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Impact of *Topsequence* and Type of Cropping System on Soil Properties in Mid-western Uganda

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Abstract: The impact of cropping and slope position on major physical and biochemical properties of the soils in mid-western Uganda was evaluated. The study sites had been under annual and perennial cropping systems cultivated for more than 10 years, a time scale long enough to evaluate the impact of cropping on the selected soil properties and how these varied across a toposequence. Samples from 30 annual and 30 perennial farms were collected to a single depth of 20 cm along a toposequence and subjected to routine laboratory analyses. Soil samples were analyzed for physical properties (like texture) and chemical properties (like N, P, K and Ca; Cation Exchange Capacity (CEC) and pH) and biochemical properties (like soil organic matter (SOM)). All the soils were found to be moderately acidic with pH within a range of 5.5 – 6.5.Cation exchange capacity (CEC) was also moderate-to-high (18-25) cmol (+) kg^{-1} of soil. Along the toposequence, there was significantly higher clay content at the bottom (43.4%) compared to either top (35.6%) or mid (30.5%) slope positions regardless of cropping. Within cropping, clay content and SOM were significantly higher under perennial cropping (38.8%) than annual cropping (34.0%), implying that the soils under annual cropping were less protected against loss of finer particles for example through soil erosion. The soil was moderately deficient in nitrogen (0.16%N) and severely deficient in P (2 mg P kg^{-1} of soil), compared with their critical levels of 0.25% and 15 mg P kg^{-1}soil, respectively. Annual cropping had significantly lower nutrients than perennial cropping, irrespective of slope position. Perennial cropping and agro-forestry systems that improve soil protection as well as application of N and P fertilizers should be encouraged for soil improvement in mid-western Uganda and related agro-ecological zones elsewhere.

Keywords: Annual Cropping, Perennial Cropping, Soil Properties, Toposequence.

I. INTRODUCTION

The present state and future prospect of feeding the ever increasing population depends on how best the world's soil resources are managed. Many studies have reported declining soil fertility in Sub Saharan Africa (Stoorvogel & Smaling, 1990, Smaling et al., 1993; Smaling et al., 1996). The major causes include human interference leading to loss of soil functions (FAO, 2006), soil fertility decline owing to mining of plant nutrients (Stoorvogel & Smaling, 1990; Bekunda et al., 2002; Muzoora et al.,2011). Fortunately, there has been an increasing awareness of soil degradation and its impacts (Bouajila et al., 2011). The need to address soil fertility degradation is particularly motivated by the realization that soil nutrient depletion is an impediment to sustainable agriculture and rural development in Sub Saharan Africa (Smaling et al., 1993, Smaling et al., 1996) and a threat to global food security especially with the rapidly increasing population (FAO, 2001) that has resulted in land fragmentation. Since Ugandan farmers face cash constraints (Benson et al., 2012), they have majorly depended on use of local knowledge and local materials to restore the fertility of their soils in cropping systems. Soil physiochemical properties like texture and status of nutrients have been shown to affect soils productivity the most (Coleman et al., 2004). There is a sequence of soils in which distinctive soil characteristics are related to topographic situation which is their toposequence**.**

Little is known about the interaction between cropping and toposequence on physiochemical properties of soils and how this affects soil productivity. In addition, limited farmers' knowledge about their soils and their management endangers food security in the near future (Bekunda, 1999) and also puts at stake the livelihoods of over 90% of Ugandan farmers (Nkonya etal., 2004). This study was conducted to characterize the soil physicochemical properties of the western Uganda under annual and perennial cropping systems along a toposequence with a view to identifying measures for restoration of degraded soils or for better protection of conserved soils.

II. MATERIALS AND METHODS

This study was conducted in the mid-western part of Uganda, Hoima district, Kyabigambire Sub County, Bulindi parish from January to September 2013. This area also comprises of Bulindi Zonal Agricultural Research Institute (BUZARDI).The mid of this area is at $1^{o}28^{'}35''$North and 31026'26''East (Fig. 1). The area has an average of 27^{o}C and with a bimodal type of rainfall with two rainfall seasons. First rains commence from March peaking in May at 580 with June having the lowest rainfall (around 40mm) and subsiding in June to pave way for the short dry spell between July and mid-August. Second rains last from September to November, peaking in October at about 620 mm, paving a way for the longer dry spell with the lowest rainfall (about 20mm) in January as the driest month. The total rainfall is always between 1200 to 1600mm per annum. The major annual crops in the area are; maize (Zea mays L.), common bean (Phaseolus vulgaris L.), sweet potatoes (Ipomea batatas L.), groundnuts (Arachis hypogea L.), onions (Allium cepa L.) and perennial crops like; bananas (Musa spp.), Robusta coffee (Coffea canephora), cassava (Manihot esculenta), sugarcane (Saccharum officinarum) and yams (Dioscoreaceae spp.).

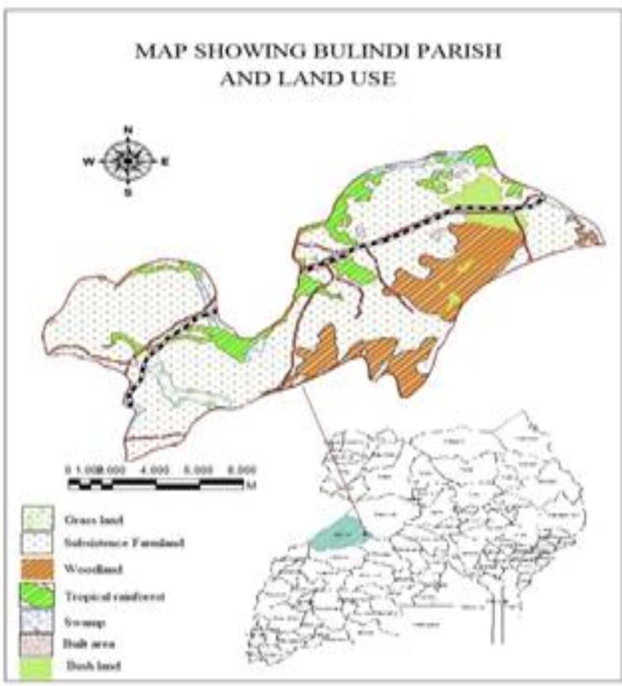


Fig.1. Study area and the different land uses.

A random selection of 60 farms (30 annual and 30 perennial) cultivated for over 10 years, each at three slope positions: upper, middle and lower, with slope position as the blocking factor were studied. Ten fields were studied for each of the three slope positions as replicates. Three bulk soil samples were taken to a depth of 0-20cm from each slope position for each of the selected fields, homogenized and quarter sampled to constitute a composite sample. A total of 60 composite samples (2 cropping systems x 3 slope positions x 10 fields) were collected and transported to the Makerere University Soil, Water and Plant Analytical Laboratory for analyses. In the laboratory, samples were assigned Laboratory numbers and then processed for analyses by air-drying in a well-ventilated drying chamber. This was followed by breaking clods and manually picking plant roots and other unwanted materials before the air-dried soil samples were crushed, ground and sieved through a 2mm sieve. From each of the sieved soil samples, a representative sample of about 250g was collected for laboratory analyses. The soil samples that were used for the determination of total N, P and organic matter were further ground using a mortar and a pestle in order to obtain finer well homogenized samples.

Soil pH and soil texture were determined using the glass electrode method at a soil: water ratio of 1:2.5 and hydrometer method, respectively following the routine procedures compiled by Okalebo et al. (2002). The textural classes of the soil samples were determined using the USDA-soil textural triangle (Fig. 2) based on the percentages obtained above that indicated the size distribution of the different particles in the soil samples (Okalebo et al., 2002). We used the Walkley-Black method compiled by Okalebo et al. (2002) and as described by Olupot et al. (2015) to determine total soil organic carbon (TOC). This involved wet oxidation of 0.5 g soil with a combination of K_2Cr_2O7 and concentrated H_2SO_4 at 150 ^{o}C for 30 minutes and titration of the $Cr_2O_7^{2-}$ residue with $FeSO_4$. A correction factor of 1.3 was used in the calculation of the results to compensate for the incomplete oxidation of organic matter in the soil in the process (Van-Reeuwijk, 2006). We used the conservative 1.724 Van Bemmelen factor (Schumacher 2002) to convert %SOM into %SOC, based on the assumption that 58% of SOM is SOC (Van Reeuwijk, 2006).Total soil %N was determined using the Kjeldahl method based on the principle that all the N-containing components of the soil, which are not present in the crystal lattice of soil minerals, are reduced to ammonium compoundsby the Kjeldahl digestion procedure (Okalebo et al., 2002).

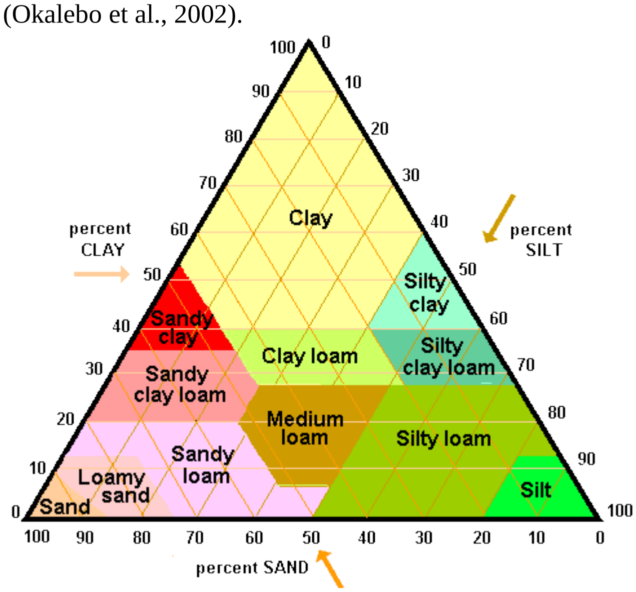


Fig.2. Textural triangle used in the determination of textural classes (Okalebo et al., 2002).

Available P was determined using the Bray 1 method as described in the methods compiled by Okalebo et al. (2002). Exchangeable cations were determined following routine procedures (Okalebo et al., 2002). The data were entered into Microsoft Excel and thoroughly checked to eliminate any errors that could have been made during data entry before exportation into Genstat software for statistical analyses. Prior to analyses, data were checked to ensure that the assumptions for conducting ANOVA were met, including the normality assumption (using the Q-Q normality plots), equal variance assumption (using the residual vs fitted value plots) and for extreme outliers using Cook's Distance plots. Where data did not satisfy any of the assumptions for conducting ANOVA, appropriate transformations were conducted to ensure that the data met all the conditions for conducting ANOVA. For each of the parameters, a two-way ANOVA was conducted using Genstat statistical package14th Edition with toposequence (at three levels: bottom, middle and upper slope positions) and cropping (at two levels: annual and perennial cropping) as the two factors. Wherever ANOVA results were found to be significant, means were separated using Fischer's Protected LSD at 5% level of significance. Unless stated otherwise, all mean separations were conducted at two standard deviations.

III. RESULTS

A. Toposequence And Cropping System Effects On Soil Texture

The main effects of both toposequence and cropping on soil texture were both strongly significant (P < 0.001). For toposequence, clay content was significantly higher at the bottom slope position (43.4 ± 1.65)% than at either the top (35.6 ± 1.65)% or mid (30.50 ± 1.65)% slope position. Expectedly, the smallest content of sand (39.4 ± 2.26)% was observed at the bottom slope position whereas the largest sand fraction (52.0 ± 2.26)% was at the mid slope position, although it did not differ significantly (P ≤ 0.05) from the sand content on the top slope position (45.3 ± 2.264)%. For cropping, there was significantly higher clay content under perennial cropping (38.8 ± 1.35)% than under annual cropping (34.2% ± 1.35)%. For sand, the main effect of cropping was also significant (P = 0.027) with annual cropping having significantly higher sand content (47.7 ± 1.85)% than perennial cropping (43.5 ± 1.85)%.

The Interactive Effects of Toposequence And Cropping On Soil Texture: The impact of cropping on clay content was marginally significant (P= 0.054) when averaged over the effect of toposequence. This implies that the variation in clay content under annual and perennial cropping was not consistent across the slope positions. For example, under annual cropping, the bottom slope position had marginally lager clay content (39 ± 2.30)% than the mid (30.4 ± 2.30)% and upper slope(33.4 ± 2.30)%. In contrast, the impact of cropping on sand content was significant (P = 0.024) when averaged over toposequence. For example, under annual cropping, the sand content at the bottom slope position (46.2 ± 3.20)% was significantly smaller than that on either the mid position or upper slope position both of which were above (50 ± 3.20)%. A similar pattern was also observed for perennial cropping. In the case of silt, whereas the main effects of toposequence and cropping did not differ significantly (P > 0.05), a significant interaction was observed (P = 0.019). Thus, the silt content varied between annual and perennial cropping when averaged over slope position. For example, under annual cropping, the smallest silt content was observed on the top slope position (16.4 ± 2.44)% compared with the mid or bottom slope position (19.2 ± 2.44 and 18.8 ± 2.44)%, respectively. This contrasted with perennial cropping that had significantly larger silt content (P ≤ 0.05) at the top slope than the mid and bottom slope positions (Table 1).

TABLE I: Mean Interactive Impacts Of Toposequence And Cropping On Soil Texture

Texture	Perennial			Annual			
	Up	Mi	Lo	Up	Mi	Lo	s.e.d
Sand (%)	40.40	50.40	33.60	50.20	55.60	46.20	3.201
Clay (%)	37.80	33.80	50.80	33.40	30.20	39.00	2.304
Silt (%)	21.80	15.80	15.60	16.40	19.20	18.80	2.440

n=60, Up=Upper, Mi=Middle and Lo=Lower

B. Toposequence And Cropping Effects On Amount Of Soil Organic Matter (SOM)

Whereas the main effect of slope position on SOM did not differ significantly (P = 0.30), the main effect of cropping was strongly significant (P= 0.001). Perennial cropping had significantly higher SOC (5.7 ± 0.17)% than the annual cropping (5.4 ± 0.17)%. Overall, the soil had relatively larger SOM, above which is recognized as the critical minimum below which crop production is affected Okalebo et al., (2002).

The Interactive Effect Of Toposequence And Cropping On SOM: The interactive impact of cropping system and toposequence on SOM was strongly significant (P=0.004). For example, under perennial cropping, the bottom slope position had smaller SOM levels (4.8 ± 0.29)% compared with the mid and top slope positions (6.6 ± 0.29 and 5.4 ± 0.29)%, respectively (Fig.3). Annual cropping also followed the same trend as that in perennial.

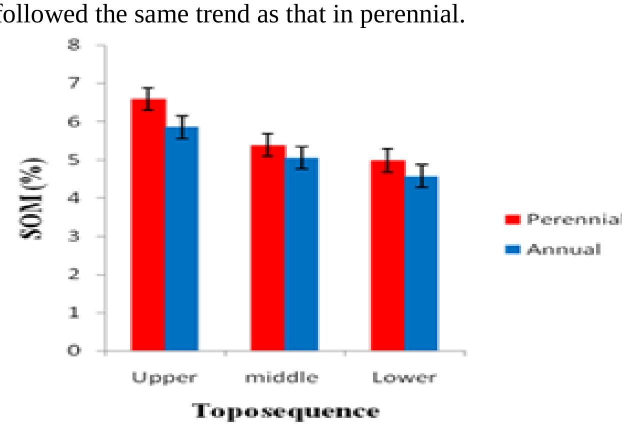
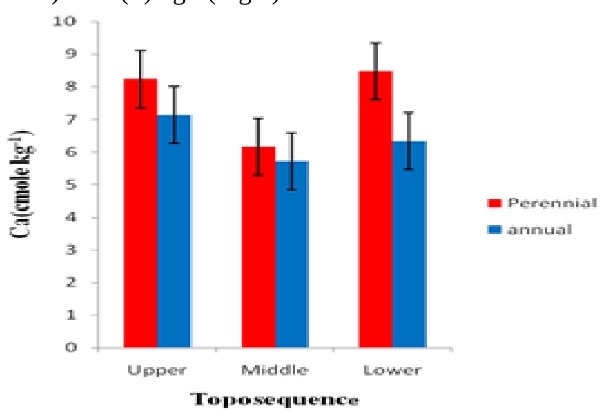


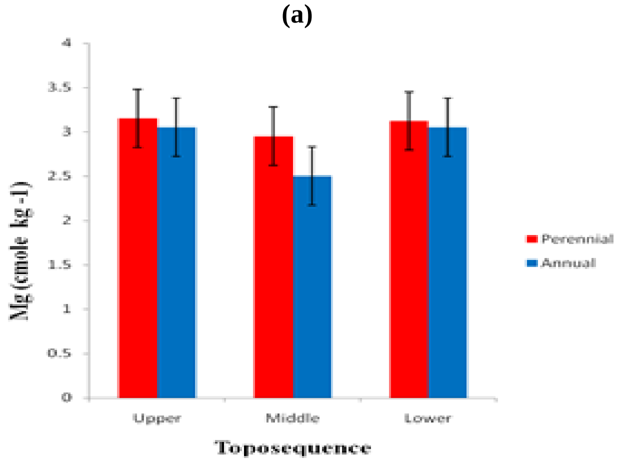
Fig.3. Mean interactive impact of toposequence and cropping on SOM levels.

C. Main Effects Of Toposequence And Cropping On Soil Ph And Cation Exchange Capacity (CEC)

There was no significant effect of either slope position or cropping on soil pH although it is important to note that perennial fields tended to have slightly higher pH values than the annual cropping fields. The main effects of slope position and cropping on CEC were both strongly significant ($P < 0.001$). For example, CEC varied significantly in the order of bottom (24 ± 1.16) > top (20.92 ± 1.16) > middle (18.08 ± 1.16) cmol(+) kg^{-1} soil along the toposequence. For cropping, the CEC was significantly higher (22.2 ± 0.67) cmol (+) kg^{-1} under perennial cropping than it was under annual cropping (19.8 ± 0.67)cmol (+) kg^{-1} (Fig.4).



(a)



(b)

Fig.4. Mean interactive impacts of cropping on Ca and Mg along a toposequence in (A) Ca and (B) Mg.

The Interactive Effects Of Toposequence And Cropping On Cation Exchange Capacity(CEC): When averaged over toposequence, the interactive impact of cropping on CEC was significant (P=0.021). For example, under perennial cropping, CEC was higher at the bottom slope position (26.4 ± 1.15) cmol (+) kg^{-1} whereas it was smallest (18.13 ± 1.15) cmol (+) kg^{-1} at the mid slope position. In contrast, annual cropping had the highest CEC (21.8 ± 1.15) cmol (+) kg^{-1} at the top slope position and the smallest CEC (18.03 ± 1.15) cmol (+) kg^{-1} at the mid slope position (Table 2).

TABLE II: Interactive Mean Impacts Of Cropping On Soil Ph And CEC Along A Toposequence

Toposequence	P	A	P	A
	pH($-\log H^{+}$)		CEC	
Upper	6.36	6.06	22.21	21.80
Middle	6.37	6.30	18.13	18.03
Lower	6.36	6.36	26.41	19.63

n = 60, SED = 1.159 for CEC, P-Perennial, A-Annual

D. Main Effects of Toposequence And Cropping On Nitrogen (N) Stocks In The Soil

There was a significant effect of slope position ($P = 0.003$) on N stock. The N stock at the bottom slope position (2.86 ± 0.219) $MgNha^{-1}$ was significantly smaller than that at either mid (3.49 ± 0.219) Mg N ha^{-1} or top (3.60 ± 0.219) $MgNha^{-1}$ slope positions. In contrast, the main effect of cropping on N stock was marginal ($P = 0.053$) with marginally larger N stock under perennial cropping **(**3.50 ± 0.179) Mg N ha^{-1} as compared with annual cropping (3.14 ± 0.179) $MgNha^{-1}$. When averaged over the effects of toposequence and cropping, the soils had a grand mean total N of (0.16%), which was below the critical level of 0.2% N for growth of most cereals**.**

Interactive Effect Of Toposequence And Cropping On N Stocks: When the impact of cropping on N stock was averaged over toposequence, there was no significant effect ($P = 0.22$).

E. Main Effects Of Toposequence And Cropping On Phosphorus (P) Stocks In The Soil

The effect of slope position on available P was strongly significant ($P < 0.001$). The P stock at the bottom slope position (3. 4 ± 0.40) kg P ha^{-1} was significantly smaller than that at either mid-(4.2 ± 0.40) or top (4.4 ± 0.4) kg P ha^{-1} slope positions. On the other hand, the main effect of cropping on P stocks was marginally significant ($P = 0.054$) with P stocks tending to be larger under perennial cropping (4.0 ± 0.30) kg P ha^{-1} than annual cropping (3.0 ± 0.30) kg P ha^{-1}.

Interactive Effect Of Toposequence And Cropping On The P Stocks: When the impact of cropping was averaged over toposequence, the result was significant ($P = 0.012$). For example, under annual cropping, the mid position had significantly larger P stocks (4.0 ± 0.5 kg P ha^{-1}) compared with top and bottom slope position. In contrast, under perennial cropping, there were larger P stocks (5.8 ± 0.5 kg P ha^{-1}) at the top slope position as compared with the mid and bottom slope positions that had <5.0 ± 0.5 Mg P ha^{-1} (Fig.5).

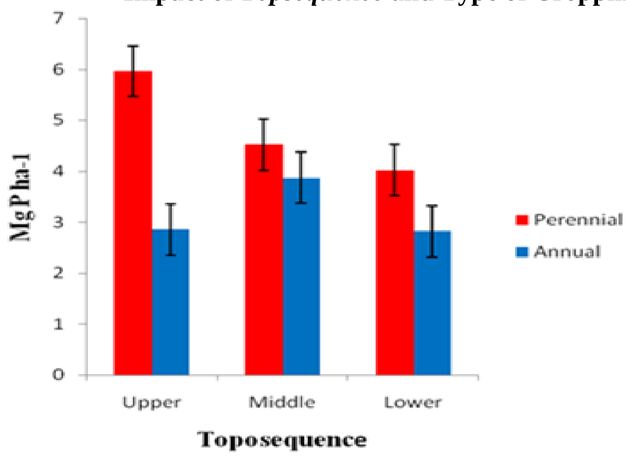


Fig.5. Mean interactive impact on P stock for annual and perennial cropping systems along a toposequence.

F. Main Effects Of Toposequence And Cropping On Potassium Stocks (K)

Both slope position and cropping had strongly significant effects on K stocks ($P < 0.001$). The K stock at the top slope position (0.57 ± 0.03) Mg K ha^{-1} was at least significantly larger than that at the bottom slope position (0.39 ± 0.03) Mg K ha^{-1}. On the contrary for cropping, perennial cropping had significantly smaller K stocks (0.45 ± 0.02) Mg K ha^{-1} as compared to the annual cropping (0.52 ± 0.02) Mg K ha^{-1}. When averaged over cropping and toposequence, the soils had a high K content (0.6cmol (+) kg^{-1} = 234 mg/kg^{-1}).

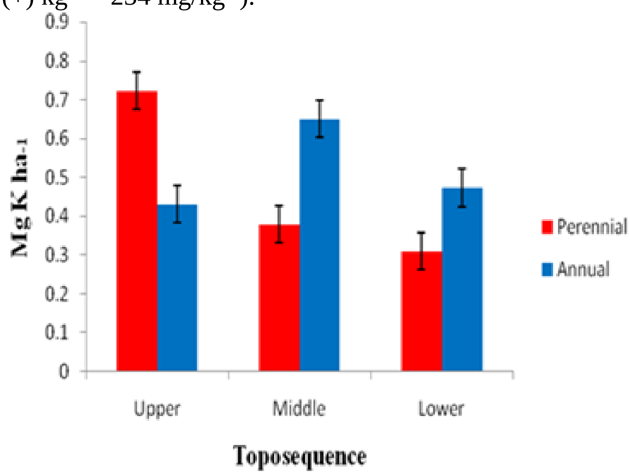


Fig.6. Interactive mean effect of cropping and topo sequence on K stocks.

The Interactive Effects of Toposequence And Cropping On K Stocks: When the interactive impact of cropping was averaged over the toposequence, the result was strongly significant ($P < 0.001$). For example, under annual cropping, the mid slope position had significantly larger K stock (0.65 ± 0.047) Mg K ha^{-1} than the bottom and top slope positions. In contrast under perennial cropping, the top slope position had significantly larger K stock (0.6 ± 0.047 Mg K ha^{-1}) than the mid and bottom slope positions that had K stocks less than (0.40 ± 0.04) Mg K ha^{-1} (Fig.6).

IV. DISCUSSION OF RESULTS

Overall, the soils in the west were identified as sandy clay soils, soils that contain 35% or more clay and 45% or more sand (USDA). Highervalues of clay content on the bottom slope position were expected owing to increased clay depositons from the mid slope position, given its relatively steeper angle. Steep slopes can trigger erosion of finer particles like clay to low-lying areas (Hassel, 2013), selectively removing clay and silt-sized particles while leaving behind coarse-textured particles (Ritter, 2012). The moderate sand and clay content observed in the top slope position were attributed to reduced tillage and agroforestry that constitute major soil and water conservation practices in the study area. Such practices have been reported to increase infiltration and reduce soil erosion, thus conserving soil physical properties (Bosch et al., 2005). The larger sand content under annual cropping compared to perennial cropping could be attributed to the intensive conventional tillage practices under annual-cropped fields. Soil disturbance not only destroys soil structure but also increases soil erosion and thus loss of clay and silt-sized particles. Loss of clay and silt under intensively cultivated soils has been linked to losses of large quantities of nutrients (Lindstrom, 2002). Tillage has also been shown to promote redistribution of soil particles according to their sizes thus enhancing loss of finer clay and other finer particles (Ritter, 2012). Higher silt contents at the top slope position of perennial cropped fields compared with the top slope position of annual cropped fields could be due to differences in vegetation cover between the two cropping systems. Under perennial cropping there is cover throughout the year whereas annual cropped fields are regularly disturbed. Vegetation cover plays a major role in protecting clay and silt-sized particles against erosion (Farley, 1996).

A. Soil Organic Matter (SOM)

The larger SOM at the top slope position for both annual and perennial cropping could be attributed to the existing management practices like conservation tillage. In particular, litter fall from trees on the top slope positions constitutes an important source of SOM (Mccauley et al.,2009).The least SOM levels at thebottom slope position under both croppings could have resulted from frequent residue burning which lowers SOM levels (Albrechit etal.,1997).

B. Soil pH and CEC

The soils in the mid-west have an ideal pH (5.5 - 6.5) for availability of most nutrients (N, P, K, Ca and Mg) for plant uptake (Warncke et al., 2004) and for proper crop growth (Okalebo et al., 2002). The CEC of these soils was classified as moderate that is, soils with CEC ranging from 12 to 25 cmol (+) kg^{-1} (Hazelton and Murphy, 2007). These soils appear to have originated from a parent material inherently moderate to richer in Ca^{2+}, Mg^{2+} and K^{+} ions (grand mean = 7.0, 2.9, 0.6)cmol(+) kg^{-1}, respectively (Fig.4), that are important contributors to CEC of soils (Brown et al., 2003). The larger CEC at the lower slope position could be attributed to the large clay content at the bottom slope position (Berry et al., 2007). Clay soils tend to have a large negative charge on to which cations like Ca^{2+} and Mg^{2+} get adsorbed (Mccauley et al., 2009). Most nutrients like K^{+},Ca^{2+} and Mg^{2+} are contained in SOM (Semalalu et al., 2012) that mineralizes to slowly release cations that raise the soil CEC at the top slope(Salgado et al., 2010).

In this study**,** both the pH and CEC were larger under perennial cropping system which had higher clay and SOM content attributed to inputs from mulches and leaf shed by banana plants (Berry et al., 2007). The large SOM under perennial cropping could have contributed to thelarge CEC observed,which is important in increasing a soil's buffer capacity(Hazelton and Murphy, 2007;Mccauley et al., 2009). The larger CEC at the bottom fields under perennial cropping as compared to the mid and top slope position could have been due to the large clay content at the bottom slope position and reduced tillage under perennial cropping. These two factors have been shown to improve and conserve soil structure and also reduce on the leaching of cations (Laura and Huge, 2009). The larger CEC at the top slope position than the bottom slope position under annual cropped fields was attributed to proper management of adjacent lands coupled with better management practices like hedges (made of Calliandra) around upper annual fields that are effective in controlling soil erosion which can reduce cation losses in eroded soils.

C. N-stocks

Overall, the soil N contents were all below the critical level of 4 Mg N ha^{-1} set for proper growth of most cereals, the values were also within the range of 0.12 to 0.25% N which is considered moderate (Okalebo et al., 2002). However, the relatively larger N stock at the top slope position was attributed to the high SOM levels, an important reservior of ~ 99% N which is released during the process of mineralization (Van et al.,2009). The smallest N stock at the bottom slope position could be due to sparse vegetation cover that was cut for cultivation (Vitosh et al.,1995). Over cultivation enhanceslossof NO_3^-, since the crop residues were not also ploughed back to the farms. SOM levels are strong determinants of N and P levels. On contrary,He et al.(2005) contends that N stocks are always high in lower slope positions than middle and top slope postions. Continuous presence of vegetation leads to larger N stock under perennial cropping system than annual systems which protect the soil against erosion and also contribute litter that is crucial in replenishing soil N stocks.

D. P-stocks

Overall, the soils were found to have very low levels of available P (grand mean = 2.0 mg P kg^{-1} = 4.0 kg P ha^{-1}) that is, acute deficiencies. This value is far below the critical value (15 mg P kg^{-1} = 30 kg P ha^{-1}) which is always required for cropping (Hazelton and Murphy, 2007). The largest amounts of clay found at the lower slope position could have accelerated P retention and mimization of P contact with soil Wolfswinkle, (2010) thus smallest available P stocks at the bottom slope position.The slightly larger stocks of available P in perennials at all slope positions could be due to less soil erosion under perennial cropping also attributed to the high SOM level that is a P reservoir (Balirwa, 1992). Other scientists also reported that P losses under annual cropping farms are always more than those under perennial farms mainly due to erosion and runoff caused by increased tillage (Wolfswinkle, 2010). The larger P stocks at the mid slope position than the bottom and top slope positions under annual cropping were attributed to applications of phosphatic fertilizers since some part of the middle land is under Bulindi Zonal Agricultural Research Institute (BuZARDI) Research Station (Nkonya et al., 2004). P stocks under perennial cropping followed the same trend as that of SOM along the slope, that is (upper > middle > lower). The results observed corresponded well with levels of SOM that is known to be a reservoir for at least 60% of P in the soil and therefore a major determinant of P stocks (He et al.,2005).

E. K-stocks

The soils in the mid-western Uganda have moderate to large K contents that is, K contents above the critical level of (0.4cmol/kg =156 mg kg^{-1}), which were within the range for high K contents of 175-300 $mgkg^{-1}$ (Okalebo et al., 2002) which could be attributed to the original parent material. However, larger K stocks at the top slope position than mid and bottom slope positions was attributed to the growth of majorly Banana plants in the mid and bottom slope positions which are known to extract large amounts of K (Samathiamorthy and Jeyabaskaran,2000), which could have led to the lower K levels as compared to limitted banana growth in the top lands. This is because banana is a heavy feeder of K, implying that the crop can absorb K in luxurious quantities (Sathiamoorthy and Jeyabaskaran, 2001; Ganeshhamurthy et al., 2010). Larger K stocks at the top slope positionthan at mid and bottom slope positions under perennial cropping was due to less cultivation at the top slope position where tree growth is common that preserves the structure leading to reduced susceptibility ofK^{+} to leaching. Another reason for larger K stocks was that the perennial fields at the top slope position had largest SOM levelsthat attract the K^{+} cations on their negatively charged sites in its exchangeable and available form and prevented its loss. With increased ash additions in perennial fields at the top slope position, K levels were considerably higher (Khanna and Raison,1986; Etiegn and Campabell,1991). The annual fields at the mid slope position had the largest K stocks than the annual fields at the top and bottom slope positions due to addition of potash fertilizers as some of the middle lands fall under BuZARDI Research Station that has continuously added murate of potash (60% K_2O) to sustain growth of crops especially Zea mays.

V. CONCLUSION ANDRECOMMENDATION

A. Conclusions

This study reveals that the soil under perennial cropping system had better soil conditions/properties for plant growth than did soils under annual cropping regardless of the slope position. The soils were acutely deficient in P which is the second most limiting nutrient to primary production in tropical soils after N, which was also moderately deficient in the study area of mid-western Uganda.

B. Recommendations

Intercropping perennial crops with annual crops should be encouraged for improvement of soil properties. Reduced tillage especially under annual cropped fields and retention of crop residues can be effective in improving soil physicochemical properties under annual cropping. Farmers should be encouraged to apply N and P fertilizers from the sources that are available or affordable to them from both organic and inorganic sources. Inclusion of leguminous plants for example trees like Calliandra, cover crops like Mucuna, lablab and Crotalaria; and rotation of leguminous and non- leguminous crops, can solve the problem of N deficiency. Management practices like agro-forestry observed at the top slope positions might have contributed to the larger SOM and improved soil physical properties observed compared with the mid and bottom slope positions and should be encouraged.

VI. ACKNOWLEDGEMENT

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VII. REFERENCES

[1]Albrecht S.L, Baune H.L.M, Rasmussen P.E. and Douglas C.L. 1997. Light fraction of organic matter in long-term agro ecosystems. Columbia Basin Agricultural Research Annual Report. Special report 977: 38-42.

[2]Balirwa K. E. 1992. Maize research and production in Uganda.

[3]Bekunda M.A, Nkonya E, Ebanyat P, Mugendi D and Msaky J.J. 2002. Soil fertility status, management and research in East Africa. Journal of Rural Development. 20(1) 94-112.

[4]Bekunda Mateete. 1999. Farmers' responses to soil fertility decline in banana-based cropping systems of Uganda, managing Africa's soil Ed N0.4.

[5]Benson T, Lubega P,Bayite-kasule S, Mogues T and Nyachwo J. 2012. The supply of inorganic fertilizers to Small holder farmers in Uganda, International food Policy Research institute. Discussion paper 01228.

[6]Berry W, Kettings Q,Antes S, Page S, Ruselli-Anelli J, Rao R and DeGloria S. 2007. Nutrient management spear programme http. // nmsp.css.cornell.edu, Cornelli University Cooperation Extension.

[7]Bosch D. D, Potter T. L, Truman C. C, Bednarz C. and Strickland T. C. 2005. Surface runoff and lateral subsurface flow as a response to conservation tillage and soil-water conditions. Transactions of the American Society of Acoustic Ecology (48) 2137–2144.

[8]Bouajila, A., and T. Gallali. 2008. Soil organic carbon fractions and aggregate stability

[9]Coleman, D.C, D.A. Crossley., Jr. P.F. Hendrix. 2004. Fundamantals of Soil Ecology.

[10]DavisJ.G.,WilsonC.R.2012.Choosingasoil amendment, No.7.235.

[11]Etiegni L, and Campbell A.G. 1991. Physical and chemical characteristics of wood ash Bioresource Technology, 37 (1991), pp. 173–178

[12]Farley, C. 1996. Smallholder knowledge, soil resource management and land use change in the highlands of southwest Uganda. PhD Dissertation, University of Florida.

[13]Food and Agricultural Organization in US. 2001. Soil fertility management in support for food security in Sub Saharan Africa.

[14]Food and agricultural organization of United Nations. 2006. Guidelines for soil description fourth edition from Rome.

[15]Ganeshamurthy A.N, Satisha G.C and Prakash P .2010. Potassium nutrition on yield and quality of fruit crops with special emphasis on bananas and grapes. India institute Horticulture research.

[16]Hassel M. 2013. Annual report of the soil and water conservation.

[17]Hazelton P and Murphy B. 2007 Interpreting soil test results-what do all numbers mean.

[18]He V, Hai-yan S, Perera A.G and Gomez A. 2005. Measurement and analysis of soil organic matter content using near-infrared spectroscopy technique, online publication.

[19]Kanmegne J.,E.M.A. Smaling, L. Brussaard, A. Gansop-Kouomegneand A. Boukong. 2006. Nutrient flows in smallholder production systems in the humid forest zone of southern Cameroon. Nutrient Cycling in Agroecosystems 76:233–248. DOI 10.1007/s10705-005-8312-3

[20]Khanna P.K, Raison R J. 1986. Effect of fire intensity on solution chemistry of surface soil under a Eucalyptus Pauciflora Forest. Austria Journal Soil Research 24:423–434.

[21]Laura F and Huge J. 2009. The importance of soil organic matter in cropping systems. Northern Great Plains.

[22]Lindstrom M J. 2002. Tillage erosion, description and process, United States Department of Agriculture Research. USDA Ed. Morris Minnesota, U.S.A 1324-1326.

[23]McCauley A.M, Jones C and Jacobsen J. 2009. Soil pH and organic matter, nutrient content module. A self study course from MSU extension continuing education series No.8: 448-9, Montana state university.

[24]Muzoora A.K, Turyahebwa N and Majaliwa G.M.J. 2011. Validation of farmer perceived soil fertility improving tree species in Agropastoral communities of

Bushenyi district, article ID 212515, International journal of Agronomy.
[25]Nkonya E, Pender J and Kaizzi C. 2004.Determining of soil nutrient balances and implications for addressing land degradation and Poverty in Uganda.
[26]Okalebo, J. R, Gathna K. W, and Woomer P. L. 2002. Laboratory methods for soil and plant analysis. A working manual. Second Edition. Tropical soil fertility and Biology program, Nairobi Kenya.
[27]Olupot G., Antonia Nyamukuru, Doreen Muhumuza, Enock Ssekuubwa, Kellen Aganyira, Vincent B. Muwanika, Josephine Esaete, John RS Tabuti. 2015. Soil carbon and nitrogen distribution under contrasting land cover types in Kibale National Park, Uganda. International Journal of Research on Land-use Sustainability 2: 101-112, DOI:10.13140/RG.2.1. 1762.0885
[28]RitterJ.M.2012. Soil erosion causes and effects. No.87-040.
[29]Salgado M.M, Gutierri R, Jannsens M and Ortega B. 2010. Biological soil quality indicators. A review on current research, technology and education topics in applied microbiology and microbial Biotechnology. Ed. Mendez A-vilas.
[30]SathiamoorthySand Jeyabaskaran K.J.2001.Potassium management of banana. Natural research center for banana 499-517.
[31]Schumacher,B.A.,2002. Methods for the determination of total organic carbon (TOC) in soils and sediments: Las Vegas, United States Environmental Protection Agency.
[32]Semalalu O, Kimaro D, Kasenga V, Isabirye M and Makhori Patrick. 2012. Soil and nutrient losses in banana based cropping systems of Mt.Elgon hillside of Uganda: economic implications, international journal of Agricultural sciences 2 (9): 256-262.
[33]Smaling E.M.A. 1993. An Agroecological Framework forIntegrated Nutrient Management with Special Reference toKenya.WageningenAgriculturalUniversity, Wageningen, TheNetherlands,(Ph.D. thesis).Smaling E.M.A., Stoorvogel J.J. and Windmeijer P.N. 1993.
[34]Calculating soil nutrient balances inAfrica at different scales.II District scale. Fert. Res. 35: 237–250.
[35]Smaling E.M.A., Fresco L.O. and de Jager A. 1996. Classifying,monitoring and improving soil nutrient stocks and flows inAfrica agriculture. Ambio 25(8): 492–496.
[36]Stoorvogel J. J and Smaling, E. M. A. 1990. Assessment of soil nutrient depletion in Sub-Saharan Africa Report 28 DLO Winand starring Center for integrated land, soil and water research (CSC-DLO), Wageningen Netherlands. 1983-2000.
[37]Van, D. B. A., De, B. S., De, N. S., and Hofman, G., (2009). Effect of tillage intensity on N mineralization of different crop residues in a temperate climate. Soil & Tillage Research 103: 316–324.
[38]Van Reeuwijk, L.P., 2006. Procedures for soil analysis. 7th edition. Technical Report 9. ISRIC—World Soil Information. Wageningen, Netherlands.
[39]Vitosh M.L, Johnson J.W and Mengel D.B. 1995. Nitrogen Fertilizaer management in good and bad times.Reviwed in 2003 by Bruder S, Joern B, Vyn T and Nielson B.
[40]Warncke D, Dahl J, Jacobs L and Laboski C. 2004. Nutrient recommendation for field crops in Michigan University.
[41]WolfswinkeV.M.2010. Intercropping of annual food crops.http:www.agromisa.org/agrobriefs/AB4%20Intercropping.pdf. 24/07/13.