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Evaluation of soil fertility status in the Kyoga Basin of Uganda: A physio-chemical study in Buyende and Serere districts

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Nutrients present in the soil are important elements required for the healthy growth of plants. This study, therefore, sought to examine the physio-chemical properties of soils in Buyende and Serere districts, in the Kyoga basin, Uganda. Using soil auger, soil samples were purposively picked from Serere (23) and Buyende (17) districts at depth of (0-25 cm). Routine soil analysis was done for the macro soil nutrients of pH, nitrogen, phosphorus, organic matter, potassium, and soil texture. The physio-chemical properties were then subjected to statistical analyses to assess the soil properties variability using the coefficient of variation. The study also examined Soil Structural Stability Index and mapped the spatial distribution of soil physio-chemical properties using ArcMap10.2.2. Results indicated that the soil physio-chemical properties varied spatially and sandy clay loam was identified as the major textural class (Serere (52.2%) and Buyende (47.2%)). Additionally, Soil structural stability index results showed that the soils were structurally degraded across the two districts. The study recommends that the government and NGOs intervene by revising policies and providing subsidies that support farmers to test their soils as well as other farm inputs that improve soil fertility.

Key words: Soil fertility status, physio-chemical, soil structural stability index, Kyoga Basin, Uganda.

INTRODUCTION

Soil is the “soul” of infinite life and biodiversity and its quality affects nutrient cycling and human well-being (Kekane et al., 2015; Bogunovic et al., 2017). As a terrestrial ecosystem component, soil performs various functions, including storage of plant-available water, supply of adequate oxygen to roots, provision of favorable seedling establishment conditions, storage of nutrients, suppression of plant pathogens, and immobilization of contaminants, all of which are essential to plant growth (Khatoon, 2020). Previous studies have revealed that agricultural production was negatively impacted by soil degradation and poor soil nutrients (NPK), mainly where the agricultural intensification has been observed (Ebanyat et al., 2010; Giller et al., 2011; Mubiru et al., 2017). In addition, there are strong indications that nutrient balances and soil fertility status differ widely between farms in different wealth categories and between plots at different distances from homesteads (Zingore et al., 2007; Tittonell et al., 2010).

In Sub-Saharan Africa, most of the arable land is estimated to have low soil fertility, a situation which has been exacerbated by the ongoing decline in soil physio-chemical properties and loss of nutrient stock (Hengl et al., 2015; Bamutaze et al., 2021). For example, a magnitude of studies has highlighted similar soil fertility status trends generally in Central and Eastern Uganda (Mubiru et al., 2017; Nimusiima et al., 2018; Bamutaze et al., 2021). This does not exclude Buyende and Serere districts from this scenario. Soil physio-chemical properties are key components of soil fertility and ecosystem functioning since they govern the efficacy of vertical and horizontal terrestrial processes, influence cumulative feedbacks, geochemical cycles, and overall stability of the earth system (Bamutaze et al., 2021). A plethora of studies e.g. (Moody and Phan, 2008; De Laurentiis et al., 2019) portrayed how different soil physio-chemical properties such as texture, pH, organic matter, total Nitrogen, extractable phosphorus, potassium, soil depth among others can be used to assess soil fertility status.

Soil fertility assessment is fundamental to suggest optimum conditions for plant growth (Yerima and Van Ranst, 2005). According to Khan et al. (2018), deficiency in soil nutrient parameters such as; nitrogen (N), phosphorus (P), and potassium (K), remains one of the major yields limiting factors for crops. Other vital nutrient parameters like soil organic matter (OM) and soil pH, provide macronutrient blocks for protein building in plants and also responsible for the absorption capabilities other nutrients (Minasny et al., 2016; Wood et al., 2018). The differences in fertilization, cropping systems and farming practices are the main factors influencing soil fertility at the field scale and therefore, the ability to produce sufficient crops for food security and income (Woniala and Nyomb, 2014). Understanding the variability of soil fertility status, its distribution, and the causes of the observed variability are important in improving sustainable crop production for districts. smallholder farmers in areas like Buyende and Serere

Since soil is fundamental for sustainable agriculture production with prominent outcomes on food security due to increasing population and living standard (Mulumba and Lal, 2008), thorough knowledge of soils quality, and fertility status is required. Given the magnitude of key roles played by soil in many sub-Saharan African regions, such as in East Africa (Uganda), rapid population growth, poor farming methods, and an unfavorable developmental project have exerted great pressures on soil resources, interfering with its fertility status making farmers who cultivate on fragile environments to experience tremendous soil degradation and severe crop yield decline on their lands. Therefore, it is from this background that the present study attempts to assess the soil fertility status using physio-chemical soil properties for the suitability of different rain-fed crop cultivations in the districts of Buyende and Serere given their importance at the local and national scale.

Thus, the study intended to map spatial distribution of the physiochemical soil properties of the respective study districts.

MATERIALS AND METHODS

Study area

This study was conducted in the districts of Buyende and Serere which are within the Lake Kyoga basin (Kyoga Plains Agro-Ecological Zone) of Uganda (Figure 1). The study area has mean annual rainfall that ranges from 800-1500mm/year with a mean elevation of about 1214 m.a.s.l (Lugoi et al., 2019). The two districts are associated with various agroecological characteristics including moist thicket supporting combretum in the South Eastern and Eastern part of Buyende district while terminalia woodland features are found in Serere district (Mubiru et al., 2017).

Soil sampling

Relevant information related to the registration, referencing and identification of the soil to be described was noted before the actual soil sampling such as the general site information including; location (district/sub-county and GPS coordinates), auger/sample number, farm owner, authors, and date. Two farms from each sub-county of Serere and Buyende districts (Figure 2) were purposely selected using a judgmental sampling technique (Weber et al., 2021).

This technique involves selecting sample points based on the knowledge held by the researcher and the field attendant, however, for this study, the farm owner guided in the selection of the sampling points on his/her farm and marked using a GPS. At each of the identified locations (Figure 2), soil samples were obtained

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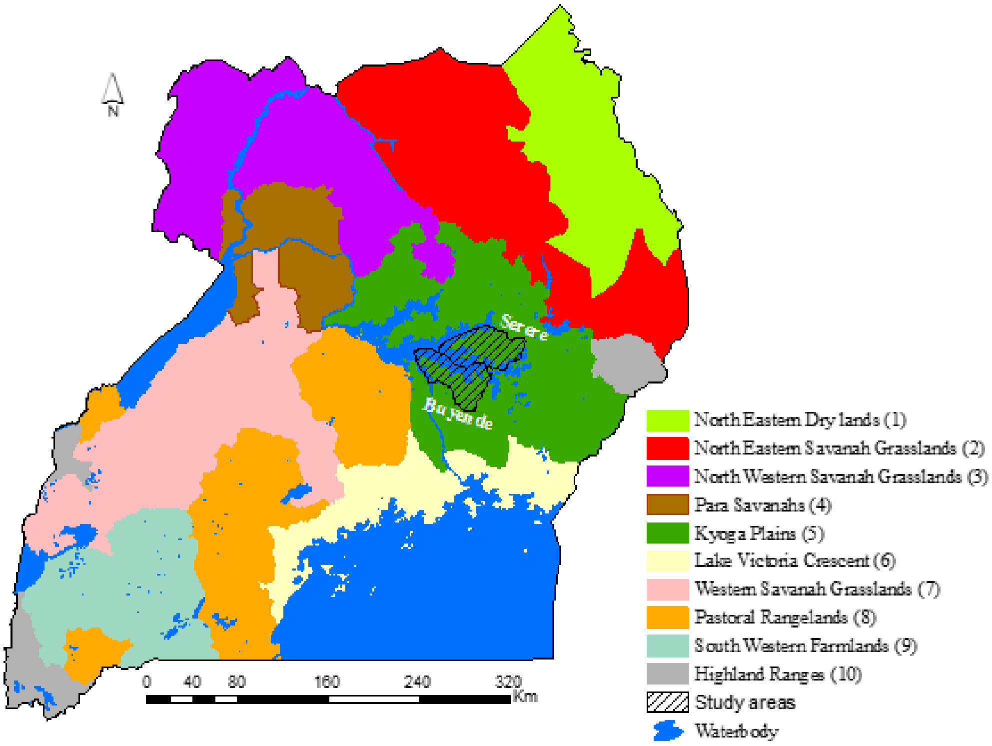

Figure 1. Shows the location of the two study districts in accordance with the agro-ecological zones. Source: Adopted from National Adaptation Plan for the Agricultural Sector, MAAIF, November 2018.

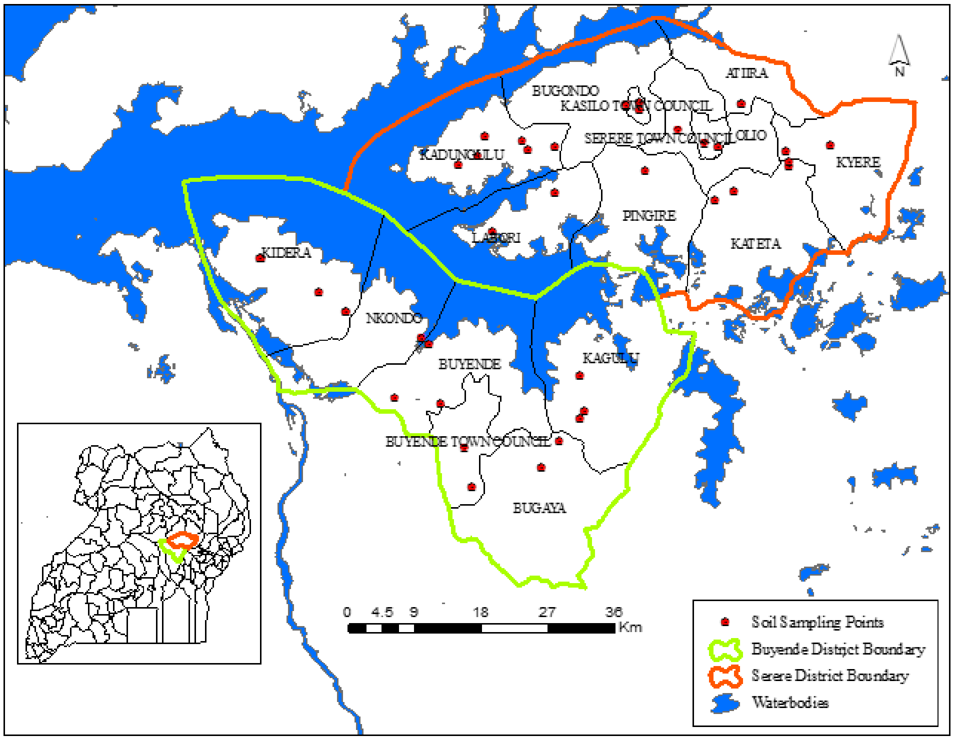

Figure 2. Map drawn in ArcGIS 10.2 showing soil sampled points in the sub-counties of Buyende and Serere districts.

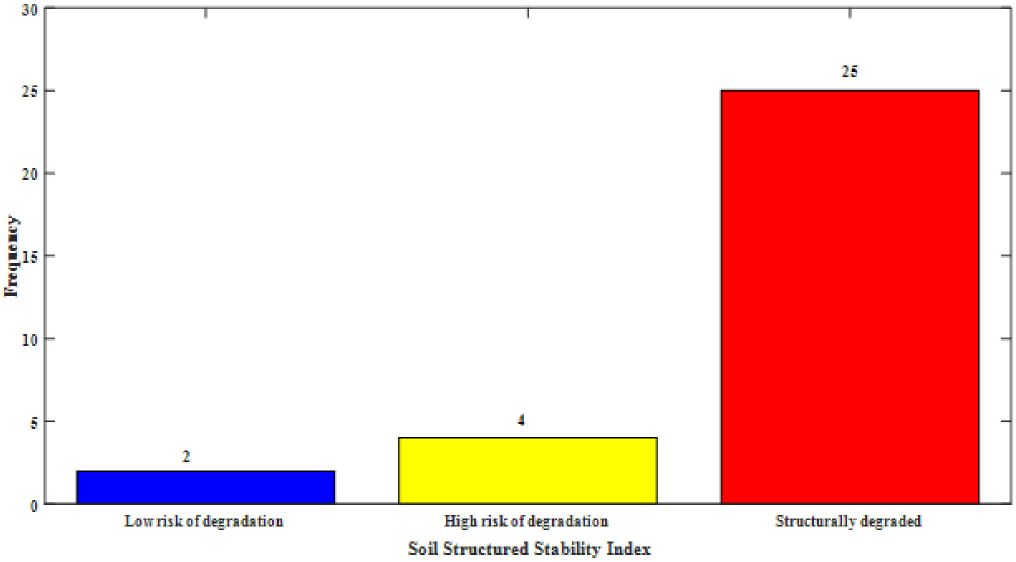

Figure 3. Frequencies of soil structured stability index for Buyende and Serere.

using a soil auger at a depth of (0-25 cm) to allow sufficient examination and description of the different soil properties (Nimusiima et al., 2018). This soil depth level was chosen because it has very little or no laterite (Kitutu et al., 2009), and soil at this depth show very little horizon differentiation apart from slight changes in firmness that fall within the agricultural layer (Majaliwa et al., 2010)..Soil sampling was done based on the guidelines for soil sampling (De Crop et al., 2017). Following the soil sampling protocols, 23 and 17 soil samples were collected from Serere and Buyende respectively. Soil sample information and data were recorded on a field data collection form for each site and sample (approximately (0.5-1 Kg). At each of these sites, the samples were securely packed in plastic bags and labeled appropriately with the date, time, and sample number. The samples were sent to the soil, plant, and water analytical laboratory at the College of Agricultural and Environmental Science, Makerere University for scientific analysis.

Laboratory soil sample preparations

The samples collected (Figure 3) were prepared for laboratory analysis. The samples were air-dried for 3 days to eliminate moisture (Mubiru et al., 2017). Thereafter, they were grounded using a porcelain pestle and mortar, and sieved through a 2-millimeter sieve to remove debris and other non-soil materials including stones and roots. The sieved soil particles were repackaged, relabeled, and analyzed (Ladwani et al., 2012). Several agronomical soil properties (soil pH, nitrogen (N), phosphorus (Av.P), organic matter (OM), exchangeable cations Potassium (K+) and soil texture (Proportions of Sand, Cay and Silt), were prepared for analysis.

Each of the above soil properties was specifically analyzed by a particular analytical method and procedure as described here; pH was measured using a pH meter with a soil/water solution at a ratio of 1:2.5 (Mahajan et al., 2022); N was determined calorimetrically by digestion using concentrated sulphuric acid and Selenium powder with Salicylic acid (Huang et al., 2022). P was determined spectrophotometrically at 882 nm wavelength using ammonium molybdate in the presence of ascorbic acid on Mehlich-l extract (Murphy and Riley, 1962). K+ was read on Mehlich-1 extract using a flame photometer; Texture analysis was performed using the hydrometer method (Mubiru et al., 2017) and organic matter was analyzed using the Walkley-Black method. All analysis procedures were performed using routine analytical procedures as outlined by Perkins et al. (2021) and other standard operating procedures that are internationally recommended. For each analysis, a reference sample and blanks were repeatedly included for quality control and assurance purposes.

Soil structural stability index

Structural Stability Index (SSI) is a physical parameter that determines the degree of degradability and erodibility of soil (Peng et al., 2023). According to Shen et al. (2022), SSI values provide a useful guide on the relative stability of the soil to externally imposed destructive forces and, hence, appropriate indicators of the relative susceptibility of the soils to detachment, runoff, and erosion. Therefore, in this study, equation (1) was adopted to compute SSI in R software for Buyende and Serere districts into the following categorical Indices; (that is [< 5%;5-7%;7-9%;>9%]) for structurally degraded soil, high risk of degradation, low risk of degradation and stable structure respectively.

$$SSI = [Msom/(Msilt + Mclay)] * 100\% \quad (1)$$

Where is soil structural stability index,$Msom$,$Msilt$ and $Mclay$ are mean values of soil organic matter, silt, and clay content respectively.

Statistical analysis

Field soil datasets were subjected to statistical analysis using R software. The descriptive statistics of minimum, maximum, range,

Table 1. Observed soil physiochemical properties from Serere district.

Lab No.	Serere district									
	Particulars	**N (%)**	**P(mg/kg)**	**K(cmol/kg)**	**OM (%)**	**pH**	**Textural (%)**			**Textual class**
	Recommended ranges	**0.15-0.5**	**26-250**	**0.26-0.78**	**>3**	**5.5-6.5**	**Sand**	**Clay**	**Silt**	
1	Bugondo	0.124	196.612	0.658	3.19	6.25	70	10	20	Sandy loam
2	Olio	0.123	1.832	0.284	1.983	5.20	46	22	32	Loam
3	Kyere	0.058	2.473	0.076	0.259	5.02	86	10	4	Loamy sand
4	Kyere	0.031	0.916	0.076	1.121	5.15	74	14	12	Sandy loam
5	Atiira	0.085	132.326	0.320	0.776	6.98	70	20	10	Sandy loam
6	Buyende T/C	0.076	1.557	0.117	1.121	4.99	70	20	10	Sandy loam
7	Buyende T/C	0.041	2.106	0.272	1.638	4.21	60	34	6	Sandy clay loam
8	Nkondo	0.052	144.597	0.455	1.466	6.42	64	24	12	Sandy clay loam
9	Buyende T/C	0.106	2.564	0.295	2.155	4.41	56	34	10	Sandy clay loam
10	Kagulu Bugaga s/c	0.086	2.747	0.441	1.446	4.88	60	30	10	Sandy clay loam
11	Nkondo	0.061	23.443	0.252	1.121	5.55	74	12	14	Sandy loam
12	Nkondo s/c	0.050	11.270	0.126	0.490	6.17	70	24	6	Sandy clay loam
13	Buyende T/C	0.080	38.220	1.134	1.220	6.5	52	34	14	Sandy loam
14	Kagulu s/c	0.040	2.535	0.196	0.490	5.51	72	22	7	Sandy clay loam
15	Kidera s/c	0.342	2.747	0.076	0.604	5.04	80	12	8	Loamy sand
16	Kidera s/c	0.087	4.945	0.117	1.121	5.52	76	16	8	Sandy loam
17	Kidera s/c	0.038	3.114	0.360	2.328	4.37	56	36	8	Sandy clay

Table 2. Descriptive statistics of the physio-chemical properties of soils in Serere district.

Variable	N (%)	P(mg/kg)	K(cmol/kg)	OM (%)	pH	Sand textural (%)	Clay textural (%)	Silt textural (%)
Min	0.031	0.733	0.076	0.259	4.29	40.000	10.000	4.000
Max	0.170	196.612	0.658	3.19	6.25	86.000	36.000	44.000
Range	0.139	195.879	0.582	2.931	1.96	46.000	26.000	40.000
Sum	2.286	376.492	5.030	39.873	12.0	12.720	50.000	51.800
Median	0.100	2.379	0.179	1.638	5.20	54.000	20.000	24.000
Mean	0.099	16.369	0.219	1.734	5.21	55.304	21.739	22.522
SE.mean	0.007	9.010	0.031	0.146	0.107	2.551	1.735	2.142
Var	0.001	1866.953	0.022	0.489	0.265	14.9	69.202	10.534
Std.Dev	0.034	43.208	0.149	0.699	0.515	12.234	8.319	10.273
Coef.var	0.347	2.640	0.681	0.403	0.099	0.221	0.383	0.456

Var-Variance; Coef.var-Coefficient of variation.

mean, standard deviation (SD), and coefficient of variation (CV%) were computed for the selected physio-chemical properties. From this analysis, three variability classes as adopted from Asongwe et al. (2016)'s study were created (that is [< 15%; 15-35%; >35%]) for slightly variable, moderately variable, and highly variable respectively.

Spatial distribution of physio-chemical soil properties

Spatial Maps of Buyende and Serere for N, P, K, OM, Sand, Clay, and Silt were prepared in ArcGIS 10.2.2 by interpolating the measurements at the soil sampling sites using inverse distance weighting (IDW) (Tunçay et al., 2016; Mugume et al., 2018). IDW was selected because of its accurate consistency in interpolating point data using the mean squared error as the main criterion (Ganawa et al., 2011).

RESULTS AND DISCUSSION

Physio-chemical soil properties

Results of physio-chemical soil properties of both Serere and Buyende varied considerably (Tables 1 to 4).

Table 3. Observed soil physiochemical properties from Buyende district.

Lab No.	Buyende district									
	Particulars	**N (%)**	**P(mg/kg)**	**K(cmol/kg)**	**OM (%)**	**pH**	**Textural (%)**			
	Recommended ranges	**0.15-0.5**	**26-250**	**0.26-0.78**	**>3**	**5.5-6.5**	**sand**	**Clay**	**Silt**	**Textual class**
1	Buyende s/c	0.077	33.608	0.185	0.776	4.94	80	10	10	Sandy loam
2	Buyaya s/c	0.144	28.205	0.590	3.190	5.52	50	36	14	Sandy clay loam
3	Yikanda village	0.063	9.890	0.103	0.776	5.57	80	10	10	Sandy loam
4	Kakungulu s/c	0.007	11.355	0.252	0.431	4.21	70	18	12	Sandy loam
5	Buyende T/C	0.104	132.326	0.320	0.776	6.98	70	20	10	Sandy loam
6	Buyende T/C	0.076	1.557	0.117	1.121	4.99	70	20	10	Sandy loam
7	Buyende T/C	0.041	2.106	0.272	1.638	4.21	60	34	6	Sandy clay loam
8	Nkondo	0.052	144.597	0.455	1.466	6.42	64	24	12	Sandy clay loam
9	Buyende T/C	0.106	2.564	0.295	2.155	4.41	56	34	10	Sandy clay loam
10	Kagulu Bugaga s/c	0.086	2.747	0.441	1.446	4.88	60	30	10	Sandy clay loam
11	Nkondo	0.061	23.443	0.252	1.121	5.55	74	12	14	Sandy loam
12	Nkondo s/c	0.050	11.270	0.126	0.490	6.17	70	24	6	Sandy clay loam
13	Buyende T/C	0.080	38.220	1.134	1.220	6.5	52	34	14	Sandy loam
14	Kagulu s/c	0.040	2.535	0.196	0.490	5.51	72	22	7	Sandy clay loam
15	Kidera s/c	0.342	2.747	0.076	0.604	5.04	80	12	8	Loamy sand
16	Kidera s/c	0.087	4.945	0.117	1.121	5.52	76	16	8	Sandy loam
17	Kidera s/c	0.038	3.114	0.360	2.328	4.37	56	36	8	Sandy clay

Table 4. Descriptive statistics of the physio-chemical properties of soils in Buyende district.

Variable	N (%)	P(mg/kg)	K(cmol/kg)	OM (%)	pH	Sand Textural (%)	Clay Textural (%)	Silt Textural (%)
Min	0.007	1.557	0.076	0.431	4.21	50.000	10.000	6.000
Max	0.342	144.597	1.134	3.19	6.98	80.000	36.000	14.000
Range	0.335	143.04	1.058	2.759	2.77	30.000	26.000	8.000
Sum	1.454	455.229	5.291	21.169	90.79	11.400	39.200	16.900
Median	0.076	9.89	0.252	1.121	5.51	70.000	22.000	10.00
Mean	0.086	26.778	0.311	1.245	5.34	67.059	23.059	9.941
SE.mean	0.018	10.604	0.062	0.181	0.20	2.396	2.289	0.633
Var	0.005	1911.655	0.065	0.560	0.69	97.559	89.059	6.809
Coef.var	0.858	1.633	0.820	0.601	0.16	0.147	0.409	0.262

Var-Variance; Coef.var-Coefficient of Variation.

According to soil textural class, Serere soils were generally sandy-clay-loam (52.2%), sandy-loam (21.7%), loam (17.4%) and only 8.6% for both clay-loam and loamy-sand (Table 1). Additionally, the textural content was more of sandy (55.3%) compared to clay (21.7%) and silt (23%), although high variations were observed in the silt content (CV>35%) (Table 1). In Table 2 for example, one site possessed recommended ranges of total nitrogen which are moderately variable (CV=34.7%). While three sites registered recommended ranges of Phosphorous though this component exhibited higher levels of variations across the study sites with CV=264% much greater 35%. For Potassium, six sites had recommended value ranges though with high variations across other sites (CV=68.1%), only two sites have values that suited recommended ranges of soil organic matter, though this parameter was too highly variable across all the sites. Six sites, possessed recommended ranges of pH, however, across the all sampling sites, this parameter registered very low levels of variability (CV=9.9%).

For Buyende district, the soil textural class were generally sandy-clay-loam (47.2%), sandy-loam (41.2%) and only 11.6% for both sandy clay and loamy-sand (Table 3). For textural content, Buyende soils contain more sand (67.1%) compared to clay (23%) and silt

Table 5. Soil structural stability index for Serere and Buyende.

Serere			Buyende		
Sampling sites	**SSI (%)**	**Interpretation**	**Sampling sites**	**SSI (%)**	**Interpretation**
Bugondo SC	8.7	Low risk of degradation	Buyaya SC	6.4	High risk of degradation
Bugundo SC	6.8	High risk of degradation	Yikanda village	3.9	Structurally degraded soil
Kasiro SC	3	Structurally degraded soil	Kasozi village	1.4	Structurally degraded soil
Olio SC	3.7	Structurally degraded soil	Bukokoba	2.6	Structurally degraded soil
Kyere SC	3.6	Structurally degraded soil	Buwoira village	4.1	Structurally degraded soil
Atiira SC	7.4	Low risk of degradation	Bugende- Nkondo	4.1	Structurally degraded soil
Kandugulu SC	2.5	Structurally degraded soil	Buyende SC	3.9	Structurally degraded soil
Serere TC	2.6	Structurally degraded soil	Buyende TC	3.7	Structurally degraded soil
Kandugulu SC	3	Structurally degraded soil	Bugaga SC	3.7	Structurally degraded soil
Labori SC	5	High risk of degradation	Nkondo SC	1.6	Structurally degraded soil
Katete SC	3.1	Structurally degraded soil	Kagulu SC	1.7	Structurally degraded soil
Kandugulu TC	2.7	Structurally degraded soil	Kidera SC	5.3	High risk of degradation
Bugonda SC	4.3	Structurally degraded soil			
Kadungulu SC	3.7	Structurally degraded soil			
Labori	3.3	Structurally degraded soil			
Kitete village	4.7	Structurally degraded soil			
Olio SC	4.1	Structurally degraded soil			
Pingire SC	2.1	Structurally degraded soil			
Masembe village	3	Structurally degraded soil			

(9.9%), although high variations were observed in the clay content (CV>35%) (Table 4). One site possessed recommended ranges of total nitrogen which are highly variable (CV=85.8%). Five sites registered recommended ranges of Phosphorous that exhibited higher levels of variations across the study sites with CV=163.3% much greater 35%. For Potassium, seven sites had recommended value ranges though with high variations across other sites (CV=82%), only one sites have values that suited recommended ranges of soil organic matter, though this parameter was too highly variable across all the sites. Nine sites, possessed recommended ranges of pH, however, across the all sampling sites, this parameter registered very low levels of variability (CV=15.5%). Mengel et al. (1987) revealed that, areas with a high percentage of clay and silt, are recommended for agricultural practices because they provide good aeration and retention, and thus supply nutrients and water, with the above results, one can conclude that the soils of Buyende are not good enough as compared to their counterpart (Serere district) to support agricultural practices if practices like conservation agriculture among others are not implemented to improve on the levels of the required soil nutrients. This argument is supported by earlier studies (Mubiru et al., 2017; Nimusiima et al., 2018; Bamutaze et al., 2021) whose findings indicate that various land use system affects variations in surface soil physio-chemical properties and if done in a sustainable way, they can significantly improve soil fertility status.

Soil structural stability index

Table 5 and Figure 3 depict a greater percentage of the soils of both districts being structurally degraded across the sampling sites, Moreso in Buyende district compared to Serere district which showed some few spots of low risk to soil degradation. It should be noted that these scenarios are as a result of the deficiency in soil organic matter, with more spots of silt and clay content particularly in Buyende district.

Spatial distribution of physio-chemical soil parameters

Results from spatial analyses (Figures 4 and 5) indicate great variations in the different soil physio-chemical properties. It can be observed that much of total nitrogen content is found in the sub-counties of Kidera, Kasilo, Serere TC, Bugondo, Kyere and Bugaya, while Buyende TC and Kagulu have relative low values of total nitrogen content. For available Phosphorus, more was observed in the sub-counties of Bugaya, Labori and Kasiro TC and low values of available Phosphorus was found in Kidera, Kyerere and Kateta. Higher values of Potassium were found in Labori, Bugaya, Kagulu,Kasilo TC and Buyende TC; Kidera,Nkodo,Kateta and Atiira generally had lower values of Potassium content. Labori, Bugondo and Bugaya registered higher values of soil organic matter as

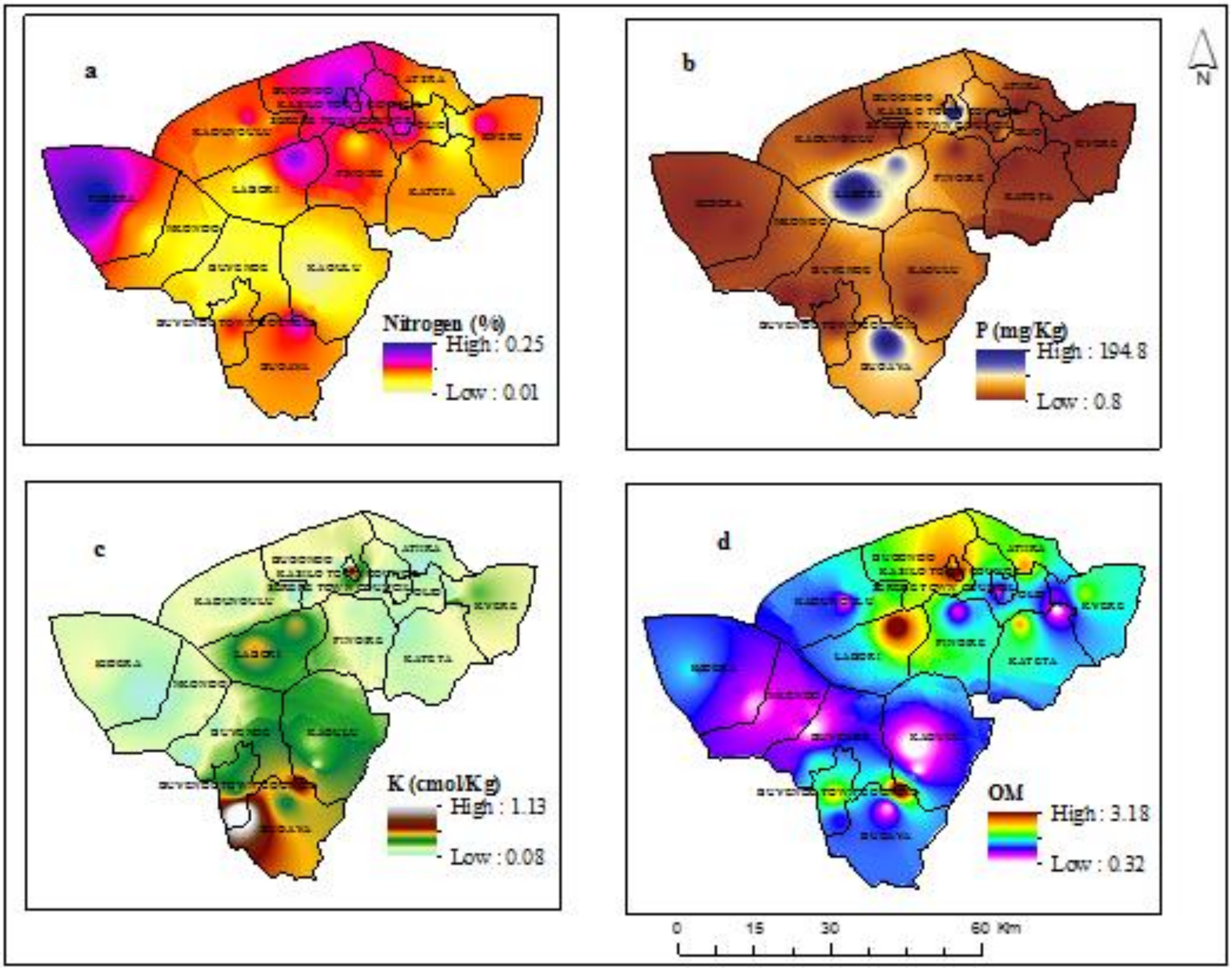

Figure 4. Maps drawn in ArcGIS 10.2 showing spatial distribution of observed soil properties (Nitrogen [a], Phosphorus [b], Potassium [c] and Organic matter [d]).

compared to Kagulu, Nkondo and Buyende TC. High pH values were observed in Bugaya,Labori and Buyende TC. For clay content, more was found in Labori, Buyende TC, Bugaya, Kateta and Pingire. However, the analysis further indicated that Buyende district was sandier while Serere district was siltier. Generally, these results depict a mixed conclusion about the presence and absence of the different physio-chemical properties in the two districts (Wang et al., 2021), with high and low parameter values not dictated by one sub-county.

Conclusions

Soil physio-chemical results from the two districts (Buyende and Serere) varied, though the two districts are within the same major agro-ecological zone (Kyoga Plains). Sandy-clay-loam was identified as the major textural class across the two districts, followed by sandy-loam. Variations of soil physiochemical property were more pronounced in Buyende district compared to Serere district. SSI results showed that soils across the two districts were structurally degraded though this scenario was more emphasized in Buyende district compared to Serere district which showed some few spots of low risk to soil degradation. Additionally, great variations in physio-chemical properties were spatially observed across the two study districts thus portraying a mixed conclusion about the presence and absence of the different physio-chemical parameters in the two districts

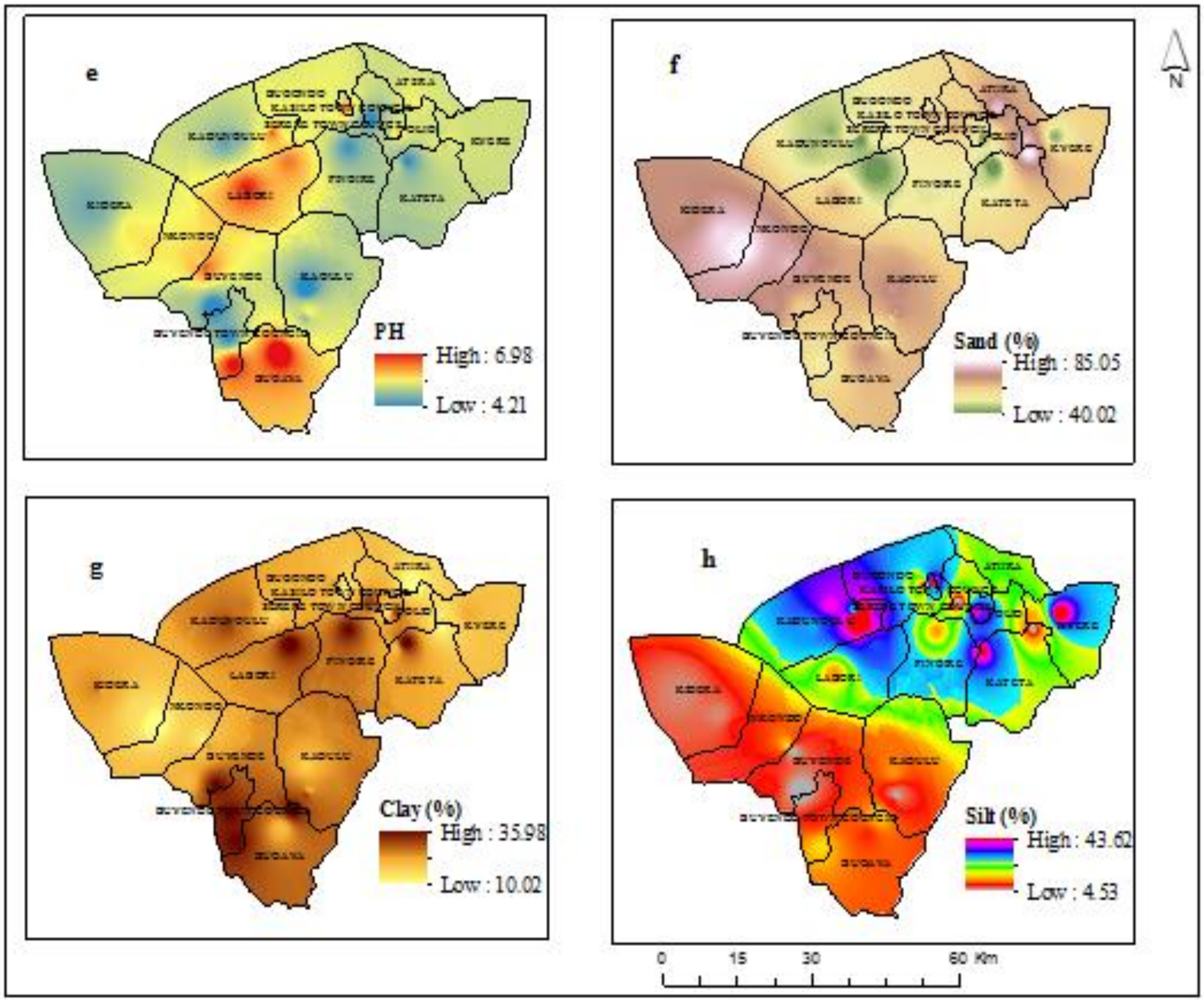

Figure 5. Maps drawn in ArcGIS 10.2 showing spatial distribution of observed soil properties (Potential of Hydrogen [e], Sand [f], Clay [g] and Silt [h]).

with high and low parameter values not dictated by one sub-county. This means agricultural practices such as conservation agriculture among others must be implemented to improve on the levels of the required soil nutrients.

The recommendations are based on the status of the soils in both study districts. The study recommends the adoption of climate-smart agricultural practices including application of fertilizers like green composite and farm yard manure which are proven to be cheap and environmentally friendly; avoiding burning or removing crop residues from the fields after harvesting; burning of destructive weeds and testing the soil fertility status. In addition, the government should support farmers to growing crops that perform well such as sorghum and cassava in Serere and maize, beans, and cassava in Buyende districts respectively in terms of subsidized farm inputs. Lastly, long-term studies are needed to establish the effects of land use systems on levels of physio-chemical soil parameters.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Asongwe GA, Yerima BP, Tening AS (2016). Spatial variability of selected physico-chemical properties of soils under vegetable cultivation in urban and peri-urban wetland gardens of Bamenda municipality, Cameroon. African Journal of Agricultural Research 11(2):74-86.

Bamutaze Y, Meadows ME, Mwanjalolo M, Musinguzi P (2021). Effect of land use systems and topographical attributes on the condition of surface soil physicochemical properties in a highland catchment of the Lake Victoria Basin, Uganda. Catena 203:105343.

Bogunovic I, Pereira P, Brevik EC (2017). Spatial distribution of soil chemical properties in an organic farm in Croatia. Science of the total environment 584:535-545.

De Crop W, Ryken N, Tomma Okuonzia J, Van Ranst E, Baert G, Boeckx P, Verdoodt A (2017). Soil erosion risk assessment using interviews, empirical soil erosion modeling (RUSLE) and fallout radionuclides in a volcanic crater lake watershed subjected to land use change, western Uganda. In EGU General Assembly Conference Abstracts pp. 18313.

De Laurentiis V, Secchi M, Bos U, Horn R, Laurent A, Sala S (2019). Soil quality index: Exploring options for a comprehensive assessment of land use impacts in LCA. Journal of Cleaner Production 21563-74.

Ebanyat P, Tukamuhabwa P, Elepu G (2010). Adapting soybean varieties to soil fertility variability for increased productivity in smallholder systems of Uganda. In Second RUFORUM Biennial Regional Conference on" Building capacity for food security in Africa", Entebbe, Uganda, pp. 935-942..

Ganawa E, Kheiralla AF, Hussan H (2011). Spatial Variability of Soil Physio-chemical Properties Related to Sugarcane Yield for Gunied Scheme (Sudan).

Giller KE, Tittonell P, Rufino MC, Van Wijk MT, Zingore S, Mapfumo P, Vanlauwe B (2011). Communicating complexity: integrated assessment of trade-offs concerning soil fertility management within African farming systems to support innovation and development. Agricultural systems 104(2):191-203.

Hengl T, Heuvelink, GB, Kempen B, Leenaars JG, Walsh MG, Shepherd KD, Tondoh JE (2015). Mapping soil properties of Africa at 250 m resolution: Random forests significantly improve current predictions. PloS one 10(6):e0125814.

Huang, Xue-Jing, Shao-Fen Jian, Dong-Liang Chen, Chu Zhong, Jian-Hua M (2022) "Concentration-dependent dual effects of exogenous sucrose on nitrogen metabolism in Andrographis paniculata." Scientific Reports 12(1):4906.

Kekane SS, Chavan RP, Shinde DN, Patil CL, Sagar SS (2015). A review on physico-chemical properties of soil. International Journal of Chemical Studies 3(4):29-32.

Khan A, Lu G, Ayaz M, Zhang H, Wang R, Lv F, Zhang S (2018). Phosphorus efficiency, soil phosphorus dynamics and critical phosphorus level under long-term fertilization for single and double cropping systems. Agriculture, Ecosystems and Environment 256:1-11.

Khatoon A (2020). A blockchain-based smart contract system for healthcare management. Electronics 9(1):94.

Kitutu MG, Muwanga A, Poesen J, Deckers JA (2009). Influence of soil properties on landslide occurrences in Bududa district, Eastern Uganda. African journal of agricultural research 4(7):611-620.

Lugoi LP, Bamutaze Y, Martinsen V, Dick ØB, Almås ÅR (2019). Ecosystem productivity response to environmental forcing, prospect for improved rain-fed cropping productivity in lake Kyoga Basin. Applied Geography 102:1-11.

Mahajan GR, Das B, Gaikwad B, Murgaokar D, Patel KP, Kulkarni RM (2022). Hyperspectral remote sensing-based prediction of the soil pH and salinity in the soil to water suspension and saturation paste extract of salt-affected soils of the west coast region. Journal of the Indian Society of Soil Science 70(2):182-190.

Majaliwa JGM, Twongyirwe R, Nyenje R, Oluka M, Ongom B, Sirike J, Barasa B (2010). The effect of land cover change on soil properties around Kibale National Park in South Western Uganda. Applied and Environmental Soil Science 2010.

Minasny B, Hong SY, Hartemink AE, Kim YH, Kang SS (2016). Soil pH increase under paddy in South Korea. Agriculture, Ecosystems & Environment 221:205-213.

Moody PW, Phan TC (2008). Soil Constraints and Management Package (SCAMP): guidelines for sustainable management of tropical upland soils. Australian Centre for International Agricultural Research (ACIAR).

Mubiru DN, Namakula J, Lwasa J, Otim GA, Kashagama J, Nakafeero M, Coyne MS (2017). Conservation farming and changing climate: More beneficial than conventional methods for degraded Ugandan soils. Sustainability 9(7):1084.

Mugume I, Mesquita MDS, Bamutaze Y, Ntwali D, Basalirwa C, Waiswa D, Ogwang BA (2018). Improving quantitative rainfall prediction using ensemble analogues in the tropics: case study of Uganda. Atmosphere 9(9):328.

Mulumba LN, Lal R (2008). Mulching effects on selected soil physical properties. Soil and Tillage Research 98(1):106-111.

Murphy J, Riley JP (1962). A modified single solution method for the determination of phosphate in natural waters. Analytica chimica acta 27:31-36.

Nimusiima A, Basalirwa CP, Majaliwa JG, Kirya D, Twinomuhangi R (2018). Predicting the impacts of climate change scenarios on maize yield in the cattle corridor of Central Uganda. Journal of Environmental and Agricultural Sciences 14:63-78.

Peng J, Yang Q, Zhang C, Ni S, Wang J, Cai C (2023). Aggregate pore structure, stability characteristics, and biochemical properties induced by different cultivation durations in the Mollisol region of Northeast China. Soil and Tillage Research 233:105797.

Perkins MJ, Langford VS, McEwan MJ (2021). Application of routine analysis procedures to a direct mass spectrometry technique: Selected ion flow tube mass spectrometry (SIFT-MS). Reviews in Separation Sciences 3(1):e21003-e21003.

Shen Q, Wu M, Zhang M (2022). Accumulation and relationship of metals in different soil aggregate fractions along soil profiles. Journal of Environmental Sciences 115:47-54.

Tittonell P, Muriuki A, Shepherd KD, Mugendi D, Kaizzi KC, Okeyo J, Vanlauwe B (2010). The diversity of rural livelihoods and their influence on soil fertility in agricultural systems of East Africa–A typology of smallholder farms. Agricultural systems 103(2):83-97.

Tunçay T, Bayramin I, AtALAY F, Ünver İ (2016). Assessment of Inverse Distance Weighting IDW Interpolation on Spatial Variability of Selected Soil Properties in the Cukurova Plain. Journal of Agricultural Sciences 22(3):377-384.

Wang J, Wang W, Hu Y, Tian S, Liu D (2021). Soil moisture and salinity inversion based on new remote sensing index and neural network at a salina-alkaline wetland. Water 13(19):2762.

Weber CJ, Weihrauch C, Opp C, Chifflard P (2021). Investigating microplastic dynamics in soils: Orientation for sampling strategies and sample pre-procession. Land degradation and development 32(1):270-284.

Woniala J, Nyombi K (2014). Soil fertility management by smallholder farmers and the impact on soil chemical properties in Sironko district, Uganda. Agricultural Science Research Journals pp. 232-6063.

Wood SA, Tirfessa D, Baudron F (2018). Soil organic matter underlies crop nutritional quality and productivity in smallholder agriculture. Agriculture, Ecosystems and Environment 266:100-108.

Yerima BP, Van Ranst E (2005). Introduction to soil science: Soils of the tropics. Trafford publishing.

Zingore S, Murwira HK, Delve RJ, Giller KE (2007). Influence of nutrient management strategies on variability of soil fertility, crop yields and nutrient balances on smallholder farms in Zimbabwe. Agriculture, ecosystems and environment 119(1-2):112-126.