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Physical, Chemical and Pedological Characterization of the Soils of Solomon Mahlangu Campus Farm, Sokoine University of Agriculture Morogoro, Tanzania

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Authors' contributions

This work was carried out in collaboration between all authors. Author UKA designed the study, wrote the protocol, and wrote the first draft of the manuscript. Author JPM managed the literature searches, analyses of the study performed the spectroscopy analysis and author JJM managed the experimental process and identified the species of plant. All authors read and approved the final manuscript.

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ABSTRACT

A study was undertaken with a view to examine the morphological and physical properties and classifying the soils of part of the Solomon Mahlangu Campus farm, Sokoine University of Agriculture Tanzania, for improved agricultural productivity of the farm. Four soil profiles were excavated to represent the mapping units of the study area, examined and described. Samples were collected from the four pedons according to the pedogenic horizons identified, analyzed for both physical and chemical properties and characterized. The study reveals that, all the soils belong to two soil orders (Oxisols and Alfisols) in United State Development Agency (USDA) Soil Taxonomy or Acrisols in Food and Agricultural Organization FAO) / United nations educational Scientific and Cultural Organization (UNESCO) system of classification. At the suborder, the soils

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belong to Ustox and Ustalfs (Soil Taxonomy), while Ferric and Haplic in the level 2 category of FAO/UNESCO Classification [1]. Based on findings it was observed that, continual cropping without concurrent use of manure / inorganic fertilizer, over grazing and burning have contributed to low soils deficiencies and reduced soil fertility, leading to low crop yields in the farm. To increase the productive capacity of this farm, an integrated nutrient management system should be adopted which embraces a holistic approach of integrated use and management of organic and inorganic nutrient sources in a sustainable way.

Keywords: Soil characterization; soil classification; profile; horizon; solomon mahlangu.

1. INTRODUCTION

Most of the soils in Tanzania are characterized by inherent or induced deficiencies of the major plant nutrient elements, namely N and P and in some cases, low or excess K and micronutrients. Other constraints include low nutrient retention capacities, high acidity and alkalinity and low organic matter contents [2]. Some of the aforementioned constraints lead to land degradation which has been caused by ill-suited land use and in appropriate management practices, notably poor crop rotation, shortening or elimination of the fallow, insufficient use of manure/fertilizer, and removal of crop residues for fodder, just to mention but a few. The low agricultural productivity in Tanzania, hence the very high rate and risks of food insecurity is related to the low quality of the soil resources base.

[3] Performed a land evaluation project for Shonyang country in Shanxi province, China, in which maize, soybean, potato, sunflower, wheat as well as tree crops were studied. [4] investigated the land suitability for agricultural crops in Danling country-Sichuan province, China-using the Sys's parametric evaluation system. Several crops were analyzed; in particular the suitability for rice was compared to the one for other summer crops like sweet potato and maize.

In Morogoro, there have been a substantial number of studies on the basic information on soils in the form of soil surveys and soil fertility studies for sound land use planning [5-7]. These studies have centered on a few selected areas and have not been specific to Solomon Mahlangu Campus (SMC) and some adjacent lands hence inadequate information on these soils inherent nutrients content. The parent materials of the studied soils are different from soils of SMC farm, which are derived from pyroxene granulites' containing plagioclase and quartz-rich veins [8].

The objective of this study entails a classification and detailed characterization of the soils. This study will provide information that will enable the land users of the farm to make proper use of the farm and the appropriate alternative management practices to be adopted. For appropriate and profitable use of the SMC, calls for study of the classification and characterization of the soils.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The study was based at Solomon Mahlangu Campus (SMC) farm of Sokoine University of Agriculture (SUA) in Mazimbu, Morogoro Municipality, Tanzania. The farm is located at 6°47'S and 37°37'E at an elevation of 500 m above sea level in agro ecological zone 2 (AEZ 2) with a total area of 1 030 ha. The mean annual rainfall varies from about 750 mm to about 1050 mm (Fig. 1). The area has a sub – humid tropical type of climate with a bi-modal rainfall distribution. The short rains (Vuli) lasts from October to January and the long rains (Masika) from February to May.

2.2 Site survey

A reconnaissance survey of the study area was conducted to identify the external features (local indicators of soil fertility), followed by transect walks; auguring and selection of representative transect sampling points. Soil from the auger points were grouped into mapping units' based on similarities of the morphological properties. Four mapping units were thus delineated and identified from the selected area. The coordinates and elevation of the study area were taken with the aid of a portable global positioning system (GPS) receiver (MODEL GARMIN 12 x L).

2.3 Field Work

Representative profiles (one for each identified mapping unit) as presented in Fig. 2 were dug and comprehensively described for the classification of the soil based on the soil profile description by [10]. A total of four profiles (1.5 m x 1.5 m long x 2 m deep) were excavated in the four mapping units that made up the study area. The profiles were identified as profile I to IV (Fig. 2). All Profiles were sampled according to pedogenic horizons from bottom to the top. Soil colour was determined by Munsell soil colour charts [9]. A total of 21 soil samples were collected from genetic horizons of the four profiles representing four mapping units. The horizons were sampled using a hand trowel and put directly into well labeled polythene bags.

Samples collected were bagged and labeled to reveal profile horizon number, depth and horizon designation. The soils samples collected from the horizons were air-dried, grounded and passed through a 2 mm sieve. The soil samples were taken to the laboratory for analyses.

2.4 Soil Analysis

Particle size distribution was determined by the hydrometer method as modified by [10]. Bulk and particle densities were determined by the methods of Black as described by [11]. Soil pH was determined in 1:1 soil: water and 1:2 soils: 0.01M KCl_2 suspensions respectively, using a glass electrode pH meter (Longanathan, 1984). Organic carbon was determined by the [12] wet oxidation method as modified by [29]. Exchangeable basic cations (Mg, Ca, K and Na) were extracted by IM NH_4AC buffered at pH 7. Total nitrogen was determined by Kjedahl digestion distillation method of [13] while extractable phosphorus was determined by the Bray and Kurtz No. 1 for acid soils and Olsen method for alkaline soils [10]. Available micronutrients (Cu, Zn, Fe and Mn) were extracted by NH_4F and HCL (0.03M NH_4F+0.025 M HCL) and determined quantitatively by Atomic Absorption spectrophotometer (AAS) [14]. Soil moisture was determined by the gravimetric method [15].

2.5 Data Description and Analysis

The data of physical and chemical characteristics of soils were summarized using descriptive statistics such as minimum, maximum, mean and standard deviation. All data collected were subjected to analysis of variance (ANOVA) using the [16].

2.6 Classification of the Studied Soils

Using field and laboratory data, the soils were classified to suborder group level of the USDA Soil Taxonomy [17] and to level-2 of the [18] Soil Classification system.

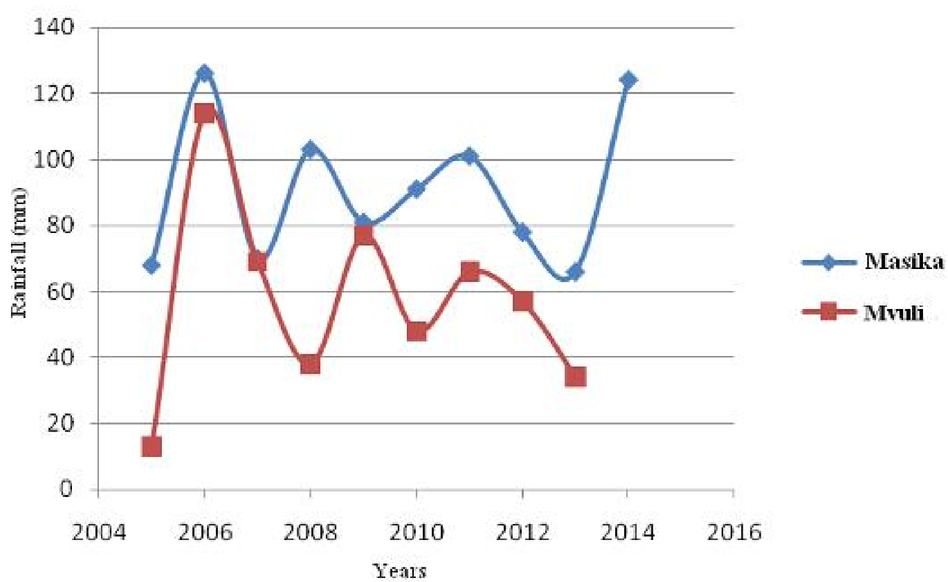

Fig. 1. Mean annual rainfall (Masika and Vuli) of SMC for the past 10 years

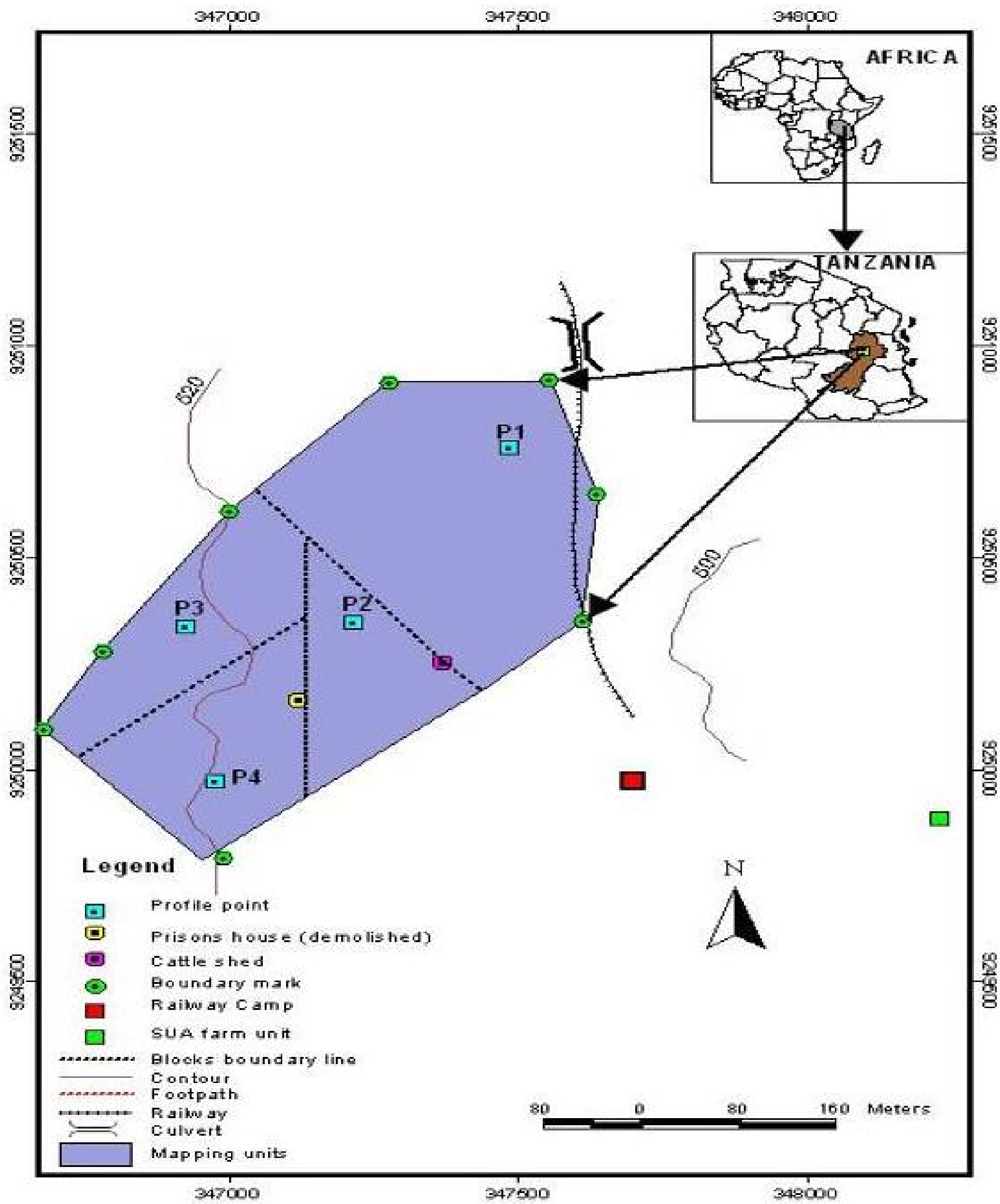

Fig. 2. Map of the study area showing pedons location

3. RESULTS AND DISCUSSION

3.1 Morphology and Genesis of the Soils

Table 1 gives the distinctive characteristic features of the study site soils (Profiles I to IV), while Table 2 revealed the morphological properties of all the four pedons studied at Mazimbu Farm Soils. The results indicated that the soil pedons have structures that varied from weak-sub-angular-blocky peds (W-sbk) in the surface of horizons to crumby-sub-angular blocky peds (cr-sbk) in the subsurface soil with abrupt, clear and smooth to diffuse and smooth horizon boundaries from surface to subsurface horizons respectively. The weak sub angular blocky peds of very friable to loose consistence were probably due to the low clay content.

The pedons had different colour matrix that ranged from brown (7.5 YR 4/4), light brown (7.5 YR 4/2) to dark brown (7.5YR 4/4) and red (2.5 YR 4/6) in the surface and subsurface horizons.

The variation in colour and the presence of mottles most likely is due to the high degree of hydration and redox reactions, occasioned by the proximity of fluctuating underground water Table (70-100 cm) within the zone. The parent materials of the SMC farm, are derived from pyroxene granulites containing plagioclase and quartz-rich veins [8].

The soil texture showed that the materials were largely sandy and sandy loam in the surface horizons to sandy clay and clay loam in the sub-horizons. This explains why the consistence of the materials was friable to loose when moist due to weak cohesion and adhesion forces acting on the soil materials.

3.2 Soils Physical and Chemical Characteristics

Tables 3, 4 and 8 show the physical and chemical properties of Solomon Mahlangu campus farm soil. The clay content of the soils from all profiles ranged from 8.12 to 38.12%. Generally the clay values were highest at the subsurface horizons of all the profiles and increased regularly down the profile (Table 3). These increases in clay content with depth could be probably due to illuviation process. Similar results were obtained by [19,20].

The sand content ranged from 24 to 90.24%. The highest value of sand was recorded in the surface horizon of profile 1, while the least sand value was occurred in the subsurface (last) horizon of profile 3. Unlike clay content, the sand values were generally highest at the surface horizon of all the profiles and decreased with increased in depth down the profile with the lowest value occurring at the last horizons of all the profiles. The differences between the sand contents of the surface (first) and last horizon were greater than 20%.

The percent silt content was constant throughout the profiles (1.64%) except for profile 4 and surface horizon of profile 2. The values of silt were lowest compared to those of sand and clay fractions.

The soil textural class was predominantly sandy clay loam/loamy sand/sand clay. The general characteristics of the soils were high sand and low silt contents. Most of the profiles had greater than 60% sand, 20% clay and less than 5% silt (Table 3). The sandy nature of these soils could be attributed to the nature of parent materials. [21] also reported similar findings in soil of Kano Nigeria.

Sand fraction appears to be the dominant size in the surface horizons in all profiles, while silt and clay contents are low and medium. This is in the line with [22] and [23] when stated that the levee crest and levee slopes were dominantly sandy, which the flood plains and back swamps were dominantly clay in textures in their study of soil in Rivers State Nigeria.

Soil pH values range from slightly acidic (pH in H_2O = 5.06; pH in KCL = 4.27) to mildly alkaline (pH in H_2O = 6.95; pH in Kcl_2 = 5.48). The soil pH decreased with soil depth in Profiles 2 and 3, while it increased with increase in depth in Profile 4. The soil pH in KCL was lower than the pH in H_2O with almost 1 unit in all the profiles as expected. The pH of these soils currently could not pose any serious problem to crop production, as most crops will thrive well in soils with pH between 5.5 and 6.5 [24].

The content of organic carbon of the soils was low to moderate. The surface horizons have higher percentage organic matter and organic carbon than the subsurface horizons. The surface horizons had organic carbon contents that ranged between 0.29% and 0.51%, while the subsurface had a value of 0.02% and 0.27% of organic carbon.

The organic matter values were ranged from 0.23 to 0.84% for the surface horizons and 0.03 to 0.54% for the subsurface horizons (Table 4). The low levels of the organic matter related properties might be partly attributed to the rapid organic matter mineralization and the frequent burning of the area commonly carried out in dry season which destroys valuable organic materials that add organic matter.

The cation exchange capacity (CEC) for the surface soils ranged between 9:0 to 11.40 cmol (+) kg^{-1} for the surface horizons and between 15.0 to 17.80 cmol (+) Kg^{-1} for the subsurface horizons. The CEC content increased down the profile with increased depth in all the profiles except in horizon 3 of profile 4 (Table 4). The low values of CEC as per the rating scale in Table 7 may be attributed to the very low clay and organic matter contents of these soils.

Table 1. Site characteristics of the Solomon Mahlangu Campus farm soils

Pedon No.	Soil Unit	Elev. m.a.s.l	Coordinates	Landforms	Parent material	Land use/Vegetation	STR	SMR	DRG	Slope (%)
1	SMC-1	500	347485'S 9250758'E	Colluvium Plains	Sedm. rock from geological formation	Maize, grazing Natural grasses, Acacia, Eucalyptus spp.	hyp	Ustic	well	3(2.5) gnt.
2	SMC-2	509	347216'S 9250347'E	Colluvium Plains	Sedimentary rocks Weathering	Maize livestock shed & grazing	hyp	Ustic	well	2(2.5) gnt.
3	SMC-3	522	346928'S 92500335'E	Colluvium Plains	columvium derived From mafic metamophic of the Ulluguru.	Grazing, natural grasses & shrubs	hyp	Ustic	Moderately well	2(2.5) str.
4	SMC-4	522	346928'S 9249972'E	Colluvium Plains	Sediment Rocks From geologic Fomation.& Weathering of Ulluguru.	grazing & shrubs	hyp	Ustic	well	4(3) gnt., mid

SMC= Solomon Mahlangu Campus SMR= Soil moisture regime STR= Soil temperature regime Colmv.=colluvium Spp=species DRG= Drainage Sedm=sedimentary hyp= hyperthemic gnt= gently str= straight m=mid Elev.= elevation m.a.s.l=meters above sea level

Table 2. Some morphological/physical characteristics of SMC farm from soil profile description

Pedon	Horizon	Sampling depth (cm)	Horizon Boundary	Munsel soil colour mutations		Texture	Consistency		Structure	Cutans	Pores	Roots	Other features
				Moist	Dry		Dry	M & W					
1	AP	0 – 27	A & S	7.5YR4/4	7.5YR3/2	SL	sh	vfr,ns&np	w-sbk	-	a,f-m	vf-m	
	Bt1	27 – 35	C & S	5YR4/4	5YR4/6	CL	h	fr,ss&sp	w-msbk	f,cc	m,f-m	mf&vf	v-f fer
	Bt2	35 – 77	D & S	2.5YR4/6	2.5YR3/4	CL	sh	fr,ss&sp	m-csbk	f,cc	m,f-m	mf&vf	mifes
	Bt3	77 – 120	D & S	2.5YR4/6	2.5YR4/4	CL	sh	fr,ss&sp	m-csbk	f,m,cc	m,f-m	fvf-vf	nets
	Bt4	120 -167+	_	2.5YR4/8	2.5YR4/6	CL	h	fr,ss&sp	cr-csbk	f,m,cc	m,f	vvf&vf	___
2	AP	0 – 46	CS	7YR4/2	7YR3/2	SL	s	vfr,ns&np	w-sbk	-	F,m	fvf&fm	__
	Bt1	46 – 120	CS	7.5YR5/4	7.5YR4/4	SL	h	vfr,ss&sp	w-msbk	f,cc	f,m	fvfvfm&ff	few
	Bt2	120 – 162++	DS	7.5YR6/4	27.5YR5/4	SC	h	fr,ss&sp	cr-sbk	-	a,f	vff&m	cracks
													___
3	AP	0 – 19	DS	7.5YR4/3	7.5YR4/4	SL	sh	vfr,ns&np	w-sbk	vff,cc	a,f	vfm-f	
	Bt1	19 – 40	CS	7.5YR4/3	7.5YR4/2	SL	sh	fr,ns&np	w-msbk	f,cl	af-m	vff-m	
	Bt2	40 – 100	DS	5YR4/4	5YR4/3	SC	h	fr,ss&sp	cr-sbk	f,m	af-vf	vff	
	Bt3	100 – 175++	DS	5YR4/3	5YR4/3	SC	vh	rh,ss&sp	m-crsbk	f,cc	f-m	-	
4	AP	0 – 38	CS	7.5YR5/3	7.5YR4/2	SL	s	vfr,ns&np	wf-msbk	df,cc	vff	Vff,ff&fm	
	Bt1	38 – 79	CS	7.5YR6/4	7.5YR5/7	S	sh	vfr,ns&np	w,fsbk	ff,cc	vff	Ff,fm&vff	
	Bt2	79 – 138	CS	7.5YR6/4	7.5YR5/3	S	h	sr,ns&np	m-crsbk	mf,cc	mf	Vff-m	
	Bt3	138 – 161++	DS	7.5YR7/4	7.5YR6/4	S	h	vfr,ns&np	fm-sbk	m,cc	cf	-	

1) a = Abrupt, c=clear d = diffuse S=smooth
2) S = Sand; SL = Sandy loam; C = Clay; CL = Clay loam Sc = Sandy clay L = loam L = loam S = Silt
3) S = Soft, h = hard, sh = slightly hard vh = very hard; sfr = slightly friable fr = friable; vfr = very friable; ns = non sticky; SS = slightly sticky, np = non plastic, Sp = slightly plastic.
4) W, sbk = weak sub angular blocky; W-m, sbk = weak to moderate sub angular blocky; m-c, sbk = moderate to crumby sub angular blocky, cr - crumb, cr,sbk = crumby sub angular blocky; m-crsbk = moderate to crumby sub angular blocky. F-msbk = fine to moderate sub angular blocky
5) f,cc = fine clay cutans; f-m,cc = fine to medium clay cutans; vff, cc = very few fine clay cutans m,cc = medium clay cutans
6) a,f - m = abundant fine to medium; m,f - m = many fine to medium; mf = many fine, af = abundant fine, af - vf = abundant fine to very fine, Vff = very few fine; cf = common fine.
7) vf - m = very fine to medium; mf-vf = many fine to very fine; fvf&vf = few fery fine & very fine; vvf&vf = very very fine and very fine. Vfm - f = very few medium to fine
8) v.f = very few.

Table 3. Particle size distributions of Solomon Mahlangu Campus farm soil

Horizons	Depth (cm)	Sand	Clay	Silt	Texture
		%			
Pedon 1 SMCF,SUA					
AP	0 – 27	90.24	8.12	1.64	S
B1	27 – 35	74.24	24.12	1.64	SCL
Bt2	35 – 77	70.24	28.12	1.64	SCL
Bt3	77 – 120	70.24	28.12	1.64	SCL
Bt4	120 -162++	68.24	30.12	1.64	SCL
Pedon 2 SMCF,SUA					
AP	0 – 46	84.24	12.12	3.64	LS
B1	46 – 120	74.24	24.12	1.64	SCL
Bt2	120 – 162	60.24	38.12	1.64	SC
Bt3					
Pedon 3 SMCF,SUA					
AP	0 – 19	86.24	12.12	1.64	LS
B1	19 – 40	72.12	26.12	1.64	SCL
Bt2	40 – 100	54.24	44.12	1.64	SC
Bt3	100 – 175	44.24	54.12	1.64	C
Pedon 4 SMCF,SUA					
AP	0 – 38	86.24	8.12	5.64	LS
B1	38 – 79	82.24	16.12	1.64	SL
Bt2	79 – 138	62.24	34.12	3.64	SCL
Bt3	138 – 161	70.64	28.12	1.64	SCL

SMCF=Solomon Mahlangu Campus Farm; SUA=Sokoine University of Agriculture
S=Sandy; SCL= Sandy clay loam; LS=Loamy sand; SC=Sandy clay; LS= Sandy loam; C=clay

The available or extractable phosphorus had values that ranged between 4.97 mg/kg^{-1} and 11.52 mg/kg^{-1}for the surface horizons and between 2.6 and 5.6 mg/kg^{-1} for the sub surface.

The exchangeable bases (Ca^{2+}, Mg^{2+}, K^+ and N^+) were also low. The exchange sites of the soils were dominated by exchangeable calcium and magnesium. The values of exchangeable calcium (Ca^{2+}) of the surface horizon ranged from 0.37 to 3.16cmolkg^{-1} and for the subsurface horizons ranged from 0.37 to 5.03cmolKg^{-1}. The exchangeable magnesium content varied from 0.38 to 2.13 cmolKg^{-1}for the surface horizons and 2.20 to 3.50 cmolKg^{-1} for the subsurface horizons (Table 4). The content of Mg^{2+} increased with increase in depth in the soils, the highest content been observed in the last horizons in all the profiles.

The exchangeable K and Na status of the soils are medium in most of the horizons. The value of exchangeable K ranged from 0.13 cmolKg^{-1} to 0.52 cmolKg^{-1} and 0.10 cmolKg^{-1} to 5.00 cmolKg^{-1} for the surface and subsurface horizons respectively, while the exchangeable sodium varied from 0.12 cmolKg^{-1} to 0.60 cmolKg^{-1} for the surface horizon and 0.30 cmolKg^{-1} to 1.10 cmolKg^{-1} for the subsurface horizons.

The exchangeable bases occur in the order Mg> Ca> K> Na as also reported by many other workers in alluvial soils [25]. The low content for these exchangeable bases especially Ca and mg is due to low in CEC of the soils.

Tables 5-7 show the critical level of interpreting soil fertility level. Tables were used as a guide in rating some of the physical and chemical properties of the soils of the study area. The used of Table 5 – 7 gave us a bases in arriving at low or medium soil fertility class.

Table 4. Some chemical properties of the Solomon Mahlangu campus farm soil

Horizon	Depth (cm)	pH				Avail. P (mg/kg)	Exchangeable bases and CEC (cmol (+))/kg					TEB	BS %
		H_20	KCl	OC (%)	TN		Ca	Mg	K	Na	CEC		
Pedon 1- SMC-1													
AP	0-27	7.23	5.84	0.29	0.04	11.54	1.30	0.58	0.28	0.21	9.0	2.37	26.35
Bt1	27-35	6.29	5.54	0.33	0.04	2.75	3.16	2.13	0.21	0.22	11.8	5.73	48.54
Bt2	35-77	6.81	5.05	0.29	0.04	2.84	1.77	2.20	0.10	0.24	13.2	4.31	32.63
Bt3	77-120	6.99	5.99	0.12	0.01	6.15	2.23	2.58	0.10	0.30	15.4	5.21	33.85
Bt4	120-162	7.14	6.54	0.02	0.02	2.65	5.03	2.62	0.10	0.35	15.4	8.21	52.66
Pedon 2- SMC-2													
AP	0-46	6.76	5.85	0.49	0.04	6.73	1.30	1.03	0.25	0.24	9.20	2.58	28.03
Bt1	46-120	6.34	4.68	0.27	0.04	3.38	0.37	1.75	0.30	0.40	11.20	2.82	25.21
Bt2	120-162	6.22	4.50	0.27	0.04	4.61	0.37	2.91	0.39	1.10	15.0	4.78	31.84
Pedon 3 - SMC-3													
AP	0-19	7.12	5.53	0.51	0.04	9.30	0.37	0.74	0.36	0.18	11.20	1.65	14.76
Bt1	19-40	6.92	5.42	0.39	0.04	2.05	0.84	1.72	0.52	0.28	13.80	3.35	24.31
Bt2	40-100	6.84	5.49	0.31	0.04	2.02	1.30	2.65	1.25	0.77	16.80	5.97	35.56
Bt3	100-175	5.06	4.27	0.16	0.05	3.75	1.77	3.16	5.00	0.98	17.80	10.91	61.31
Pedon 4- SMC-4													
AP	0-38	7.25	5.32	0.14	0.03	4.97	0.37	0.38	0.14	0.12	11.40	1.02	8.96
Bt1	38-79	6.78	4.58	0.29	0.04	2.17	0.37	1.23	0.13	0.60	13.20	2.33	17.66
Bt2	79-138	6.95	5.20	0.27	0.04	1.30	0.84	3.27	0.17	0.34	10.80	4.62	42.80
Bt3	138-161	8.95	7.75	0.04	0.03	5.62	2.70	3.50	0.30	0.64	16.60	7.13	42.98

TEB= Total exchangeable bases BS= Base saturation

Table 5. Rating for soil fertility classes

Parameter	Low	Medium	High
Total Ngkg^{-1}	<1.5	1.5 – 2.0	>2.0
Bray 1p mg kg^{-1}	<8	8 – 20	>20
Exch K cmol kg^{-1}	<0.20	0.20 – 0.40	>0.40
Exch Ca cmol kg^{-1}	<5.0	5.0 – 10.0	>10.0
Exch Mg cmol kg^{-1}	<1.5	1.5 – 3.0	>3.0
Exch Na cmol kg^{-1}	<0.3	0.3 – 0.7	>0.7
Org. mtter gkg^{-1}	<20	20 – 30	>30

Sources: [26]

The low Na and K indicated that the soils have no problem of solidity and potassium availability, as weathering of soil and minerals decomposition replaces annual deflation of soils nutrients [19,27].

The percentage bases saturation (BS) values of the soils (8.96 - 61.31%) were rated moderate [28]. In almost all the profile the BS % increased with greater depth and this may be due to the higher organic matter content in the surface soils horizons.

However, the available micronutrients notably, Cu, Zn, Fe and Mn ranged from being medium to high in all the profiles (Table 8). The Cu and Zn content were medium and Fe and Mn were generally high.

The Cu value varied from 0.16 mg/Kg to 0.76 mg/Kg and Zn content ranged from 0.08 mg Kg^{-1} to 0.61 mg/Kg in all the profiles, while the exchangeable Fe and Mn varied from 4.97 mg/Kg to 64.14 mg/Kg and 2.90 mg/Kg to 31.50 mg/Kg in the surface and subsurface horizons of all the profiles. The medium to high values of these micronutrients may be due to long period of follows as land has not been under cultivation for many years

3.3 Soil Classification

The soils of the study area were classified according to the USDA Soil Taxonomy [10,9] Systems and presented in Table 9. As presented, the pedons 1 and 3 had an oxic horizon and do not have properties characteristic of kandic horizon within a depth of 150 cm with ustic SMR and are therefore classifies into the order Oxisols and suborder Ustox in Soil Taxonomy classification [1]. In the FAO/UNESCO Soil legend, these soils were grouped as Acrisols and Ferric in the level 1 and 2 because of an argilic B horizon with a cation exchange capacity and bases (at pH 7.0) of less than 24 cmol(+)/kg clay and 50 percent respectively, in addition to iron accumulation.

Soils of pedons 2 and 4 had argillic horizons with base saturation greater than 50% and are therefore classified as Alfisols. They have ustic moisture regimes which qualifies these soils to be Ustalfs [1]. In the FAO classification, the soils pedon 2 and 4 are grouped as Acrisols in level 1 and as Haplic in the level 2 category because of argillic horizon and simple/normal horizon sequence respectively.

Table 6. Critical limits for interpreting levels of analytical parameter

Parameter	Rating			
	Low	**Medium**	**High**	**Unit**
Ca	<2	2 – 5	>5	cmol (+) kg^{-1}
Mg	<0.3	0.30-1.0	>1.0	cmol (+) kg^{-1}
K	<0.15	0.15-0.30	>0.30	cmol (+) kg^{-1}
Na	<0.1	0.1-0.30	>0.30	cmol (+) kg^{-1}
ECE	<5	5.0-1.0	>10.0	cmol (+) kg^{-1}
CEC (Soil)	<6	6-12	>12	cmol (+) kg^{-1}
CEC (cky)	<15	15-25	>25	cmol (+) kg^{-1}
Exch. Acidity	<2	2-5	>5	cmol (+) kg^{-1}
Base saturation	<50	50-80	>80	Percent
Org. C	<10	10-15	>15	gkg^{-1}
Total N	<0.1	0.1-0.2	>0.2	gkg^{-1}
Avail. P	<10	10-20	>20	mgkg^{-1}

Source: [29,30]

Table 7. Rating for the status of copper (cu) zinc (zn) manganese (mn) iro (fe) exchangeable acidity (H^+ AL^{3+}) and (CEC) in the savannah zone its adopted by [31]

Parameters	Rating		
	Low	Medium	Medium
Copper (Cu)(ppm)	0—2.5	2.6—4.5	>4.5
Zinc (zn)(ppm)	1.0	-----	>1.0
Manganese (mn)(ppm)	1.0	1.0	>1.0
Iron (fe)(ppm)	0.25	2.6-4.5	>4.5
Exchangeable acidity	2	2-5	>5(mo(+)kg^{-1}
CEC (soil)	6	6-12	>12(mo(+)kg^{+1}

Table 8. Profile distribution of micro-nutrients

Horizon	Depth (cm)	Cu	Zn	Fe	Mn
		Mgkg^{-1}			
Pedon 1 SMCF, SUA					
AP	0 – 27	0.40	0.31	11.26	29.0
B1	27 – 35	0.40	0.61	20.68	31.5
Bt2	35 – 77	0.61	0.11	17.02	27.75
Bt3	77 – 120	0.73	0.11	12.30	24.0
Bt4	120 -162++	0.64	0.08	7.07	20.25
Pedon 2 SMCF, SUA					
AP	0 – 46	0.40	0.28	25.39	18.28
B1	46 – 120	0.40	0.08	43.19	13.28
Bt2	120 – 162	0.76	0.11	64.14	12.75
Bt3					
Pedon 3 SMCF, SUA					
AP	0 – 19	0.46	0.23	18.06	15.28
B1	19 – 40	0.46	0.10	19.11	14.65
Bt2	40 – 100	0.55	0.12	15.45	8.40
Bt3	100 – 175	0.61	0.13	23.30	3.90
Pedon 4 SMCF, SUA					
AP	0 – 38	0.16	0.19	17.54	7.53
B1	38 – 79	0.25	0.08	32.20	3.65
Bt2	79 – 138	0.64	0.14	27.49	4.40
Bt3	138 – 161	0.37	0.08	4.97	2.90

Table 9. Mapping units and soils classification of Solomon Mahlangu campus farm soil

Mapping unit	Area (ha)	Pedon no.	USDA Soil Taxonomy FAO/UNESCO			
			Order	Sub-order	Level 1	Level 2
SMCF- 1	25	1	Oxisols	Ustox	Acrisols	Ferric
SMCF- 2	7.5	2	Alfisols	Ustalfs	Acrisols	Haplic
SMCF- 3	10	3	Oxisols	Ustox	Acrisols	Ferric
SMCF- 4	13	4	Alfisols	Ustalfs	Acrisols	Haplic

4. CONCLUSION

The results of this study have indicated that, the predominant textures of Solomon Mahlangu Campus farm soils were sand; sandy clay loam, sandy clay and loamy sand. Morphologically, the soil has colours ranging from brown to reddish, brown, weakly sub angular blocky structure. Particle size distributions showed that sand was the dominant fraction of soils in all profiles. Chemically the soils were slightly acidic and low content of organic carbon and total nitrogen. The studied soils are also low in exchangeable basic cations and Cation exchange capacity with low electrical conductivity values. The study also indicated that, the Kaolinitic in nature of the soils and laterite composition of some of the soils influences the levels of these fertility indicators.

This study reveals that, all the soils belong to two soil orders (Oxisols and Alfisols) in United State Development Agency Soil Taxonomy or Acrisols in Food and Agricultural Organization / United Nations educational Scientific and Cultural Organization system of classification. At the suborder, the soils belong to Ustox and Ustalfs(Soil Taxonomy), and Ferric and Haplic in the level 2 category of Food and Agricultural Organization / United nations educational Scientific and Cultural Organization Classification [1].

Based on the findings the low soil fertility was attributed by low activity clays, low soil organic matter, nitrogen, phosphorous, exchangeable basic cations and low contents of the soil micro-nutrients. It was observed that, continual cropping without concurrent use of manure/inorganic fertilizer, over grazing and burning have contributed to low soils deficiencies and reduced soil fertility, leading to low crop yields in the farm.

For optimum productive capacity of this farm, an integrated nutrient management system should be adopted which embraces a holistic approach of integrated use and management of organic and inorganic nutrient sources in a sustainable way.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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