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Lunnyu Soils in the Lake Victoria Basin of Uganda: Link to Toposequence and Soil Type

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Abstract: Lunnyu as described by farmers is a rare form of soil infertility, especially in the lake Victoria Basin of Uganda. Neither the cause nor the remedy to this soil type is not known. We compared the physical-chemical characteristics of Lunnyu soils using soil type and slope position in order to explain their variability in the lake Victoria Basin of Uganda. At landscape level, 6 existing Lunnyu patches located on 4 different soil types (*Chromic lixisol*, *Mollic gleysols* and *Plinthic Ferralsols*) were identified at a scale of 1:250,000. At each Lunnyu patch, the slope was divided into 3 parts; shoulder, back-slope and foot-slope. About 5 locations along the contour of each landscape position and at distance of between 20-30 m were located and soil samples taken at 2 depths (0-20 and 20-40 cm). The soil samples were analysed for pH, available P, texture and exchangeable bases. Results show that Lunnyu patches on *Chromic lixisol* and *Mollic gleysols* had higher pH, P, sand, clay and silt compared to those on *Plinthic ferralsols* and *Petrifferic lixisol*. Neither of the soil properties was influenced by landscape position. Soil pH, Ca, Mg and K were higher in topsoil compared to subsoil. Neither slope position nor the type of Lunnyu has showed consistent differences in all the soil properties. Thus, the hypothesis that Lunnyu soils are an erosional phase, occurring characteristically at the backsolpe positions of the toposequence, according to this study does not hold. However, results suggest a pedological explanation in which pH and texture could influence occurrence of the Lunnyu soils. We recommend further studies of the pedological properties of the soils and other trace elements that this study has not investigated.

Key words: Lunnyu soil, toposequence, soil type, pedological properties, remedy, Uganda

INTRODUCTION

Soil variability is a function of soil forming factors-climate, parent material organisms (including human activities), topography and time. Most tropical soils have undergone severe weathering and the resultant soil properties are mostly dependent on parent material and the influence of human activities, especially in agricultural landscapes (Brown *et al*., 2004). Because of increased population and the introduction of annual food and cash crops that require more intensive tillage, there is increasing evidence of severe soil degradation due to nutrient mining and erosion (Lufafa *et al*., 2003). Agriculture in the lake Victoria Basin of Uganda is practiced on small holdings ranging from 0.5-1.5 ha. The Lunnyu phenomenon is a form of soil infertility described by farmers in this region of the country but the scientific understanding of the situation has not been established. Studies modeling soil variability (Moore *et al*., 1993; Gessler *et al*., 2000; Chaplot *et al*., 2000, 2001; Park *et al*., 2001; Florinsky *et al*., 2002; Brown *et al*., 2004) have used the catena concept to demonstrate that topographically associated soil profiles are repeated across certain landscapes. According to however, predictive capabilities of these models are limited, especially over large areas because relationships between soil properties and landscape attributes are nonlinear or unknown.

This is especially important if other soil-forming factors change such as differing parent materials or variations in land use. Thompson *et al*. (2006) noted that this lack of transportability of models has never been fully or explicitly tested by developing and validating models

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for fields from similar landscapes and therefore, warrants investigation into the possible cause and subsequent provision of remedial management interventions. In precision agriculture, site-specific modeling of soil properties is thus inevitable.

Lunnyu is a rare form of soil infertility that is perceived by farmers in some parts of the country, especially in the lake Victoria Basin. The phenomenon of lunnyu soils in Uganda was first documented by Chenery (1954). Their recognition was based on 3 major features; poor crop vigour, loss of soil consistency and poor quality crop and low crop yields. Another, feature common to lunnyu is occurrence of *Cymbopogan* ssp., a weed thought to negatively influence native plant communities by forming dense monotypic stands that alter ecosystem properties and lower local species diversity.

The objective of this study was to test 2 hypothess that lunnyu soils are an erosional phase, occurring characteristically at the backsolpe positions of the toposequence, implying that the soil properties at these locations were different from those at the upper and lower positions of the same landscape and that the properties of lunnyu soils depend on the soil type.

MATERIALS AND METHODS

Description of study area: The study was conducted in the microcatchment covering the districts of Masaka, Rakai and Sembabule. The districts are located on the western side of the lake Victoria Basin. The county lies approximately 31°40'E and 35°S (Fig. 1) with a spatial coverage of 126 km^2. In this zone, agriculture is rain-fed with average annual precipitation of 1,218 mm and slightly drier periods in June and July and December-February (Komutunga and Musiitwa, 2001). The average annual temperature is 21.5°C with little seasonal variation.

The altitude ranges from 1,200-1,260 m a.m.s.l. It is located within the predominantly banana-coffee farming system but other land use types present include annuals, banana and pasture/rangelands (Kisamba-Mugerwa, 2001). The slope of the area ranges between 3 and 18° with most of the area falling in above 15° and thus has a relatively high erosion hazard. It is classified under the South central moist hills and valleys land resource areas. This zone is located on the Eastern African plateaus (1,150-1,400 m a.m.s.l.) between the Western and Eastern African rift on an extremely old (mid to end tertiary) Buganda surface characterized by hills and ridges that are highly dissected (dissected plateau) by streams and drainage ways (Hadoto, 2001).

The solid geology of the area is undifferentiated acid and hornblende gneisses of the basement complex and the parent material is pre-weathered gneiss (Aniku, 2001). Geologically, the area belongs to the Buganda surface which covers the southern part of Central Uganda and consists of granites, gneisses and schists of the Precambrian age. The Buganda surface is part of the

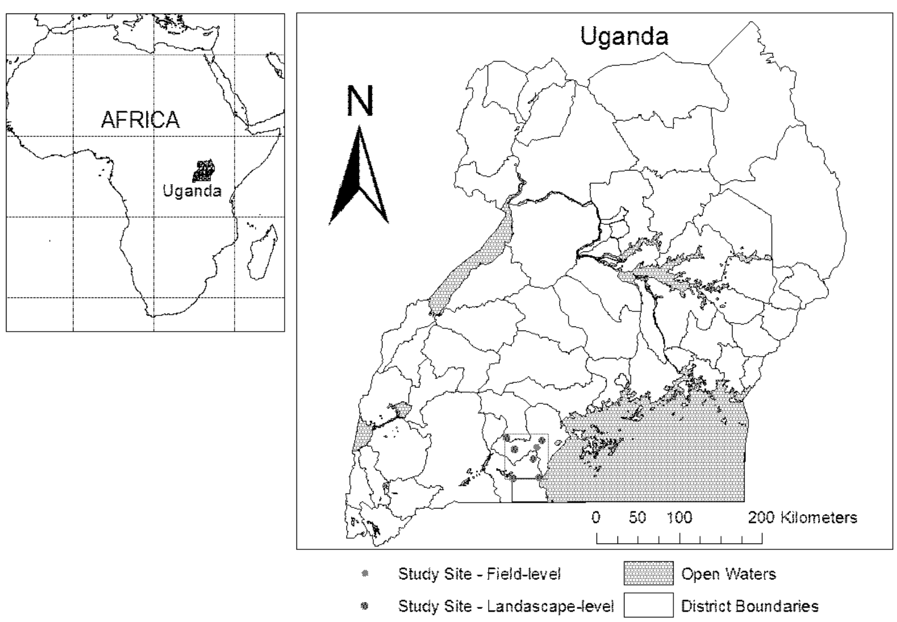

Fig. 1: Location of sampled lunnyu patches in the lake Victoria Basin of Uganda

Ugandan basement complex and a product of long-term weathering processes. Brunner *et al.* (2004) reported that soils at the summit positions had a thick solum due to the stable soil formation on the flat surface whereas soils at the shoulder position had shallow A-horizons due to active erosion processes. Valley and footslope soils showed hydromorphic features and accumulation of soil material from upslope. The soils on uplands are predominantly *Plinthic ferralsols* and *Plinthic* and *Chromic lixisol* (WRB, 2006) and are developed from Precambrian schists and quartzites (Fig. 2 and 3). They are fine textured and have an isohyperthermic temperature regime and udic moisture regime. The soils in the lowlands and valleys (drainage ways between the ridges and hills) are *Mollic gleysols* which occur in swampy and papyrus mashes and are seasonally or permanently water-logged.

The native vegetation is woodland with papyrus but this has been greatly modified by human activities (Aluma, 2001). The catenary sequence consists of shallow brown loam soils on broad crests with deep residual soil

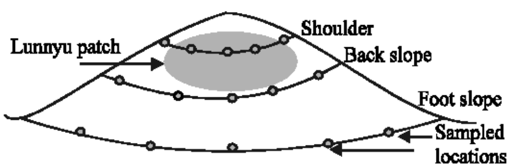

Fig. 2: Idealized locations of sampling positions on the slope

on the side slopes. Information about the land use history, soil degradation problems, soil types, evolution and management practices of lunnyu soils were collected from previous studies carried out in the area such as Lufafa (2000), Taulya (2004) and Mulumba (2004). In the area, there are 3 broad land use types; pasture/rangelands, perennials (mainly banana-coffee) and annuals.

Although lunnyu soils occur in all of them, they are more commonly found in annual and perennial cropping systems. At a scale of 1:250,000, 4 soil mapping units were identified (Fig. 3 and 4) and these include; *Chromic lixisol* (CL), *Plinthic lixisol* (PL), *Mollic gleysol* (PG) and *Plinthic ferralsol* (PF).

Methods: About 6 lunnyu patches were selected from an area covering approximately 50×50 km within the lake Victoria Basin (Fig. 1). The lunnyu patches were selected in such a way that they captured different land uses and soil types. Site conditions at each site were described and are shown in Table 1. At each patch, the slope was divided into 3 parts; shoulder, back-slope and foot-slope (Fig. 2). The division of the slope was such that the points were roughly equidistant from each other at the 3 positions. In each part of the slope, 5 locations, separated by a distance between 20 and 30 m across and along the slope were taken along the contour. Soil samples were taken at two depths (0-20 and 20-40 cm). It is worthwhile to note that lunnyu patches do not have clear-cut

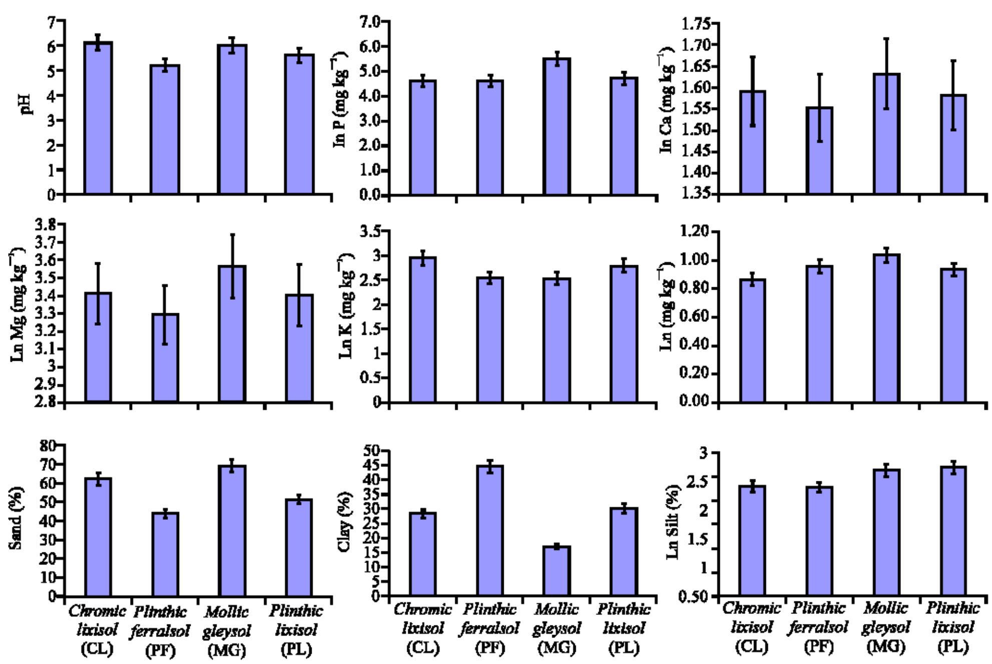

Fig. 3: Topsoil properties across (N for CL = 15; PF = 30; MG = 30 and PL = 15); 5% error bars

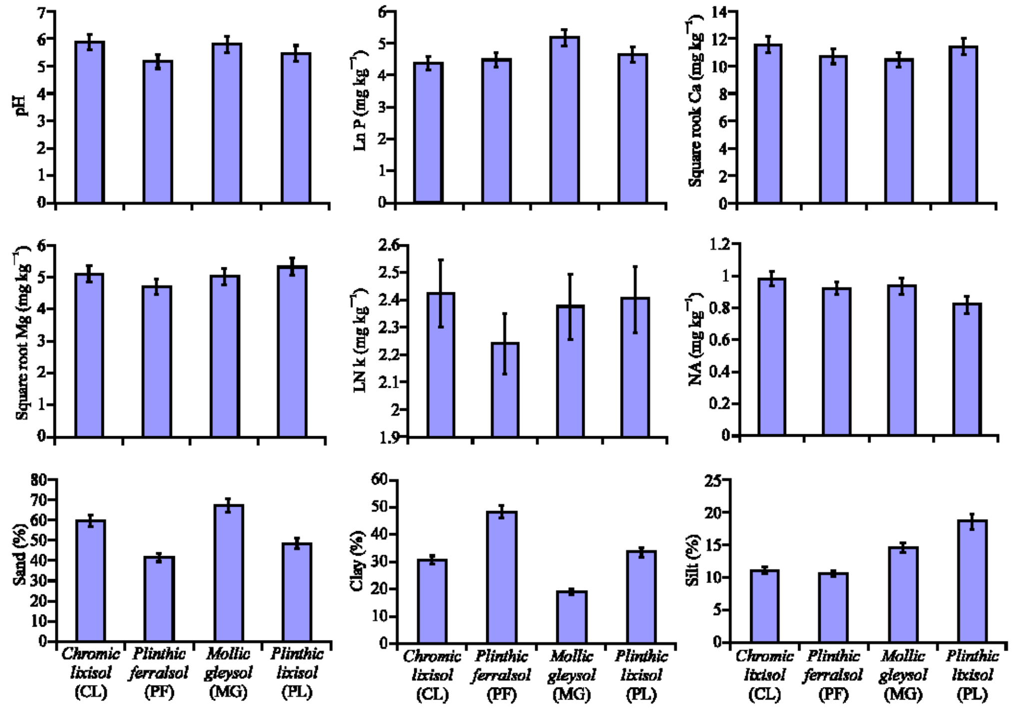

Fig. 4: Subsoil properties (N for CL = 15; PF = 30; MG = 30 and PL = 15) slope; 5% error bars

Table 1: Characteristics of sampled landscapes

Sub counties	Soil type (FAO)	Land use	Notes
Byakabanda	*Mollic gleysol* (MG)	Annual crops	Grown with maize and sweet potatoes with an Eucalyptus plantation covering the lower quarter of the sampled area. Slope was 6%
Kabila	*Mollic gleysol* (MG)	Annual crops	Planted with bananas and formerly maize millet. Lower part seasonally water-logged but upper half with high gravel content. Slope was 3%
Kalisizo	*Petroferic lixisol* (PL)	Pasture land	Pasture land with patches of thickets ranging between 5 and 10 m^2. Slope was 7%
Lwebitakuli	*Chronic lixisol* (CL)	Perennial crops	Only coffee, aged about 10 years according the farmer. Slope was 8%
Lwengo	*Plinthic ferralsol* (PF)	Annual crops	Maize and cassava intercropped and coffee occupying larger part on lower part of the slope. Age of coffee plants was about 25 years. Slope is 10%
Masaka	*Plinthic ferralsol* (PF)	Coniferous forest	Pure Eucalyptus on the lower side and maize *(Zea maize)*, potatoes *(Impomea batatus)*. Slope was 13%

boundaries with some larger and others smaller. The soil samples were taken to the Soil Science Laboratory at Makerere University.

Available P was determined using Bray and Kurtz No. 1 method. The soil was extracted by Brady 1 solution and the P determined by the calorimetric procedure using a spectrophotometer. Soil pH was determined using a pH meter (Rhoades, 1982). Exchangeable K, Ca and Mg were measured by treating the soil samples with excess 1 M ammonium acetate solution. Later, the concentrations of exchangeable sodium and K in the extract were measured by flame photometer and the concentration of Ca and Mg was measured by atomic absorption spectrophotometry (Anderson and Ingram, 1989). Laboratory analysis was done in the soils science laboratory of the Faculty of Agriculture, Makerere University.

Data analysis: The descriptive statistics for the tested soil properties are shown in Table 2. Before performing ANOVA, normality tests were performed using the Andersen-Darling test. In the topsoil, pH, Mg and K followed a normal distribution; P, Ca and Na were log-transformed while sand and silt content were arcsine-transformed. In the subsoil, pH was normally distributed, Ca, Mg were square root-transformed and K was log-transformed. When comparing different soil depths, data for topsoil and subsoil were combined and also tested for normality. In this case, soil P and percent silt were log-transformed while Mg was square root-transformed. One-way ANOVA was used to determine the effect of slope position and soil type on individual soil properties at 95% level of confidence using GenStat Discovery version 3 (VSN International Ltd., UK). Whereas, Na was the most variable property in the

Table 2: Descriptive statistics of lunnyu soils in the Lake Victoria Basin, Uganda

Statistic	pH	Av. P (ppm)	Ca (ppm)	K (ppm)	Mg (ppm)	Na (ppm)	Sand (%)	Silt (%)	Clay (%)
Topsoil									
Mean	5.52	9.19	4.07	0.49	1.43	0.04	54.44	15.18	30.04
Standard error of mean	0.05	1.55	0.24	0.04	0.08	0.00	1.73	1.12	1.12
Median	5.40	3.71	3.23	0.33	1.10	0.04	58.00	10.00	28.00
Minimum	4.40	1.10	1.05	0.15	0.24	0.02	16.00	4.00	8.00
Maximum	6.90	92.59	12.60	1.56	4.01	0.09	76.00	56.00	52.00
Coefficient of variation	8.35	160.07	56.44	73.54	51.77	34.32	30.19	69.84	35.25
Skewness	0.61	3.12	1.48	1.31	1.43	0.63	-0.87	1.81	0.25
Sub soil									
Mean	5.52	38.76	11.30	11.06	8.58	5.02	33.64	22.56	22.10
Standard error of mean	0.05	23.80	7.69	10.42	7.22	4.88	11.29	10.69	7.37
Median	5.40	3.71	3.23	0.49	1.43	0.04	30.19	10.00	28.00
Minimum	4.40	1.10	0.24	0.04	0.08	0.00	-0.87	1.12	0.25
Maximum	6.90	160.07	56.44	73.54	51.77	34.32	76.00	69.84	52.00
Coefficient of variation	8.35	162.45	179.92	249.17	222.51	257.42	88.78	125.36	88.25

topsoil, P was the most variable in the sub-soil, considering the absolute value of the coefficient of variation (Table 2).

RESULTS AND DISCUSSION

Descriptive statistics: A correlation matrix (Table 3) showed that sand and silt have the highest negative correlation while Ca and Mg have the highest positive correlation. Generally, most of the properties had very low correlation (<±0.3). The highest positive correlation was observed between Ca and Mg both in the topsoil and subsoil. Sand was highly correlated negatively with silt and clay in both the topsoil and subsoil. Sodium, sand and silt in the topsoil did not show any relationship with soil pH but sand showed a relationship in the subsoil. In the topsoil, only Na and silt did not show a significant relationship with soil P but in the subsoil, only clay showed a significant relationship. In both the topsoil and subsoil, Na showed no relationship with any textural property.

Influence of soil type on soil properties: Whereas base cations (Ca, Mg, Na and K) in the topsoil did not vary across soil types, pH, P, sand, clay and silt in topsoil varied among different soil type. Similar, topsoil pH values observed for *Chromic lixisol* (CL) and *Mollic Glaysol* (MG) and were significantly higher than those of the PF and PL (Fig. 3). For soil P, MG had a much higher content than all the other soils types which did not differ significantly from each other. All the exchangeable bases (Ca, Mg, K and Na) were not significantly different among soil types. Calcium had the highest content in the soil, followed by Mg then K and least was Na. The sand content of CL and MG was significantly higher than that of *Plinthic ferralsol* (PF) and *Petrofferic lixisol* (PL). Of the 4 soil types, PF had the highest clay content. Clay content of MG was significantly lower than that CL and PL. MG and PL had similar silt content significantly higher than that of CL and PF which also had similar values. Comparing the textual fractions showed that there was generally higher sand followed by clay and silt was least. In the subsoil, content of Ca, Mg, Na and K did not differ significantly across soil types. However, pH, P, sand, clay and silt in topsoil varied among different soil types. Topsoil pH values observed for *Chromic lixisol* (CL) and *Mollic gleysol* (MG) and were significantly higher than those of the *Plinthic ferralsol* (PF) and *Petrofferic lixisol* (PL) (Fig. 3). For soil P, MG had a much higher content than all the other soils types which did not differ significantly from each other. Percent sand was higher in CL and MG than in PF and PL. MG had the lowest percent clay, followed by CL and PL while PF had the highest content. PL had higher silt content than all the other soil types. No exchangeable bases (Ca, Mg, K and Na) were significantly different among soil types.

Influence of slope position on soil properties: Slope position did not significantly influence all the measured topsoil properties except silt which was significantly lower at the shoulder slope position (Table 4).

The silt content of the mid-slope and foot slope positions were similar but significantly higher than at shoulder position. In the subsoil, a similar trend as in the topsoil was observed (Table 5). No soil properties showed significant variation for all the slope positions. Soil pH, Ca, Mg and K were higher in topsoil compared to subsoil (Table 6). No other properties differed significantly between top and subsoil.

According to the critical levels of P, K, Mg and Ca are 10, 45, 33 and 250 mg kg^{-1}, respectively. By these standards, phosphorus is the most deficient nutrient while Mg and K are about 30% deficient. Calcium is above the critical level and pH is within the optimum range for most crops in the area. In most soils, P tends to move less then Ca and K because of all the different

Table 3: Spearman rank correlation of field-level soil properties of lunnya soils

Propertis	pH	P	Ca	Mg	K	Na	Sand	Silt
Topsoil								
P	0.33**							
Ca	0.34**	0.36**						
Mg	0.32*	0.34**	0.84**					
K	0.33**	0.21*	0.37**	0.28**				
Na	0.02	0.06	0.36**	0.31**	0.06			
Sand	0.14	0.23*	-0.15	-0.20	-0.21*	0.12		
Silt	0.13	0.00	0.30**	0.33**	0.28**	-0.07	-0.72**	
Clay	-0.32**	-0.35**	-0.11	-0.09	0.06	-0.13	-0.76**	0.13
Sub soil								
P	0.39**							
Ca	0.34**	0.11						
Mg	0.26*	0.06	0.62**					
K	0.50**	0.19	0.26*	0.15				
Na	0.11	0.07	0.26*	0.16	0.02			
Sand	0.09**	0.03	-0.26*	-0.11	-0.29**	-0.10		
Silt	0.15	0.23	0.33**	0.18	0.30**	0.05	-0.77**	
Clay	-0.29**	-0.27**	0.08	-0.01	0.16	0.09	-0.79**	0.23*

Values with * and ** were significant correlated at 0.05 and 0.01 alpha level, respectively

Table 4: Soil properties across slope positions in the lake Victoria Basin, Uganda

Slope position	N	pH	Ln P	Ln Ca	Ln Mg	Ln K	Na	Sand	Clay	Ln silt
Shoulder slope	30	5.64	4.69	1.59	3.43	2.69	0.90	52.80	30.07	2.38[a]
		(0.47)	(0.71)	(0.09)	(0.41)	(0.69)	(0.27)	(17.58)	(10.73)	(0.61)
Mid slope	30	5.7	4.83	1.57	3.36	2.87	0.96	54.73	31.07	2.54[b]
		(0.59)	(0.60)	(0.09)	(0.60)	(0.70)	(0.39)	(14.99)	(10.45)	(0.44)
Foot slope	30	5.7	4.81	1.61	3.44	2.59	0.96	55.80	29.00	2.51[b]
		(0.39)	(0.75)	(0.10)	(0.53)	(0.57)	(0.30)	(17.04)	(10.85)	(0.54)
F-value		0.18	0.35	1.00	0.20	1.39	0.30	0.25	0.28	7.52
p-value		0.837	0.706	0.372	0.822	0.254	0.739	0.777	0.756	0.038

Values in parentheses show the standard deviation

Table 5: Subsoil soil properties across slope positions in the lake Victoria Basin, Uganda

Slope position	N	pH	Ln P	√Ca	√Mg	Ln K	Na	Sand	Clay	Silt
Midslope	30	5.5	4.52	11.18	5.03	2.46	0.84	50.27	34.70	14.70
SD		(0.58)	(0.58)	(2.49)	(1.12)	(0.43)	(0.32)	(16.22)	(11.08)	(10.14)
Shoulder	30	5.5	4.50	11.31	5.31	2.28	0.94	53.00	32.03	14.97
SD		(0.41)	(0.66)	(2.39)	(0.76)	(0.53)	(0.24)	(16.64)	(11.03)	(10.96)
Toeslope	30	5.6	4.76	10.93	5.06	2.38	0.89	52.00	32.10	16.23
SD		(0.37)	(0.75)	(2.39)	(1.14)	(0.41)	(0.26)	(19.38)	(12.12)	(11.60)
F		1.2	1.40	0.20	0.66	1.01	1.15	0.19	0.53	0.17
P		0.32	0.25	0.82	0.52	0.37	0.32	0.83	0.59	0.85

Values in parentheses show the standard deviation

Table 6: Soil properties of selected lunnyu soils at two depths

Soil depth	pH	Ln P	Ca	√Mg	K	Na	Sand	Clay	Ln Silt
Topsoil	5.68[a]	4.75[a]	4.96[a]	5.68[a]	2.72[a]	0.94[a]	54.44[a]	30.04[a]	2.54[a]
	(0.49)	(0.65)	(0.51)	(1.42)	(0.66)	(0.15)	(16.43)	(10.59)	(0.56)
Subsoil	5.52[a]	4.64[b]	4.79[a]	5.26[b]	2.45[b]	0.93[b]	51.76[a]	32.94[a]	2.54[a]
	(0.46)	(0.73)	(0.45)	(1.22)	(0.56)	(0.15)	(17.31)	(11.36)	(0.59)
F-value	5.42	0.93	5.61	4.64	8.58	0.17	1.14	3.14	0.01
p-value	0.021	0.335	0.019	0.033	0.004	0.685	0.287	0.078	0.941

Within each column, means with the same superscript do not differ significantly at 5%. Values in parentheses show the SD (Standard Deviation)

types of chemical reactions that may occur, rendering it insoluble. Ironically, the lower level of P compared to other nutrients could be due to the large quantities utilized by plants.

It is also possible that P fixation is high as the soils in the area are highly weathered with potential of high content of aluminum oxides. The observed high and negative correlation between sand and silt is expected because these 2 soil properties are complementary to each other. On the other hand, the high positive correlation between Ca and Mg is explained by the fact that they may have similar parent material mineralogy. For example, mafic mantle-derive rocks typically weather to a smectite and iron oxide-rich colloidal fraction with the simultaneous release of both Ca and Mg.

Influence of soil type on soil properties: According to the WRB (2006) (World Reference Base for soil classification), Ferralsols are either red and/or yellow strongly weathered tropical soils with a high content of sesquioxides;

resulting in a residual concentration of resistant primary minerals (e.g., quartz) alongside sesquioxides and kaolinite. The chemical fertility of Ferralsols is poor; weatherable minerals are scarce or absent and cation retention by the mineral soil fraction is weak. On the other hand, Lixisols have high base status and low-activity clays throughout the argic horizon and a high base saturation at certain depths and without marked leaching of base cations or advanced weathering of high-activity clays.

The fact that there was no difference in content of exchangeable base cations was expected for *Plinthic ferralsol* (PF) and *Petroferic lixisol* (PL) and probably *Chromic lixisol* (CL) because they exhibit almost similar levels of weathering. Additionally, since they occur within the same climatic zone with similar annual precipitation, leaching differences are expected not to differ significantly.

However, the pH did not follow the same trend as for base cations. The significantly higher pH of CL is probably because the site on which the soil occurs is a perennial cropping system (coffee). In perennial systems, there is limited change in vegetation and turning of the soil compared to annual systems. Therefore, the tendency for leaching of base cations may be less likely in annual systems where the soil is turned several times, thereby returning leached ions to near-surface layers.

Thus, the pH is likely to remain unaffected. On the contrary, the frequency of cultivation may result in a more rapid decomposition of organic matter and weakening of soil structure which later results in lowering soil pH. Steenwerth *et al*. (2002) found lower values of soil pH in the grassland than in cultivated soils.

The low pH under grasslands was attributed to leaching. Some cropping systems may also have an acidifying effect on the soil that is related to the amount of materials removed at harvest, amount and type of fertilizers normally used and the amount of leaching that occurs (Mulumba, 2004). The latest classification of soils in this area is based on fairly old and probably outdated soil survey by.

Over time, land use has altered the soil significantly and the taxonomic units are not proficient in precisely explaining variation in soil properties. Noteworthy is the fact that the soil taxonomic units in the memoirs on the basis of which the classification of this study relied were obtained at a very small scale (1:1,500,000) and therefore, the profiles sampled could not have adequately extort lunnyu properties.

Influence of slope position on soil properties: Relocation of topsoil material from upper to lower slopes is attributed mainly to the effects of cultivation, either directly through mechanical movement of soil material during cultivation operations or indirectly through the promotion of soil erosion. These results corroborated strongly with the findings of Brunner *et al*. (2004) and Mulumba (2004) in Uganda where it was observed that soils at the summit position had a thick solum due to the stable soil formation on the flat surface and soils at the shoulder position had shallow A-horizons due to active erosion processes. Mulumba (2004) also observed no significant different in pH at different slope positions in non-lunnyu soils. However, the observed pattern in soil properties is difficult to reconcile within these concepts.

We expect that the soil redistribution and subsequent formation of distinct soil layers along a toposequence should be reflected in differences in other soil properties. Paradoxically did not find indication of the expected catenary relationship involving translocation of exchangeable bases from upper to lower slopes as no differences were observed in these aspects. In the current study, the reason could be that considering the gradient of all the sites that ranges between 3 and 13%, soil redistribution may not be significant to cause distinct patterns in soil properties at different slope position. It is also possible that pedeturbation (*in situ* processes along the vertical soil profiles) mask and overshadow horizontal transport and erosion/deposition processes. This is quite common in African soils.

Influence of soil depth on soil properties: The difference in salt content between top and sub soil is the net balance between leaching and upward flux due to Evapotranspiration (ET). When the downward leaching flux of water exceeds upward flux due to ET, soluble salts are minimal throughout the profile. When leaching is slightly greater than ET, salts are leached from the surface to deeper soil layers. When ET exceeds leaching, salts are carried to the evaporating surface. Differences in vegetation cover can influence the rate of ET and therefore, the rate and direction of movement of ions in the soil. The random changes in the vegetation cover and plant species over the seasons could have introduced the unpredictable variability in soil cations at different depths.

All the soil types in the present study lie in the region with the same rainfall pattern and therefore, rainfall likely did not differentiate leaching at different sampling sites. Soil pH, Ca, Mg and K were higher in topsoil compared to subsoil. The soil depth of 0-20 and 20-40 cm was subjectively selected and may not reflect real top/sub soil profile characteristics. The study area is a generally gently sloping area with gradient of 6-15%. The influence of slope can be thought to be general insufficient to make significant contribution to microclimatic conditions that result in differences in soil depth. In future, it would be better to compare properties of horizons rather that fixed depth as was the case in this study.

CONCLUSION

Lunyu soils on *Chromic lixisol*s and *Mollic gleysols* had higher pH, P, sand, clay and silt compared to those on *Plinthic ferralsols* and *Petrifferic lixisols*. All the soil properties were not influenced by slope position. Soil pH, Ca, Mg and K were higher in topsoil compared to subsoil. Neither slope position nor the type of lunnyu has showed consistent differences in all the soil properties. This means that the lunnyu phenomenon cannot be explained by these 2 factors and other factors such as mineralogy and soil management aspects. There may also be need to redefine the concept of lunnyu to understand the basis for the local definition and further explore its occurrence and description in other parts of the country. Getting a more recent classification and management history of these soils could be useful in further understanding the causes and trends. Factors affecting nutrient utilization efficiency by crops in this area are a critical area worth of exploration. Field experimentation on lunnyu soils with some crops needs to be done to establish the relationship between crop productivity and soil quality, especially to cover long-term trends. There is a strong need for research to address management levels in more detail, encompassing weed cover, mulch cover, ground cover and the crop stand (varieties).

RECOMMENDATION

We recommend further studies of the pedological properties of the soils and other trace elements that this study has not investigated.

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