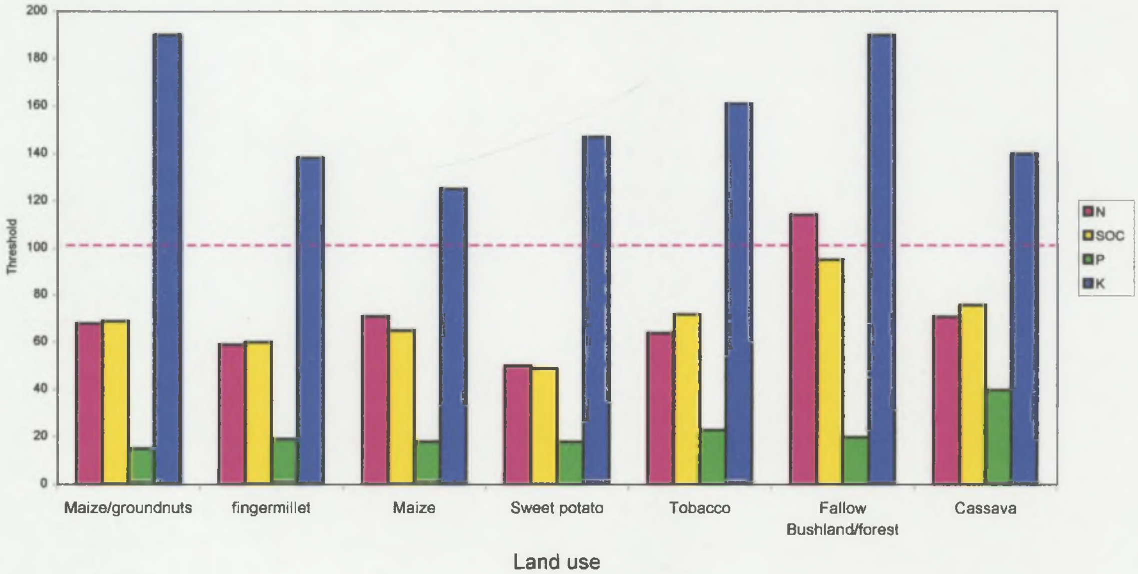

Figure 4: Variations of N, P, K and soil organic carbon in Tororo District, Uganda.

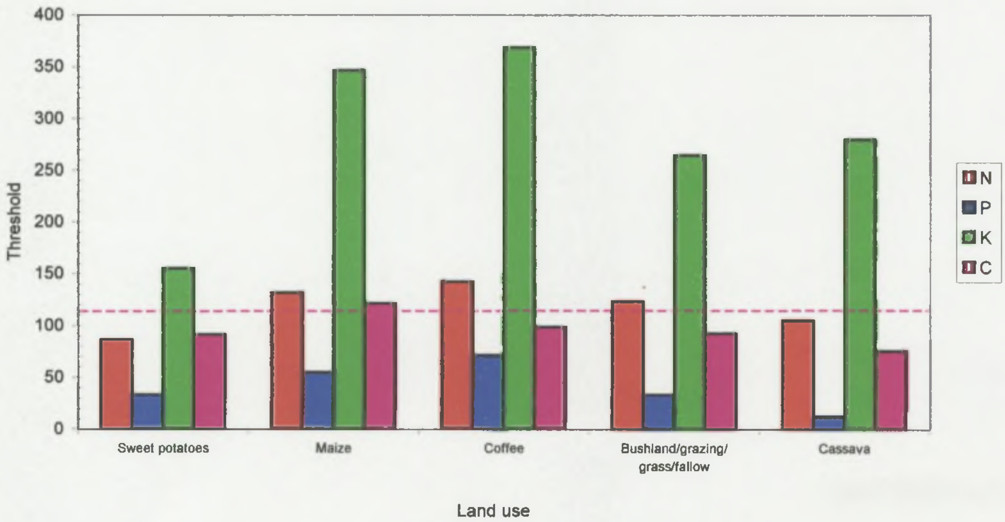

Figure 5: Variations of NPK and soil carbon in Namwendwa Sub county, Kamuli District, Uganda

There was excessively greater amounts of exchangeable potassium in tobacco, bananas, maize, groundnuts, coffee and finger 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. Similarly total nitrogen in rice, maize and coffee was just slightly above the threshold levels in Iganga. This indicates use of N-containing fertilizers on these crops and decomposition of litter from coffee. Decomposing coffee husks have been found to contain over 21%N (Kathuli and Nandwa, 2000). The slightly high amounts of nitrogen under bushland and grazing/fallow are attributed to N recycling via litter composition and exudates by the trees and grass that contains nitrogen. N under cassava is only through cassava decomposition. The actual organic carbon in all the land uses was 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 Kenya side of the study sites (Gachimbi, 2004).

3.6 Variability of soil PH, NPK and organic carbon across land uses in four sites in Uganda.

The variation of soil PH across land uses in Kamuli, Soroti, Tororo and Iganga is as shown in (Figure 6-9) respectively. The results show that at Kamuli site (Figure 6), sweet potatoes, maize and coffee were being grown on soils of almost suitable PH. But for maize and coffee, at least 1t/ha lime application is required to raise the PH above the present PH. Cassava will thrive under present PH since liming for this crop has been said to be uneconomical (AIC tech. Hand book). Bushland/grazing/grass/fallow will change their PH automatically but if the grass is to be produced commercially at least 1t/ha lime application is necessary. At Soroti, the soil PH under the current land uses is acceptable except application of 1t/ha of lime on land use under maize/millet will boost the maize yields. All major nutrients and organic carbon are lower than their critical levels except potassium in all cases.

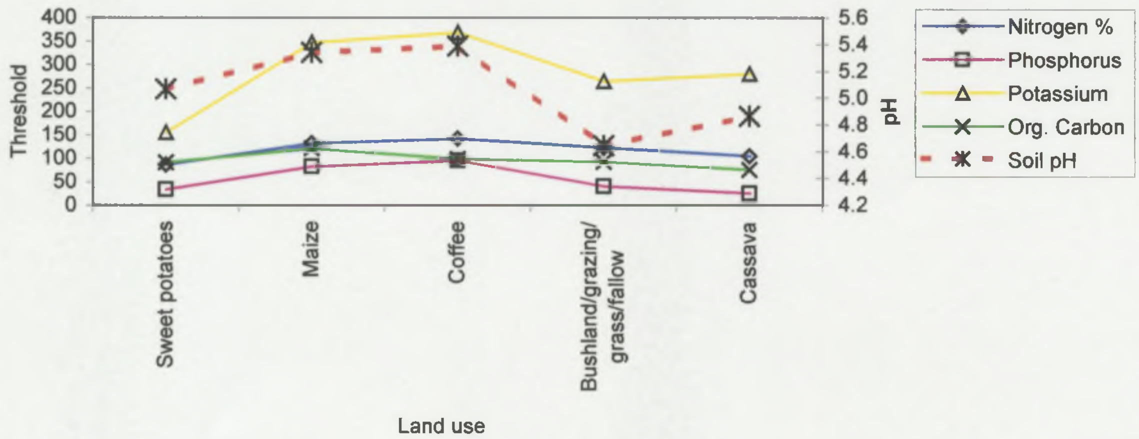

Figure 6: Variations of NPKC and pH across land uses in Namwendwa Sub county, Kamuli District, Uganda

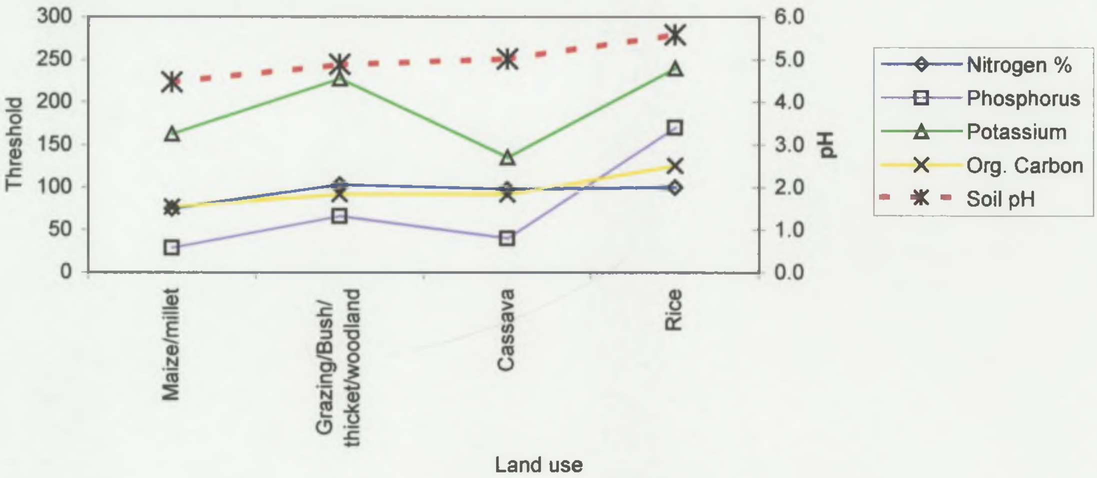

Figure 7: Variations of NPK and soil carbon and pH across land uses in Akoroi Sub county, Soroti District, Uganda

At Iganga (Figure 8), the soil PH is suitable for the current land uses provided acidifying fertilizer like DAP are avoided. Fertilizer use under coffee should be alternated between those with residual acidifying and basicity (top dress with CAN and ASN in alternation). Maize should be planted using triple super phosphate and top-dressed using CAN to raise the soil PH with time. The situation is the same at Tororo (Figure 9) in maize fields. Use at least 1t/ha of lime and avoid acidifying fertilizers. Use triple super phosphate at 300kg/ha and top dress with calcium ammonium nitrate. Just like at Iganga District, sweet potatoes will yield at optimum when grown at the present PH. The levels of major nutrients N, P and soil organic carbon is lower than their critical levels except potassium. As indicated in another section application of compound fertilizers or triple super phosphate followed by top dressing using CAN is recommended.

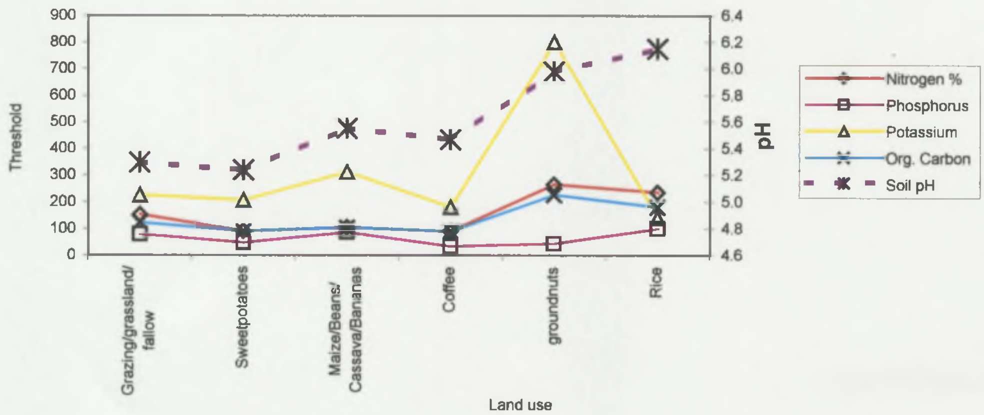

Figure 8: Variations of NPK and soil carbon and pH across land uses in Iganga District, Uganda.

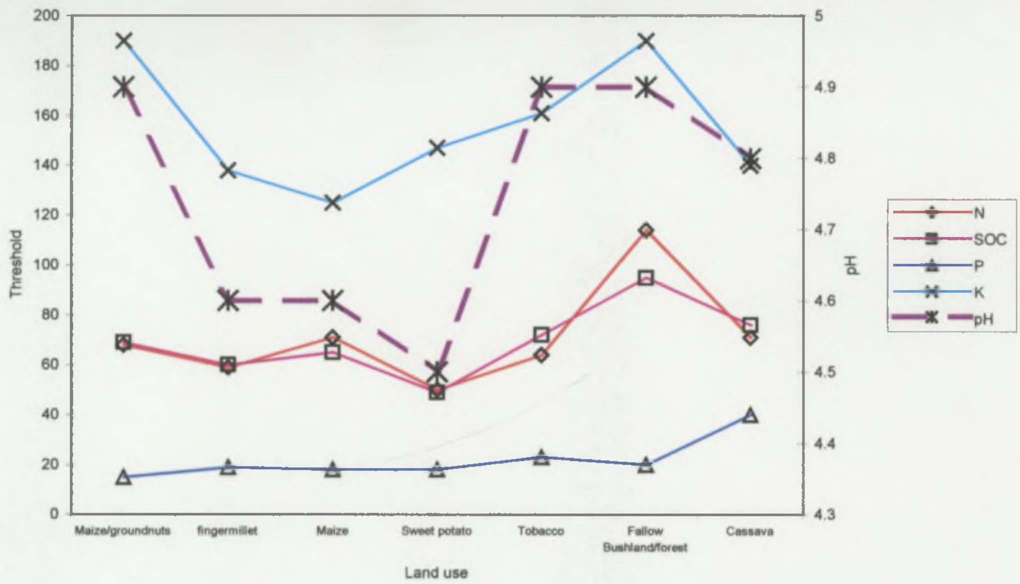

Figure 9: Variations of NPK and soil carbon and pH across land uses in Tororo District, Uganda

3.7 Distribution of land uses in the four sites in Uganda.

The distribution of land uses in Kamuli, Soroti, Iganga and Tororo is shown in (Figure 10, 11, 12 and 13) respectively. 49% of land in Kamuli is under bushland/grazing/grass/fallow, 17% coffee and 13% maize and sweet potatoes respectively. It shows most farmers are pastoralist with coffee as their cash crop and cassava or maize as their food crops. At Soroti (Figure 11), 65% of land is under grazing/bush/thicket/woodland. The staple food here seems to be maize/millet (20%) and cassava (10%). Rice is also grown by 5% of the farmers for food and commercial purposes. Most farmers are also herding livestock.

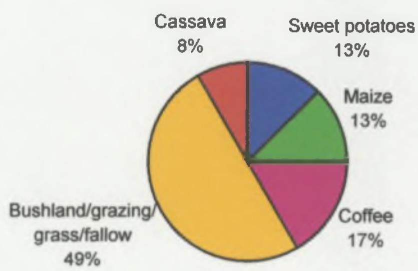

Figure 10: Distribution of land uses in Namwedwa Sub county, Kamuli District, Uganda.

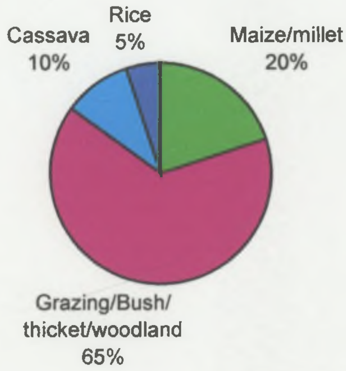

Figure 11: Distribution of land uses in Soroti District, Uganda.

At Iganga (Figure 12), 47% of the land use is grazing/grassland/fallow indicating that most farmers are livestock keepers. 35% grow maize/beans/cassava/bananas while coffee is grown by few farmers (4%). Other crops grown in small proportions are rice, groundnuts occupying 1% of land use. It appears most people in these sites are agro-pastoralists and should diversify their agriculture so that in case of a disease out break on animals they don't suffer a lot. They also grow maize, beans, cassava and bananas which are climatically adapted in the area. At Tororo study site (Figure 13) farmers grow an assortment of crops including finger millet (22%), maize (27%) or maize intercropped with groundnuts (19%). Their cash crop is tobacco which occupies 15% of land use. They also keep livestock which graze on abandoned cropland, bush or forest.

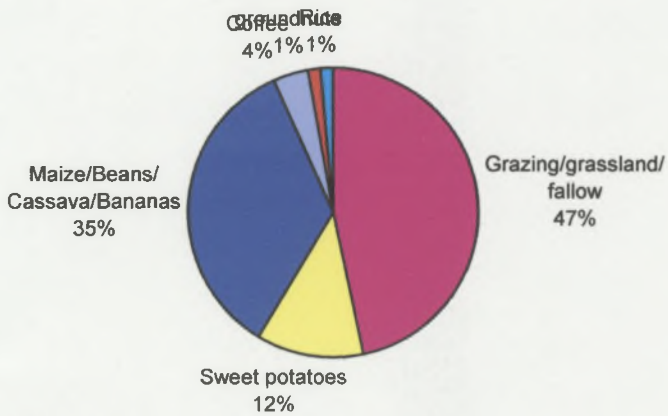

Figure 12: Distribution of land uses in Bubaka Village, Iganga District, Uganda.

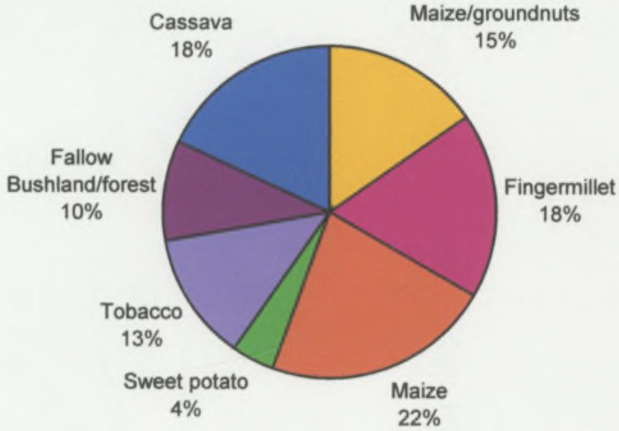

Figure 13: Distribution of land uses in Tororo District study site, Uganda.

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 2μM down to 50μM (USDA classification). Silt particles has diameter 50μM-2μM while the clay is the smallest sized fraction whose particle size range from 2μM downwards 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) and 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 carried out.

4.1 Variability of soil texture within four sites in Uganda

The soil texture for Soroti, Kamuli, Iganga and Tororo is as shown in Table 11. The %sand, %silt and %clay indicated that soils sampled from the four sites had a mean textural class of sandy clay loam (SCL) as inferred from the textural triangle (Hillel, 1980). At the extreme range e.g. Tororo the soils are of clay nature usually dark/black clacking clays. This texture implies that the soil have been slightly eroded otherwise they would have sandy texture if all the fine material has been considerably taken away by water or wind erosion leading to poor soil fertility problems. This was also observed by Maitima *et al* (2003) in Iganga study sites where 93% of the respondents erosion problem in their farms. These soils will have high bulk density and less porous. The soils are of low infiltration capacity according to Braun and

Kibe (1978) as detailed in Table 12 and this characteristic make them be manipulated for rice growing as could be seen at some farms within the sampling sites.

Table 11: Mean percent soil texture and textural class in the study sites in Uganda.

Site	No. of points	% Sand			% Silt			% Clay			Textural class
		Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	
Soroti	20	41.8	4.8	31.2-51.7	22.3	6.5	6.6-32.1	35.9	5.9	25.3-47.1	SCL
Kamuli	24	48.8	9.6	26.5-71.9	13.5	6.1	2.0-27.7	37.7	8.8	14.7-49.9	SCL
Iganga	75	56.9	10.8	9.3-87.5	13.6	6.5	0.3-33.9	29.5	8.0	10.3-56.8	SCL
Tororo	72	60.9	10.9	31.3-87.8	12.2	4.4	2.2-24.2	26.9	9.8	5.8-52.5	SCL

Table 12: 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)

These soils retain more moisture at wilting point than sandy loams due to their low porosity that can hold hygroscopic moisture. Their easily available moisture can be calculated from the difference between P.f 2.3 which is the field capacity at which water is lightly held on the soil particles (at 0.2 bar pressure) and P.f 3.7 which is the point at which there is uninhibited plant growth (Braun and Kibe 1978). From the regression equation M.C (Moisture holding capacity) P.f 2.3 = 0.54 x clay% + 3.1 and MC. P.f 3.7 = 0.49 x clay% - 0.7, the easily available water would be 3.81mm water for 10cm of soil. This is far much less than what is normally quoted for soils of this textural class as reported by Braun and Kibe (1978). Textural change will have implications on soil moisture storage characteristic and susceptibility to erosion and land use suitability. Rice is being grown on soil of loam clay and low silt. This crop will require a soil with large proportions of clay and silt than sand in order to reduce downward water infiltration in a rice field. Except on sweet potatoes and coffee which are being grown at Kamuli on a sandy clay soil, the rest of crops in Kamuli and Iganga appear to be grown on soil of right texture for their requirements. FYM or compost must be added on soils under sweet potatoes and coffee to modify the soils texture and improve its water holding characteristics.

5.0 RECOMMENDATIONS

At Kamuli, Soroti, Iganga and Tororo apply FYM or compost at 5t/ha to raise soil organic matter, PH and supply sufficient nitrogen to most of the crops. Apply 1t/ha of lime on maize/millet land use at Soroti, and maize and coffee at Kamuli. No lime application required at Iganga under current land uses. Apply 80kg/ha TSP on maize and top dress with 80kg/ha CAN. For coffee, apply one debe or 10kg/tree of FYM or compost around the tree base; apply further 50g of TSP by broadcasting around the tree/year and top dress with 25kg/10tonnes CAN or ASN per year in alternate years. No need of fertilizer application on sweet potatoes and cassava. Apply 25kg of ASN to coffee at nursery. For maize in sites top dress with 250kg/ha sulphate of ammonia in two portions 2nd half 40 days later or knee high. Apply 80kg/ha TSP on groundnuts after manure application. Majority of people in these places are pastoralists with limited dairy farming. They should be advised to diversify and intensify their agricultural practices because in case of a disease or draught. Crop diversification noticed in most sites is recommended to utilize available nutrients and for crops to complement each other e.g. maize/groundnuts in terms of nutrients. A combination of organic and inorganic fertilizer should be used to reduce costs of production. Foliar feed containing zinc and iron is recommended for application on tree crops like coffee and bananas due to its scarcity in most sites.

6.0 ACKNOWLEDGEMENT

I would like to thank all those people who assisted in collecting the data used in this report. These are GPS mapping teams, Field guides, Botanists, Sociologists, Drivers and including various teams in Soroti, Iganga, Kamuli and Tororo Districts where this project is being carried out.

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8.0 ANNEXES

Annex 1: Soil samples and land use/cover from different sites in Uganda.

Annex 1 (a): Soil sample number, land use/cover and other notes for Buyuba-Bigiri Kamuli District Uganda (24 samples)

KP2 = Sweet potatoes	KP4Q2
LU = Cultivation	LU =Bushland
LC = Sweet potatoes, Bare ground, Weeds	LC = Bush
KP3 near Plot 3	KP1Q1 8/7/03
LU = Cultivation	LU = Old fallow
LC = Maize	LC = Thick bush
KP2Q1 10/7/03	KP2Q4 10/7/03
LU = Fallow/Bush	LU = Grazing
LC = Bush	LC = Bushed grassland
KP4Q4 14/7/03	KP3Q3 12/7/03
LU = Old fallow with coffee	LU = Fallow with coffee
LC = Coffee plants	LC = Wooded bushland
KP4 near Q1 14/7/03	KP4 - near Q1 14/7/03
LU = Cultivation	LU = Cultivation
LC = Bushed grassland	LC = Cassava (Outside plot)
KP1Q4 8/7/03	KP2 = Maize cultivation 10/7/03
LU = Cultivation (sweet potatoes)	LU = Cultivation maize
LU = Herbaceous, sweet potatoes, bare ground	LC = Weeds/maize/bare ground
KP1 Q2 8/7/03	KP3Q2 12/7/03
LU = Fallow/grazing	LU = Grazing
LC = Shrubs/herbs/grass	LC = Herbaceous sp./ grass
KP3Q4	KP3Q1 12/7/03
LU = Cultivation	LU = Grazing
LC = Maize + cassava	LC = Bushed grassland
KP4: near Q1 14/7/03	KP1 near quadrat 8/7/03
LU = Cultivation	LU = Cultivation maize
LC = Coffee crop (well kept coffee)	LC = Maize/weeds
KP2Q3 10/7/03	KP1 near Q4
LU = Grazing/fallow	LU = Cultivation
LC = Bushed grassland	LC = Cassava + little maize
KP1Q3 8/7/03	KP4Q3 14/7/03
LU = Grazing	LU = Fallow (old)
LC = Grass & herbs	LC = Bush woodland (coffee)
KP4Q1 14/7/03	
LU = Bushland/no use	
LC = Bush	

Annex 1 (b): Soil sample number, land use/cover date sampled and other notes for Bubaka, Iganga District, Uganda (75 samples)

IGA S3 6/9/03	IGA S9	IGA S7
P2 Q3	P2 Q9	P4 Q8
LU = Grazing	LU = Cultivation	LU = Cultivation
LC = Forbes	LC = Maize/forbes	LC = Groundnuts/maize
WP = 164	WP = 170	WP = 40
IGA S1	IGA	IGA S4
P2 Q1	Q10	P5 Q4
LU = Grazing	LU = Cultivation	LU = Cultivation
LC = Grass	LC = Banana	LC = Harvested maize/forbes
WP = 162	WP = 52	WP
IGA S15	IGA S1	IGA S12
P1 Q15	P5 Q1	P6 Q12
LU = Grazing	LU = Cultivation	LU = Cultivation
LC = Grass	LC = Forbes & harvested maize	LC = Maize/beans/forbes
WP = 158	WP = 100	WP = 139
IGA S8	IGA S12	IGA S16
P2 Q8	P1 Q12	P4 Q16
LU = Cultivation	LU = Grazing	LU = Fallow
LC = Sweet potatoes	LC = Forbes	LC = Coffee/herbs
WP =169	WP = 155	WP = 87
IGA S16	IGA S5	IGA S9
P2 Q16	P2 Q5	P4 Q9
LU = Cultivation	LU = Grazing	LU = Fallow
LC = Sweet potatoes	LC = Grass	LC = Grass
WP = 177	WP = 166	WP = 80
IGA S12	IGA S7	IGA S14
P2 Q12	P1 Q7	P5 Q14
LU = Cultivation	LC = Horbes/sedges	LU = Cultivation
LC =Maize	LC = Horbes/sedges	LC = Cassava/banana/forbes
WP 173	WP = 150	WP =115
IGA S15	IGA S13	IGA S7
P2 Q15	P1 Q13	P4 Q7
LU = Cultivation	LU = Cultivation	LU= Grazing
LC = Maize	LC = Grass	LC = Grass
WP = 176	WP = 156	WP 78
IGA S14	IGA S6	
Maize	P2 Q6	IGA S6
	LU = Grazing	P5 Q6
IGA S14	LC = Grass	LU = Cultivation
P2 Q2	WP = 167	LC = Forbes
LU = Grazing		WP = 107
LC = Grass/horbes	IGA S14	
WP = 163	P1 Q14	IGA S15
	LU = Grazing	P3 Q15
IGA S4	LC = Grass/forbes	LU = Grazing
P2 Q4	WP = 157	LC = Grass
LU = Grazing		WP = 56

LC = Forbes/grass	IGA S6	
WP = 165	P3 Q6	IGA S9
	LU = Cultivation	P5 Q9
IGA S8	LC = Maize/cassava	LU = Cultivation
P1 Q8	WP = 39 (0548152/0073335)	LC = Maize
LU = Grazing		WP = 110
LC = Grass	IGA S17	
WP = 151	P1 Q17	IGA S3
	LU = Cultivation	P6 Q3
IGA S16	LC = Maize/grass	LU = Cultivation
P1 Q16	WP = 160	LC = Maize/cassava
LU = Grazing		WP = 130
LC = Grass	IGA S5	
WP = 159	P5 Q5	IGA S11
	LU = Cultivation	P3 Q11
IGA S5	LC = Forbes	LU = Cultivation
P1 Q5	WP = 106	LC = Rice
LU= Grazing		WP = 52
LC = Grass	IGA S4	
WP = 148	P6 Q4	IGA S6
	LU = Cultivation	P6 Q6
IGA S6	LC = Maize/coffee/bananas/ cassava/beans	LU= Cultivation
P1 Q6	WP =131	LC = Maize/beans
LU = Grazing		WP =133
LC = Grass	IGA S11	
WP = 149	P1 Q11	IGA S14
	LU = Grazing	P4 Q14
IGA S1	LC = Grass	LU = Cultivation
P1 Q1	WP = ?	LC = Sweet potatoes
LU = Grazing		WP = 88
LC = Grass	IGA S11	
WP = 144	P5 Q11	IGA S3
	LU = Cultivation	P4 Q3
IGA S18	LC = Cassava	LU = Grazing
P1 Q18	WP = 112	LC = Grass
LU = Cultivation		WP 74
LC = Maize/forbes	IGA S12	
WP = 161	P5 Q12	IGA S15
	LU = Cultivation	P4 Q15
IGA S9	LC = Beans/maize	LU = Fallow
P1 Q9	WP = 113	LC = Coffee
LU = Grazing		WP = 86
LC = Grass	IGA S7	
WP = 152	P6 Q7	IGA S16
	LU = Cultivation	P3 Q16
IGA S3	LC = Sweet potatoes	LU =Cultivation
P1 Q3	WP = 134	LC = Sweet potatoes
LU = Grazing		WP = 57

LC = Grass/forbes	IGA S8	
WP = 146	P3 Q8	IGA 55
	LU = Fallow	P4 Q5
IGA S2	LC = Grassland	LU = Fallow
P1 Q2	WP = 41	LC = Herbs
LU = Dig (using hoes)		WP = 86
LC = Grass	IGA S1	
WP = 145	P4 Q1	IGA S13
	LU = Grazing	P4 Q13
IGA S10	LC = Fallow/grazing	LU =Cultivation
P2 Q10	WP = 72	LC Sweet potatoes
LU = Cultivation		WP 84
LC = Coffee/forbes	IGA S7	
WP 171	P2 Q7	IGA S15
	LU = Grazing	P5 Q15
IGA S3	LC = Grass/forbes	LU =Cultivation
P3 Q3	WP = 168	LC = Maize (harvested)/grass/forbe
LU = Cultivation		WP 116
LC = Banana/cocoa yams	IGA S2	
WP = 36,	P6 Q2	IGA S8
0548137, 0073371	LU = Cultivation	P6 Q8
	LC = Maize/ grass	LU = Cultivation
IGA S13		LC = Maize/beans
P2 Q13		WP = 135
LU = Cultivation	IGA S5	
LC = Cassava	P3 Q5	IGA S14
WP = 174	LU = Cultivation	P3 Q14
	LC = Sweet potatoes	LU = Grazing
IGA S10	WP = 38	LC = Herbaceous/swamp
P3 Q10		WP = 55
LU = Cultivation	IGA S4	
LC = Sweet potatoes	P4 Q4	IGA S1
WP = 51	LU = Grazing	P6 Q1
	LC = Herbaceous	LU = Fallow
IGA S15	WP =75	LC = Grass
P6 Q15		WP 38
LU = Cultivation	IGA S10	
LC = Maize/coffee	P5 Q10	IGA S12
WP = 142	LU = Cultivation	P3 Q12
	LC = Cassava/forbes	LU = Cultivation
IGA S12	WP = 111	LC = Herbaceous
P4 Q12		WP = 33
LU = Fallow	IGA S8	
LC = Herbs	P4 Q8	IGA S14
WP = 83	LU = Cultivation	P5 Q14
	LC = Sweet potatoes	LU = Cultivation
	WP = 79	LC = Cassava/Banana/forbes

		WP = 115

Annex 1 (c): Soil samples number, land use and date sampled and other notes for Tororo, District Uganda (72 samples)

Lab No.	Date	Lab No.	Date
2353	21/06/04	2386	21/6/04
	MZ 4		GN 5
	New land use		New land use: MZ
	MZCA	2387	21/6/04
2354	21/06/04		FL 5
	Plot 5		New land use: MZ
	Cordinates 0647745	2388	21/6/04
	Cordinates 0079686		GNM 23
	Fallow	2389	21/6/04
2355	21/06/04		FL 10
	MZ5		New land use: FL
	New land use	2390	21/6/04
	TB		CA 10
2356	21/6/04	2391	21/6/04
	MZ 1		ML 9
	New land use		New land use: FL
	PL	2392	21/6/04
2357	21/6/04		Plot 3
	GN 2 0648013		Cordinates 0647169
	GN 2 0078460		Cordinates 0079086
	New land use		Cultivated MZGN
2358	21/6/04	2393	21/6/04
	CA 5		Plot 2 MKN
	No change in land use		Cordinates 0645747
2359	21/6/04		Cordinates 0078906
	GN 2	2394	21/6/04
	New land use		FL 2
	MZCA	2395	21/6/04
2360	21/6/04		ML 4
	FL 1 0645466		New land use
	FL 1 0079930		MZ + Parent rock reached
	No change	2396	21/6/04
2361	21/6/04		MZ 9
	ML 1 0645460	2397	21/6/04
	ML 10079988		ML 8
	New land use		New: TB
	PL	2398	21/6/04
2362	21/6/04		GN MZ 4
	CA,2		New land use: FL
	New land use: MZ	2399	21/6/04
2363	21/6/04		GN 1
	CA 4		New land use: Sweet potatoes
	New land use	2400	21/6/04
	M2CA		CA 2

2364	21/6/04		New land use: Sweet potatoes
	CA 1 0645439	2401	21/6/04
	CA 1 0079985		ML 11
2365	21/6/04		New land use: FL
	CA 9	2402	21/6/04
	New land use: FL		MZ 2
2366	21/6/04		New land use VG
	Bush land cordinataes	2403	21/6/04
	0647218, 0078961		Plot 4
2367	21/6/04		Cordinates 0644728
	TB 4 0647854		Cordinates 0080219
	TB 0078310		Bush
	New land use: FLGR	2404	21/6/04
	Parent rock reached		CA 11
2368	21/6/04		New land use: FL
	TB 1 0645476	2405	20/6/04
	TB 0080067		ML 5
	New land use		No change
2369	21/6/04	2406	20/6/04
	GNMZ 2		MZ 3
	New land use		New land use: Fallow
	MZCA	2407	20/6/04
2370	21/6/04		TB 3
	FL 11	2408	20/6/04
	New land use: MZ		Plot 1
2371	21/6/04		Forest
	MZ 10		GPS Cordinates
	New land use: CA		Cordinates 0646516
2372	21/6/04 Plot 5		Cordinates 0079596
	Cordinates 0647658	2409	20/6/04
	MZ 0079634		ML 3
2373	21/6/04		New land use: TB
	FL 4	2410	20/6/04
	New land use		Plot 1
	FLGR		Bush
2374	21/6/04		GPS Cordinates
	MZ 8		Cordinates 0646542
	New land use: FL		Cordinates 0079530
2375	21/6/04	2411	20/6/04
	ML 2		MZ 6
	New land use: FL		No change
2376	21/6/04	2412	20/6/04
	TB 6		CA 3
2377	21/6/04	2413	20/6/04
	TB 2		FL 6
	New land use: FL		New land use
2378	21/6/04		FLGR
	ML 10079988	2414	20/6/04
	New land use: FL		CA 7

2379	21/6/04		New land use: VG
	TB 7	2415	20/6/04
	New land use: Sweet potatoes		ML 6
2380	21/6/04		New land use: TB
	Plot A 2	2416	20/6/04
	Cordinates 0645776		FL 7
	Cordinates 0078973		New land use: TB
2381	21/6/04	2417	20/6/04
	FL 9		FL 7
	New land use: CA		New land use: FLGR
2382	21/6/04	2418	20/6/04
	TB 5		GN 3
	New land use		New land use: CA
	CA	2419	20/6/04
	Parent rock reached		GNMZ1
2383	21/6/04		New land use: MZ
	Plot 4	2420	20/6/04
	Cordinates 0647715		CA 6
	Cordinates 0080247		New land use: FLGR
	Cultivate: Fallow	2421	20/6/04
2384	21/6/04		GN 4
	FL 8		New land use: FLGR
	New land use	2422	20/6/04
	PL		CA 5
2385	21/6/04		New land use: ML
	MZ 4	2423	20/6/04
	New land use		ML 7
	CA		New land use: SP
		2424	20/6/04
			M 7
			New land use: FLGR

Annex 1 (d): Soil samples number, land use and other notes for Akoroi-Soroti District Uganda (20 samples)

SS1	SS 12
P5Q1	P2Q3
LU = Cultivation	LU = Grazing
LC = Maize/millet	LC = Bushed grassland
SS2	SS 12
P5Q2	P2Q4
LU = Cultivation	LU= Cultivation
LC = Maize + millet	LC = Cassava plantation
SS3	SS 13
P5Q3	P3Q1
LU = Cleared & ploughed	LU = Grazing
LC = Maize/millet	LC = Bushed grassland
SS4	SS 14
P5Q4	P3Q2
LU = Grazing	LU = Bush/grazing
LC = Bushed grazing	LC = Bush
SS5	SS 15
P1Q1	P3Q3
LU = Grazing	LU = Fallow
LC = Open woodland	LC = Woodland/shrubs
SS 6	SS 16
P1Q2	P3Q4
LU = Grazing, old fallow	LU = Grazing
LC =Bushed grassland + cassava	LC = Woodland/grassland
SS 7	SS 17
P1Q3	P4Q1
LU = Grazing fallow with cassava	LU = Cultivation
LC = Open grassland with cassava	LC = Rice crop
SS 8	SS 18
P1Q4	P4Q2
LU = Cultivation	LU = Grazing/forest
LC = Groundnut	LC = Woodland
SS 9	SS 19
P2Q1	P4Q3
LU = Grazing	LU = Forest
LC = Bushed woodland (former forest)	LC =Forest/woodland
SS 10	SS 20
P2Q2	P4Q4
LU = Grazing/forest	LU = Fallow
LC = Forest/thicket	LC = Cassava/tall grass

Annex 2: Division of crops into ranges of acidity tolerance crop

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

Liming to correct soil acidity is recommended to be depending on the acidity tolerance of the crop intended to be grown.

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