Linkages between Soil Acidity, Soil Plant Nutrients and Land Use on Ferralsols in Central Uganda

W. S. Kollie [a*], J. Byalebeka [a], T. A. Basamba [b], D. C. Adukpo [a] and J. P. Eneku [c]

[a] *Faculty of Agriculture, African Centre of Excellence in Agroecology and Livelihood Systems, Uganda Martyrs University, Kampala, Uganda.*
[b] *College of Agricultural and Environmental Sciences, Makerere University, Kampala, Uganda.*
[c] *Faculty of Natural Resources and Environmental Sciences, Busitema University, Uganda.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

A study to examine the linkages between soil acidity, soil plant nutrients and land use on Ferralsols was carried out on smallholder farms in Central Uganda. The objective of the study was to assess the effect of soil pH on soil plant nutrient availability under the current land use. The study was carried out in Mpigi, Masaka, Wakiso, Mukono and Mubende districts representing Central Uganda. Soil samples were randomly collected from Coffee, Banana, soybean, common bean, maize and virgin fields in the five districts and the pH and plant nutrient analyzed accordingly. The analysis of variance (ANOVA) showed significant difference ($p<0.01$) on soil nitrogen, Calcium ($p< 0.05$) and Magnesium ($p< 0.05$). When treatment was assessed, the study showed significant difference ($p< 0.01$) on potassium. Besides, the study also showed high concentrations of Manganese (Mn) and Iron (Fe) in addition to very high sand and low silt and clay contents. The current land use for coffee

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Corresponding author: E-mail: kolliewilliam@gmail.com;

production in Masaka district recorded the lowest soil pH (4.4) followed by annual fields (pH 4.60) in Mpigi. The highest soil pH (5.7) was recorded in banana fields in Mubende. The study also recorded very low to low N, P and K. Generally, the study observed rapid soil fertility decline in smallholder farms in the region.

Keywords: Soil pH; soil acidity; ferralsols; nutrient availability and current land use.

1. INTRODUCTION

Ferralsols are the most dominant soils constituting 25% of the soil type in Uganda [1]. The soils are weathered and leached with strong acidity containing toxic levels of Al^{3+}, Fe^{2+}, Mn^{2+}, low available phosphorus and has a pH (5.2) below the critical soil pH of 5.5 [2,3]. In East Africa, research has indicated that N, P, Mg, Ca and soil acidity are the major constraints to crop production [4]. Besides, in Central Uganda, years of continuous cropping, erosion and poor soil management have contributed to soil acidity limiting average farm sizes to about 0.8 to 1.2 hectares per household in many farming communities with subsistence farming being unavoidable (Bulyaba et al., 2020).

Soil pH known as the negative logarithm of the active hydrogen (H+) or hydroxyl ion concentration (OH−) or simply, pH = − log [H+]; pOH = − log [OH−] [5] is scaled from 0 to 14 thus describing its acidity and alkalinity. Hence, pH values less than 7 refer to acidic conditions, while those above 7 indicate an alkaline environment; however, a pH values of 7 is considered neutral [6]. Soils found in tropical regions such as Uganda are commonly acidic due to heavy precipitation and leaching. Moreover, soil acidity can result into sequestration of certain nutrients like phosphorus (P), causing it to be insoluble through binding with cations [7]. The use of compost from organic agricultural wastes has been recognized generally as an effective means for buffering soil pH, improving soil fertility and enhancing the contribution of inorganic fertilizers to soil fertility maintenance [8].

Furthermore, rainfall impacts the leaching or removal of basic cations (Ca^{2+}, K^+ and Mg^{2+}) thus replacing them with acidic cations (H^+ and Al^{3+}) over a long period of time [9]. This in turn exacerbates soil acidity by leaving the toxic and insoluble compounds of Al^{3+} and Fe^{2+} remains in the soils [10]. As the soil gets gradually depleted of its exchangeable bases through constant leaching, it gets de-saturated and becomes increasingly acidic [11]. In productive agricultural systems, the most important source of soil acidity is the application of chemical fertilizer based on ammonium N [10]. Added to soil, N-fertilizer is nitrified [10], and if the resulting NO_3^- isn't taken up by the crops, it gets leached causing acidification [10]. Application of acidifying fertilizer such as diammonium phosphate, which is used to improve the deficiencies of phosphorous has become a noticeable cause to increase soil acidity [12].

Regrettably, agricultural food production is constrained by reduced soil fertility that threatens the livelihoods of most farmers in Uganda [13]. Accelerated soil fertility reduction under the current land use in Uganda contributes to many soil management problems, including soil acidity. Though there are currently a number of soil fertility strategies being promoted in Uganda, soil acidity management has not been given serious attention. Although the extent and distribution of soil acidity are not well documented, it seems to be wide spread in many smallholder farms in the country. Besides, limited or no research emphasis has been placed on the management of acid soils (mainly Acrisols and Ferralsols) to promote sustainable crop production in Uganda. The objective of this study was to assessed the effect of soil pH on plant nutrient availability under the current land use on smallholder farms in Central Uganda. The study hypothesized that addition of different quantities of liming materials i.e., $CaCO_3$ and corncob biochar to Ferralsols will increase soil acidity (soil pH). It is expected that the findings from this study will improve on the knowledge and practices of soil fertility management on farmers' fields in Central Uganda. More to that, the study will provide information that will help the Ugandan policy makers understand the ways to increase agricultural production and productivity in the country. Results from this study will also assist in the integration of soil acidity (soil pH) management science in current soil fertility and productivity assessment for sustainable agricultural land use planning and environmental conservation.

2. MATERIALS AND METHODS

2.1 Study Location

The study was carried out in Central Uganda. Central Uganda has nineteen (19) districts, five (5) of which were randomly selected, namely Mpigi, Mubende, Wakiso, Mukono and Masaka. The Central part of Uganda is a plateau, surrounded by four main mountain ranges: Rwenzori, Elgon, Mufumbira, and Moroto; the tallest point is the peak of Mt. Rwenzori at 5,110 m. According to Drake et al. [3], the soils in these areas are highly weathered, have strong acidity and low level of phosphorus.

2.2 Soil Sampling and Preparation

Soil samples were collected at a depth of 0-20cm with the use of an auger and thoroughly mixed to form composite samples. The samples were put in plastic bags, tagged and transported at Les Rams Consultant, Water Quality, Soil and Plant Analysis Laboratory situated in Kampala, Uganda, Apollo Kaggwa Road, Bwaise. The samples were later air dried and ground to pass through a 2 mm sieve for analysis of selected soil chemical and physical properties.

2.3 Soil Physico-chemical Analyses

Soil particle size distribution was analyzed using the Bouyoucos hydrometer method [14]. Soil pH was determined in 1:2.5 soil water ratio using a glass electrode attached to a digital pH meter as described by Okalebo et al. [15] while soil organic carbon was determined by the dichromate oxidation method as described by Walkley and Black [16]. Total Nitrogen was determined by the micro-Kjedahl digestion method as described by Bremmer and Mulvaney [17]. Soil available phosphorus was determined based on the Mehlich 3 extraction procedure [18]. Exchangeable potassium was determined by use of the ammonium acetate method [19]. Exchangeable calcium was determined by the buffer method as described by Adams and Evans [20]. Copper was determined by the DTPA method as described by Lindsay and Norvell [21]. Zinc was determined by the zincon method as described by Miller [22]. Iron, Magnesium and Manganese were determined by the EDTA method as described by Schnug et al. [23].

2.4 Data Analysis

Soil pH data was analyzed using geostatistical analysis in ArcGIS to develop the study area soils' map while soil chemical data were subjected to analysis of variance (ANOVA) using GenStat 16th edition, and declared significant at p<0.05 using the statistical model as described by Gomez and Gomez [24]. Mean separation was done using the Duncan's Multiple Range Test (DMRT) and conclusions made at p<0.001 and 0.05 levels of significance.

3. RESULTS AND DISCUSSION

3.1 Soil pH Map Indicating the Average soil pH from the Current Land Use on Ferralsol in Central Uganda

According to the rating by Horneck et al, [25], the soil pH point map generated for the study area showed that the pH ranges between 4.7 to 5.0 (Fig. 1) indicating moderately to very strongly acidic soils' condition. Mubende district has an average soil pH of 5.0 of all the land use in the study area followed by Wakiso (pH 5.0), Mpigi (4.7), Masaka (4.8) and Mukono (4.9). The current soil pH in the study area indicates declining soil fertility and negative nutrient balance for agricultural production. The effect of low soil pH on mineral elements such as nitrogen (N), phosphorus (P), potassium (K) etc. is detrimental to crop growth. The findings are in agreement to those of Warner et al. (2023) who reported low soil pH on acidic soils on crop productivities in Egypt. Their findings estimated the effect low soil pH has on cereal production and the impact it would have when it is moved from 5.5 to 6.5. Their findings showed that lime increased soil pH from 5.5 to 6.5, and hence, increased yields by 22% and 19% for wheat and barley, respectively.

One research group suggests that for every 1 kg of urea applied, nearly 1.8 kg of calcium carbonate is required to neutralize the treated soil (Mosaic, 2018). Jones et al. (2013), attributed soil pH to the control of soils' physical, chemical and biological processes. The low soil pH in the study area is a growing concern requiring remediation strategy for pH improvement. Hence, for plant to grow minimum, moving the soil pH from 4.7 in the different land use in Central Uganda to 6.5 is key to improve crop production and productivities.

3.2 Soil acidity in Central Uganda

Coffee fields in Masaka was observed to have shown the lowest soil pH (4.4) under the different

land use followed by annual fields (soybean, common bean and maize) in Mpigi (pH 4.6) and virgin fields in Wakiso District (pH 4.8). In addition to the lowest soil pH observed under the current land use in Masaka, Mpigi and Wakiso districts, the study recorded deteriorating soil pH in all the districts cultivating banana, coffee and annual crops (soybean, common bean and maize) (Table 1b). According to the rating by Horneck et al. [26], the deteriorating soil pH showed strongly to very strongly acidic soils while a few soils are moderately acidic. In these acidic soil conditions, there is also a complex interaction of growth-limiting factors among which is declining plant nutrients availability. Plant growth may be restricted by one or more of the following: Al or Mn toxicity; Ca, Mg, P or Mo deficiency and reduced mineralization and nitrification [27].

3.3 Effect of Soil pH on Plant Nutrients Availability on Ferralsols in Central Uganda

Location showed significant difference on Nitrogen ($p<0.01$) content in the study. According to Karltun et al. [28], nitrogen is rated as very low ($< 0.10\%$), low ($0.1-0.15\%$) and optimum ($0.15-0.30\%$). The study however recorded low nitrogen content as shown in Table 1c. However, when %N content was assessed in the different land use, it was observed that virgin fields located in Mubende recorded optimum N (0.18%) content, followed by field cultivated with maize and soybean (0.15 %N) and banana (0.15 %N). Coffee fields located in Masaka showed low N (0.14%) level, followed by Mubende (0.14% N). Low N levels were also recorded in Wakiso District (0.05%) (Table 1c). The low soil N observed in the study area may probably be attributed to the low soil pH. Wairegi et al. (2014) reported that coffee grows well in moderate acid soils (pH>5) and banana performs better at high pH (pH above 5.5); both crops grow best in soils with total N level above 0.15%.

There were significant differences on Calcium ($p<0.05$) and Magnesium ($p<0.05$) availability in the study area. According to the rating by Dan et al. [25], Calcium and Magnesium are all low as observed in the different study locations (Table 1c). The low levels of calcium and magnesium could be attributed to the leaching of these basic cations i.e., Ca^{2+} and Mg^{2+} thus resulting to an increase in H^+ that aggravates soil acidity. Takala et al. [29], observed highest growth performance on coffee seedling as well as plant height, stem girth, leaf number and area,

tap and lateral root length, lateral root number, root volume, stem, leaf and root dry matter when 4 tons of $CaCO_3$ and 12.5 tons of coffee husk biochar were applied. Low soil pH affects the availability of plant nutrients, and particularly that of phosphorus and other macronutrients; therefore, correction of the low pH through liming is critical for sustainable management of acid soils for increased crop production [30]. Bossolani et al. [31] observed that liming lowers the soil pH by neutralizing the acidic cations (H^+ and Al^{3+}) and increases basic cations (Ca^{2+} and Mg^{2+}). Ameliorating low pH soils with liming materials such as calcium, magnesium and/or biochar reduces the toxicity effects of Al^{3+} and Mn^{2+} associated with low pH and at the same time helps create an enabling soil environment for sustainable crop production.

Potassium showed significant difference ($p<0.01$) when treatment was assessed. According to the rating by Horneck et al. [26], K^+ in the study areas is low to high across farmers' fields, with banana fields located in Masaka having the highest K^+ concentration (1.69 meq/100 g soil), followed by Coffee fields in Mubende (1.69 meq/100 g soil) (Table 1b). The lowest K^+ concentration was recorded in virgin fields located in Mpigi District (0.12 meq/100 g soil). The low to high K^+ concentration recorded in the study could be attributed to the decomposition and addition of plant litters to the soils. Similarly, Li et al. [32] reported large amounts of K^+ concentration in cereal crops such as maize and wheat. It has been well documented that both crop yield and soil K^+ availability can be improved by long-term straw return [33]. In China, crop straw return is widely practiced in agricultural production [34,35]. Relying only on the internal circulation of the soil-plant system is not sufficient to relieve the soil K^+ deficiency [32]. Plant biomass should be combined with other soil amendments such as limestone to improve K^+ cycling.

According to Dan et al. [25], organic matter is optimum, ranging from 1-4% (Table 1b). The changing soil pH in the current land use suggests an influence on soil organic matter. Besides, the optimum range (1-4%) could be attributed to the recycling of crop residues, addition of cow manure, short fallow and biomass transfer in the different land uses in the study area. Farmers in the study area carry out these practices with the hope of replacing lost nutrients and reversing soil acidity. However, the observed soil pH in the study suggests the introduction and adoption of
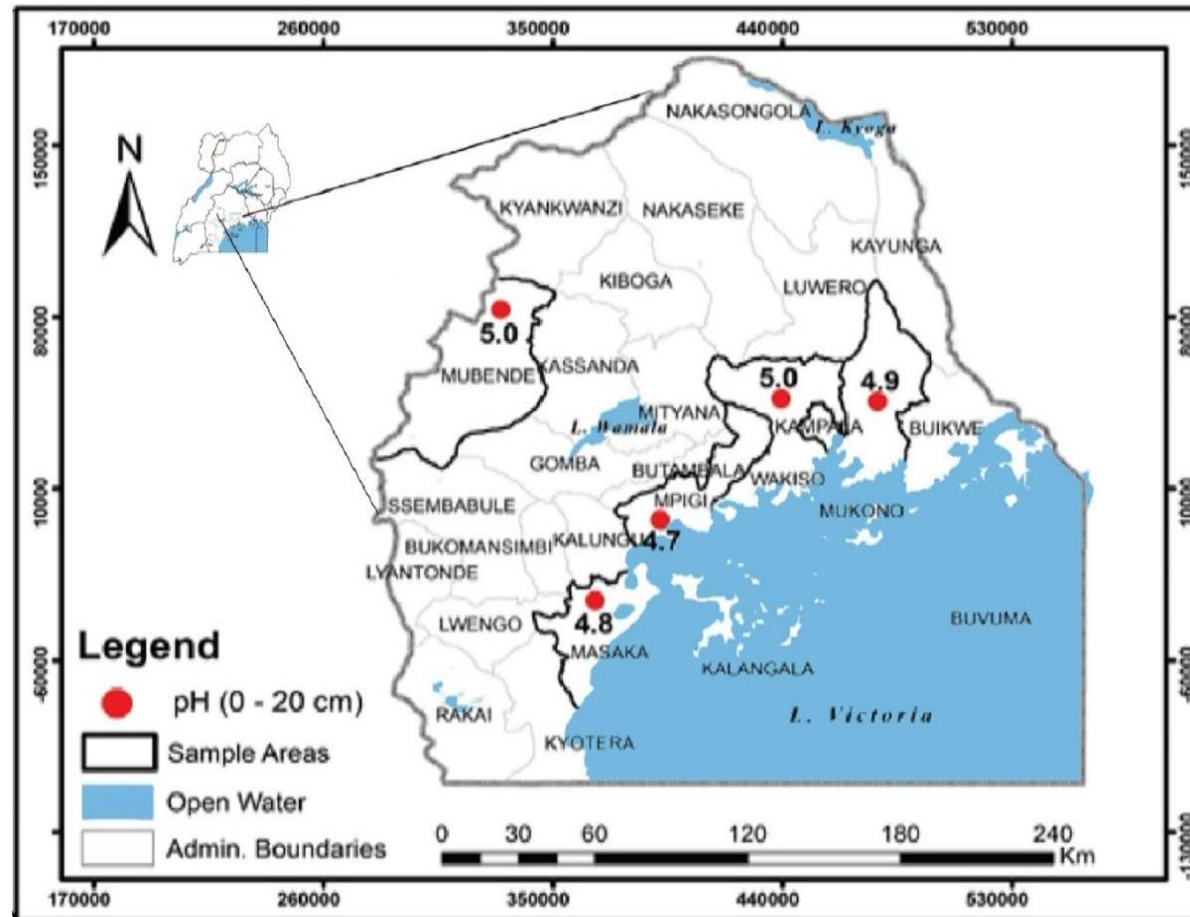
Fig. 1. Soil pH map indicating the sampling areas in Central Uganda

Table 1a. Source of variation for soil plant nutrients by location and treatment

Source of Variation	P.H	N	P	K	Ca	Mg	OM	Sand	Clay	Silt
Location	0.5325ns	0.012***	4367ns	0.9924ns	10.133**	2.8762**	4.562***	404.11***	250.76**	19.25ns
Treatment	0.8715ns	0.003ns	5828ns	1.2402*	3.555ns	0.6303ns	0.2312ns	103.5ns	112.19ns	0.71ns
Location x Treatment	0.1908ns	0.001ns	1268ns	0.2461ns	1.935ns	0.4941ns	0.2587ns	115.03ns	109.8ns	32.23ns
Residual	0.440	0.002	3020	0.5284	3.023	0.772	0.4965	69.86	72.41	30.14
LSD	1.225	0.0912	101.47	1.342	3.210	1.622	1.301	15.43	15.71	10.136
CV (%)	12.95	45.18	182.05	112.03	47.58	47.09	23.07	17.41	23.42	35.05
SE	0.663	0.049	54.95	0.727	1.739	0.8785	0.7046	8.358	8.509	5.490

**Significant at 5%, *Significant at 10%, ***Significant at 1%, ns=non-significant

Table 1b. Soil pH analysis results for the different land use on Ferralsols in Central Uganda

	Districts					
Land use	**Masaka**	**Mpigi**	**Mubende**	**Mukono**	**Wakiso**	**Grand mean**
Annual	5.27a	4.60a	5.31a	4.84b	5.07a	5.01a
Banana	5.56a	4.85b	5.70a	5.60a	5.56a	5.45a
Coffee	4.42b	4.70b	4.94b	5.16a	5.22a	4.88b
Virgin	5.16a	4.81b	5.27a	5.38a	4.80b	5.08a
Grand mean	5.01a	4.74b	5.30a	5.24a	5.16a	5.10a

*a, b and c mean sharing a letter in their superscript are not significantly different at 0.05 level. However, a and b, b and c and c and a are significantly different using Duncan Multiple Range Test (DMRT) at P≤ 0.05

Table 1c. Soil analysis results for the different land use on Ferralsols in Central Uganda

Soil properties	Farming System	Districts				
		Masaka	**Mpigi**	**Mubende**	**Mukono**	**Wakiso**
Nitrogen (%N)	Annual	0.10[a]	0.09[a]	0.15[a]	0.11[a]	0.08[a]
	Banana	0.11[a]	0.09[a]	0.15[a]	0.08[a]	0.05[b]
	Coffee	0.14[a]	0.10[a]	0.14[a]	0.06[b]	0.09[a]
	Virgin	0.13[a]	0.09[a]	0.18[a]	0.13[a]	0.11[a]
Phosphorous (ppm)	Annual	24.53	2.08[d]	39.55[bc]	68.07[b]	1.30[d]
	Banana	89.35[a]	15.00[c]	33.47[bc]	105.93[a]	45.39[ac]
	Coffee	6.29[d]	4.83[d]	18.28[c]	50.06[ac]	28.90[bc]
	Virgin	4.90[d]	2.37[d]	3.54[d]	15.91[c]	34.57[bc]
K (cmol (+)/kg soil)	Annual	0.30[b]	0.25[b]	0.72[b]	0.41[b]	0.30[b]
	Banana	1.46[a]	0.40[b]	1.69[a]	0.75[b]	0.98[a]
	Coffee	0.41[b]	0.34[b]	0.54[b]	0.86[b]	0.57[b]
	Virgin	0.53[b]	0.12[b]	1.39[a]	0.57[b]	0.26[b]
Ca (cmol (+)/kg soil)	Annual	4.89[a]	1.47[c]	5.60[a]	3.39[b]	3.59[b]
	Banana	5.04[a]	2.35[c]	4.42[b]	4.77[a]	4.45[a]
	Coffee	2.00[c]	2.31[c]	4.17[b]	3.64[b]	3.41[b]
	Virgin	3.99[b]	1.81[c]	3.62[b]	4.66[a]	2.79[c]
Mg (cmol (+)/kg soil)	Annual	2.58[a]	0.81[c]	2.43[a]	1.69[b]	1.69[b]
	Banana	2.54[a]	1.27[b]	2.27[a]	2.16[a]	2.31[a]
	Coffee	1.08[b]	1.15[b]	2.08[a]	1.89[b]	1.85[b]
	Virgin	2.39[a]	0.69[c]	2.23[a]	2.47[a]	1.39[b]

Note: a,b and c means sharing a letter in their superscript are not significantly different at the .05 level. However, a and b, b and c and c and a are significantly different at 0.05 level

Table 1d. Physical characteristics for the different land use on Ferralsols in Central Uganda

Soil properties	Land uses	Masaka	Mpigi	Mubende	Mukono	Wakiso
OM (%)	Annual	3.32[b]	2.03[b]	4.07[a]	3.55[b]	2.80[b]
	Banana	3.18[b]	2.28[b]	3.72[b]	2.89[b]	3.00[b]
	Coffee	2.80[b]	2.23[b]	3.72[b]	2.97[b]	2.66[b]
	Virgin	3.92[a]	1.77[c]	3.64[b]	3.26[b]	2.95[b]
% Sand	Annual	38.67[c]	63.00[a]	44.67[b]	40.67[c]	46.67[b]
	Banana	43.33[c]	48.00[c]	56.67[b]	52.67[b]	37.33[c]
	Coffee	38.00[c]	58.00[b]	42.00[c]	44.00[c]	51.33[b]
	Virgin	46.67[c]	63.33[a]	53.33[b]	44.00[c]	52.67[b]
% Clay	Annual	43.33[b]	26.00[c]	36.67[b]	45.33[a]	39.33[b]
	Banana	40.00[b]	33.33[c]	30.67[c]	31.33[c]	48.00[a]
	Coffee	48.00[a]	32.00[c]	39.33[b]	39.33[b]	29.33[c]
	Virgin	33.33[c]	32.67[c]	35.33[b]	39.33[b]	30.67[c]
% Silt	Annual	18.00[a]	11.00[c]	18.67[a]	14.00[b]	14.00[b]
	Banana	16.67[b]	18.67[a]	12.67[c]	16.00[b]	14.67[b]
	Coffee	14.00[b]	10.00[c]	18.67[a]	16.67[b]	19.33[a]
	Virgin	20.00[a]	14.00[b]	11.33[c]	16.67[b]	16.67[b]

Note: a,b and c means sharing a letter in their superscript are not significantly different at the .05 level. However, a and b, b and c and c and a are significantly different at 0.05 level

Table 2a. Source of Variation for selected trace elements by Location and Treatment

Source	dfs	Mn	Fe	Cu	Zn
Location	4	8.36ns	428421**	270.2ns	1055***
Treatment	3	55.26*	75985ns	137.8ns	409.3ns
Location x Treatment	12	24.2	79729ns	93.6ns	191.2ns
Residual	17	20.49	93957	124.9	227.7
LSD		13.5	914.6	33.34	45.03
CV (%)		3.37	40.3	76.99	84.15
SE		4.526	306.5	11.17	15.09

**Significant at 5%, *Significant at 10%, ns=non-significant, df=degrees of freedom

Table 2b. Soil analysis results for the different land use on Ferralsols in Central Uganda

Trace elements	Farming System	Districts				
		Masaka	Mpigi	Mubende	Mukono	Wakiso
Mn (ppm)	Annual	136.1[a]	132.4[b]	133.5[b]	132.8[b]	135.7[a]
	Banana	134.3[b]	138[a]	135.7[a]	136.8[a]	134.6[b]
	Coffee	137.1[a]	138.5[a]	132.1[b]	139.3[a]	134.2[a]
	Virgin	121.1[b]	126.7[b]	134.7[a]	135.1[a]	135.3[a]
Fe (ppm)	Annual	744.7[b]	355.8[c]	337.2[c]	742.5[b]	1084.4[a]
	Banana	947.4[b]	639.1[d]	724.4[c]	1163.8[a]	799.1[c]
	Coffee	467[c]	684.4[b]	606.7[b]	1035.8[a]	1006.9[a]
	Virgin	1271.4[a]	294.3[d]	674.7[c]	886.6[b]	1194[a]
Cu (mg kg^{-1})	Annual	14.49[b]	7.34[d]	0.8	10.56[c]	20.43[a]
	Banana	40.28[a]	12.13[c]	10.1[c]	16.43[b]	16.3[b]
	Coffee	10.47[b]	10.25[b]	7.63[c]	17.71[a]	17.01[a]
	Virgin	9.77[c]	8.31[c]	9.64[c]	20.92[b]	27.41[a]
Zn (ppm)	Annual	14.58[b]	5.47[c]	0	5.43[c]	29.38[a]
	Banana	29.6[b]	17.86[c]	14.78[c]	44.68[a]	24.35[b]
	Coffee	9.03[c]	8.24[c]	2.1[d]	35.05[a]	28.97[b]
	Virgin	0	2.5[c]	0	36.91[b]	44.17[a]

Note: a, b and c means sharing a letter in their superscript are not significantly different at the .05 level. However, a and b, b and c and c and a are significantly different at 0.05 level

Integrated Soil Fertility Management (ISFM) approaches, with the use of liming materials that could aid in alleviating the problem of soil degradation due to increasing soil acidity. Soil organic matter in particular is very important because of its influence on a number of soil chemical, physical and biological properties [25]. Several authors [36,37,38] have reported the negative impacts of low pH on Soil Organic Matter (SOM). Solly et al. [39] found that SOM content was lower in soils with pH < 5.5. However, Aye et al. [40] found higher organic carbon of an experimental soil after application of lime integrated with N and P fertilizers at Haryana Agricultural University in India.

The study locations showed significant differences on % sand ($p<0.01$) and % Clay ($p<0.05$) and not on % silt (Table 1d). Besides, % clay and sand were optimum, though high in some areas and low in others. The highest sand content (63%) was observed in annual fields in Mpigi, followed by banana fields (56.67%) in Mubende and Coffee fields (56%) in Masaka. Percentage clay (48%) was observed to be equally distributed in Coffee and banana farming systems in Masaka and Mubende, followed by annual fields in Mukono (45.33%) and annual fields in Masaka (43%). Percent silt was observed to range from 10% in Coffee fields in Mpigi to 20% in virgin fields in Masaka (Table 1b). Zhang et al. [41] also attributed macropores reduction and increase in water retention times and nitrogen supply for plant growth to the optimality of silt and clay particles. Furthermore, Chen et al. [42] reported significant effect soil texture has on soil aeration, water-holding capacity, soil fertility, crop yield and the important role it plays in regulating the leaching of soil nitrogen.

3.4 Effect of Soil pH on Selected Trace Elements in Smallholder Farms in Central Uganda

Location showed significant effects on iron ($p<0.05$) and zinc ($p<0.001$) as observed in the study (Table 2b). For treatment application, different soil parameters showed no significant effect, with the exception of manganese ($p<0.1$). The rating by Landon [43], and Lindsay and Norvell [21] showed very high iron and manganese concentration in the current land use. Manganese concentration in the study ranges from 121.1 ppm in the virgin fields in Masaka to 139.3 ppm in Coffee fields in Masaka District (Table 2b). Iron was also highest (1271.4 ppm) in the virgin fields in Mpigi. The high Fe^{2+} and Mn^{2+} concentrations indicate soil acidity problem in the area. These findings are in agreement with those of Zama et al. [44] who reported an increase in soil acidity due to the toxicity effects of Al^{3+}, Mn^{2+} and Fe^{2+}. They concluded that soil pH has a significant effect on plant growth and agricultural productivity. Similarly, Tigist et al. [30] attributed low soil pH effect to low plant nutrients availability, especially phosphorus. However, correcting the soil pH through liming or the application of organic materials is critical for sustainable soil management [45,46].

4. CONCLUSION

Soil fertility is fast declining in banana, coffee, and annual (soybean, common bean and maize) fields in Central Uganda due to soil acidity (soil pH). The low soil pH (4.4) recorded in the different banana fields situated in Masaka, followed by pH 4.7 recorded in coffee fields in Mpigi, and pH 4.6 recorded in annual fields in Mpigi, coupled with the high Manganese (Mn^{2+}) and Iron (Fe^{2+}) contents are meaningfully contributing to the low availability of plant nutrients as observed in the study. Soil acidity due to low soil pH is fast spreading across the current land use in Central Uganda. The extent of declination tends to affect soil fertility, and hence, crop production and productivities.

5. RECOMMENDATIONS

Stakeholders, policy makers, researchers and academics are required to do more to address the problem of soil acidity in the study area. Liming practices should be adopted in the current land use of Central Uganda as a means of addressing the problem of soil degradation due to soil acidity.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/99999