Asian Journal of Soil Science and Plant Nutrition

Volume 10, Issue 3, Page 208-221, 2024; Article no.AJSSPN.118266
ISSN: 2456-9682

Vertisols Pedological Characterization: Soil Morphology, Properties, Classification and Fertility Levels

Julius Jackson Nyaombo [a*]

[a] *Department of Geography, Archbishop Mihayo University College of Tabora (Constituent College of St. Augustine University of Tanzania), Tabora, Tanzania.*

Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

Article Information

DOI: https://doi.org/10.9734/ajsspn/2024/v10i3332

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/118266

Original Research Article

Received: 04/04/2024
Accepted: 08/06/2024
Published: 27/06/2024

ABSTRACT

A detailed pedological characterization of vertisols was carried out from in Itigi district central Tanzania from 2022 to 2023 to adequately attain data relevant for agricultural planning and executing soil fertility studies across the district. Six sites were selected, named as IPD-P1, DML-P1, ITIG-P1, KTR-P1, SJR-P1 and TKR-P1 and considered as benchmark sites of existing vertisols in the district with reference to existing soil information and a prior conducted reconnaissance soil survey. Four samples from each site making a total of 24 samples were collected and analyzed with standard laboratory procedures for understanding their chemical and physical properties. The soil profiles were adequately very deep dominated by clayey. The pH level in all soils were between slightly acidic (< 6.4) to moderate alkaline (> 8.2). Available P, K and Zn were generally low (> 2.1 $cmol_{(+)}$ /kg, >17.4 $cmol_{(+)}$ /kg, 0.79 $cmol_{(+)}$ /kg respectively) in all study profiles. Levels of Exchangeable bases in all study profile were adequately available in which Ca dominated over others (<15 $cmol_{(+)}$/kg. With the use of USDA soil taxonomy, profiles were classified as IPD-P1 (vertic chromic gypsitorrests) DML-P1 (vertic chromic calcitorrests) ITG-P1 (vertic chromic

Corresponding author: Email: juliusnyaombo@gmail.com;

Cite as: *Nyaombo, Julius Jackson. 2024. "Vertisols Pedological Characterization: Soil Morphology, Properties, Classification and Fertility Levels". Asian Journal of Soil Science and Plant Nutrition 10 (3):208-21. https://doi.org/10.9734/ajsspn/2024/v10i3332.*

gypsitorrests) KTR-P1 (vertic chromic calcitorrests) SJR-P1 (vertic chromic gypsitorrests) and TKR (vertic chromic gypsitorrests). The six studied profiles had slight variations among them and within their horizons in terms of physical and chemical properties, and therefore this enhances the need of carrying soil characterization for effective fertilization recommendations.

Keywords: Vertisols; soil morphology; soil properties; fertility levels; soil classification.

1. INTRODUCTION

Soil data which is scientifically identified, analyzed and related to various land uses is vital for its utility aiding in planning and management initiatives. Pedological characterization of various landscapes entailing soils of localities is critical to bring information about the nature of the slopes where are located, their colour and nature of growing vegetation [1]. Carrying out a pedological characterization enhances the understanding of the influence of abiotic and biotic factors, landscape properties and biological processes to the biophysical features of the soils. Making sustainable planning and management of soils resources becomes effective if its morphology, and characteristics are well understood [2].

Vertisols are common in tropical and subtropical areas since such areas experience extreme dryness and extreme wetness [3]. They are also found in some parts of temperate and humid regions [4]. Naming of the vertisols is locally known as in Australia are named as cracking clays, in Philippines are named as adobe, Shachiang in China, Black Cotton Soils in India, Makande in Malawi, Vleigrond in South Africa [5] and Mbuga nyeusi in Tanzania [6]. Vertisols are defined with high level of clay dominant which determine and affect other morphological features including ability to swelling during wet season and shrinking during dry season [7]. A good number of studies show that vertisols are limited in the Phosphorus and Potassium levels while exchangeable bases including Ca, Mg, CEC are always high with low Sodium levels implicating less salinity [8-10].

Vertisols occupies 350 million hectares of the global agricultural land in which 60% are located in tropics while 30% in subtropics and 10% in cooler regions [3,6]. Largest coverages of vertisols are in Australia (80,000,000 ha) while India has a total of 73,000,000 ha of vertisols followed by Sudan having 50,000,000 ha while United States having 18,000,000 ha [5]. In Ethiopia, vertisols occupies 12.61 million hectares of the total agricultural land in the country [11]. In Tanzania, vertisols occupies a total of 47497 km2 of the total available crop land in the country [12].

Vertisols are agriculturally potential benefits dryland farming in Asia, Africa and some parts of Europe occupied by such soils having vertic properties [13]. In parts of Africa as Egypt, Ethiopia and Cameroon, vertisols are used to cultivate annual crops including sorghum, rice, chickpea, and cotton. In Tanzania, semi-arid areas having vertisols including Singida, Dodoma, Shinyanga, Geita, Simiyu, Manyara, Tabora, Kigoma and Mwanza are dominated with cultivation of chickpea, Maize, cotton, sunflower, rice and onions [6,14,15]. In all these areas vertisols are useful in agriculture, are considered fertile enhancing high produces offering cultivation of two crop varieties in rotation within one agricultural season [16]. Overcultivation with minimal use of management practices are accountable for vertisols fertility depletion and decline in their quality posing a threat to semi-arid and arid crop farming [13,11]. Such decline and depletions are evidenced in Africa, Australia, and America as indicated in a number of studies [13,17-21]. This brings the potentials and indisputable of understanding fertility levels and suitability of vertisol in determining management practices for sustainable productivity of vertisols and in planning for agricultural development.

This study largely concentrated on understanding morphology of the vertisols, their fertility levels and making classification of the surveyed soils. It is grounded on the base that, vertisols are minimally studied in Tanzania while the existing studies are based on few observations with limited predictive potentials of the soils while reflecting generalized information.

2. MATERIALS AND METHODS

2.1 The study Sites

The study sites are located in the central part of Tanzania specifically in Itigi District of Singida region and a detailed description of each site is presented in Table 1.

The climate of Singida region and Itigi in specific can be termed as semi-arid type. The mean annual rainfall ranges between 500 mm to 700 mm in which the whole region experiences a unimodal rainfall pattern with a clear distinct of a dry season and wet season. The rainfall season normally begins in the end of November and sometimes early of December ending in the end of April and in few years in early May. The dry season begins in May and ends in late of November. Maximum mean temperature is 32.9℃ normally experienced in November while the minimum mean temperature is 17.8℃ normally observed in July [6]. Fig. 1 indicates the climatic observation annually of the study locations presenting rainfall and temperature observations.

2.2 Data Collection

Selection of sites were based on existing soil information of the region, reconnaissance survey and transect walks. The selection of sites considered land morphology, the observable soil physical features, and the common cropping patterns with critical consideration of the vegetation nature of the areas. Stratified random sampling was employed to ensure no effect of difference in historical practices and management of surveyed areas. In each used sampling unit in soil samples collections, observations were made effectively to maximum depth of 120cm in which beneath that follows another layer of gypsum deposits. The six profiles profile were named as IPD-P1, DML-P1, ITG-P1, KTR-P1, SJR-P1 and TKR-P1. The locations of the study sites were identified through a standard GPS receiver in which coordinates were determined and recorded. In making observation, the FAO guidelines [22] were adopted and used. The studied profiles horizons included the depths of 0-30cm, 30-60cm, 60-90cm and 90-120cm. soil colour was observed and classified based on soil colour chart as presented by Munsell Color Company [23]. Samples were collected through a combination auger and were packed in polythene labelled bags for laboratory procedures.

2.3 Standard Laboratory Procedures

The standard laboratory procedures were used to analyze chemical and physical properties. Particle distribution of the soils in particular sand, silt and clay proportions were determined through hydrometer and classified by USDA textural class triangle [24]. Soil pH was determined by using potentiometric method in water and in KCL. Soil Organic was determined through Walkley-Black method as described by FAO [25] while 1.724 factor was used to determine organic matter through multiplication. Electrical conductivity was determined using potentiometric method [26]. The soil sodium, calcium, magnesium and potassium were determined using atomic emission spectrometry through ammonium acetate saturation [27]. Soil phosphorus was extracted by Bray and Kurtz-1 method [28]. For determination of soil total nitrogen, the Micro Kjedahl digestion distillation and a titre method was used [1]. Soil extractable micronutrients including Zn, Mn and Fe were determined using atomic absorption spectrophotometer through diethylenetriaminepentaacetic acid [29].

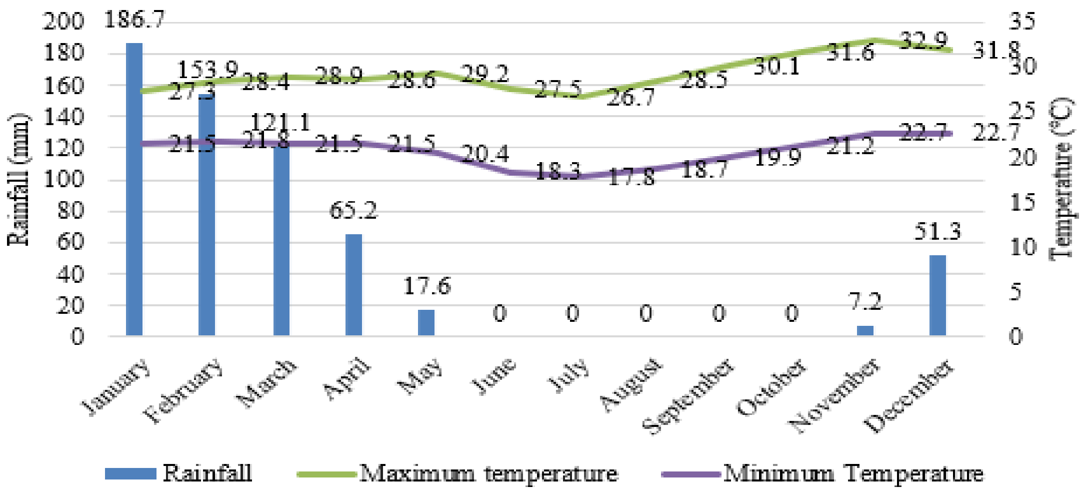

Fig. 1. Climate data of the study areas from January to December in 2022

Table 1. Site characteristics of the studied pedons in the study areas

Profile	Coordinates	Altitude (m)	MAR (mm)	MAT (℃)	AEZ	Land use	Landform	Slope
IPD-P1	5° 45’ 22’’ S 34° 29’5’’ E	1300	500-700	17.8 – 32.9	S-A	Agriculture	Flat/Plane	Gentle
DML-P1	5° 41’ 3’’ S 34° 30’ 39’’ E	1304	500-700	17.8 – 32.9	S-A	Agriculture	Flat/Plane	Gentle
ITG-P1	5° 44’ 51’’ S 34° 28’ 59’’ E	1290	500-700	17.8 -32.9	S-A	Agriculture	Flat/Plane	Gentle
KTR-P1	5° 38’ 44” S 34° 22’ 13’ E	1298	500-700	17.8 - 32.9	S-A	Agriculture	Flat/Plane	Gentle
SJR-P1	5° 39’ 30” S 34° 31’ 13” E	1300	500-700	17.8 – 32.9	S-A	Agriculture	Flat/Plane	Gentle
TKR-P1	5° 40’ 60” S 34° 29’ 20” E	1299	500-700	17.8 – 23.9	S-A	Agriculture	Flat/Plane	Gentle

Note: MAR = Mean Annual Rainfall; MAT = Mean Annual Temperature; AEZ = Agro ecological zone; S-A = Semi-Arid; IPD-P1 = Ipande Profile 1; DML-P1 = Damwelu Profile 1; ITG-P1 = Itigi Profile 1; KTR-P1 = Kitaraka Profile 1; SJR-P1 = Sanjaranda Profile 1; TKR-P1 = Tambukareli Profile 1

3. RESULTS AND DISCUSSION

3.1 Morphological Characteristics

The observed soil profiles in all their horizons were dark in colour while hard, demarcated and shrinking during the dry season. Generally, all profiles were deep ranging between 110 cm to 130 cm. all studied profiles were poorly drained and water table was found to be in more than 180 cm below. All studied profiles were very dark in colour in exception of ITG-P1 which had a dark grey soil in the topsoil. The consistence was found very hard in all studied profiles particularly in their subsoil and subsurface. A fine clayey dominated composition of the profiles and therefore affected structure which was wedge shaped structure for all profiles and limited porosity. During the dry season, the profiles were dominated by slickensides with deep cracking structures enhancing confirms existence of shrinking, swelling and pedoturbation [30].

3.2 Soil Physical Properties

Study findings based on laboratory procedures and physical surveys on soil physical properties are presented in Table 2. Particle size distribution of the studies soils was assessed since the property determines other features of the soils including structure, moisture retention, soil aeration and capacity to hold longer nutrients [30]. Silt percentages were generally low (<32%) ranged between 8 to 32% in all studied horizons of the profiles with mean value of 18.25%. Silt percentages were declining from topsoil to lower horizons in IPD-P1 and SJR-P1 contrary to other pedons as higher ratios of silt were observed in lower horizons of DML-P1, ITG-P1 and TKR-P1. Sand contents were very low (<30%) in all horizons of all profiles ranging between 5 to 29% with a mean value of 17.79%. The sand content was inconsistent from top horizons to lower ones in all profiles. The clay content was high (>43%) in all studied pedons and horizons ranging between 43% to 78%. Clay contents were observed to increase from top subsoil in IPD-P1, DML-P1, ITG-P1, KTR-P1 and SJR-P1 while an increase was noted in TKR-P1 subsoil. Highest clay content (78%) was recorded in KTR-P1 while the lowest one (43%) was in DML-P1. Based on In All studied pedons were very deep to a maximum depth of 140 m. all studied profiles had clay soil textural class [31]. The particle distribution of the studied soils implicates high ability of the soil to hold longer the moisture, enhancing immobility of Nyaombo and Majule [13] and difficult to work on particularly when extreme wet and extreme dry [32]. In crop farming, the high clay content poses difficult to some crop roots in penetration while provides supportive environment for crops that normally utilizes soil moisture for growth like chickpea and have deep roots development [6,13].

The bulk density varied over profiles and horizons (Table 2). The bulk densities of the studied pedons ranged between 1.5 g/m3 and 2.3 g/m3 with a mean value of 1.9 g/m3. The levels of bulk densities were increasing in profiles IPD-P1, DML-P1and ITG-P1 while decreasing in from topsoil to subsoil in profiles KTR-P1 and SJR-P1. Bulk densities of topsoils ranged between 1.5 g/m3 to 2 g/m3 while in the subsoil the range was between 1.6 g/m3 to 2 g/m3 marking minimal variations. The highest bulk density was 2.3 g/m3 in subsoil of ITG-P1 while the minimum level (1.5 g/m3) was in topsoil of IPD-P1. Study results in terms of bulk density indicates the soils quality and their abilities to ecosystem function in which the increasing levels of bulk density as in IPD-P1, DML-P1 and ITG-P1 limits the infiltration levels of water in the respective soils while creating easy runoff [33]. Most of pedons had high bulk density above the normal rate (1.0 g/m3 to 1.6 g/m3) meaning that the studied soils are difficult to root penetration, very compact and limited soil air movement.

3.3 Soil Chemical Properties

Soil pH differed slightly among pedons and within profiles (Table 3) from moderately alkaline to slightly acid. The maximum level of soil pH was in in IPD-P1 (8.2) while was minimum (6.37) in pedon TKR-P1. soil pH was increasing from topsoil to subsoil in all studied profiles. Topsoil pH level in all pedons ranged between 6.4 (slightly acid) to 7.9 (moderately alkaline). The subsoils of IPD-P1 and SJR-P1 were mildly alkaline while profiles DML-P1 and TKR-P1 had neutral pH. The KTR-P1 subsoil had moderately alkaline (pH = 8). The lowest horizons (Bss3) of all profiles ranged between mildly alkaline to moderately alkaline due to large $CaCO_3$ deposits beneath the horizons. In all studied pedons, the pH levels as determined by KCL were low and appeared in consistence implicating the soil having net negative charge [30].

The organic carbon of topsoil ranged between 1.07% to 1.7% while subsoil organic carbon level was between 1.01% to 1.31%. The maximum

Table 2. Physical characteristics of studied soils

Pedon	Horizon	Depth (cm)	Particle size Distribution (%)			Textural class	Bulk Density (g/m^3)
			Sand	Silt	Clay		
IPD-P1	Ap	0 – 30	11	26	63	Clay	1.5
	Bss1	30 – 60	6	24	70	Clay	1.9
	Bss2	60 – 90	11	16	73	Clay	1.9
	Bss3	90 – 120	17	8	75	Clay	2
DML-P1	Ap	0 – 30	10	22	68	Clay	1.7
	Bss1	30 – 60	12	16	72	Clay	1.9
	Bss2	60 – 90	5	20	75	Clay	1.9
	Bss3	90 – 120	10	21	69	Clay	2
ITG-P1	Ap	0 – 30	25	32	43	Clay	1.9
	Bss1	30 – 60	29	24	47	Clay	2.1
	Bss2	60 – 90	23	26	51	Clay	2.3
	Bss3	90 – 120	25	32	43	Clay	2
KTR-P1	Ap	0 – 30	16	12	72	Clay	1.9
	Bss1	30 – 60	15	11	74	Clay	1.6
	Bss2	60 – 90	15	10	75	Clay	1.9
	Bss3	90 – 120	10	12	78	Clay	2
SJR-P1	Ap	0 – 30	27	13	60	Clay	2
	Bss1	30 – 60	23	13	64	Clay	1.7
	Bss2	60 – 90	22	12	66	Clay	1.8
	Bss3	90 – 120	21	11	68	Clay	1.8
TKR-P1	Ap	0 – 30	27	15	58	Clay	2
	Bss1	30 – 60	29	17	54	Clay	2
	Bss2	60 – 90	22	18	60	Clay	1.9
	Bss3	90 – 120	16	27	57	Clay	1.9

Note: IPD-P1 = Ipande Profile 1; DML-P1 = Damwelu Profile 1; ITG-P1 = Itigi Profile 1; KTR-P1 = Kitaraka Profile 1; SJR-P1 = Sanjaranda Profile 1; TKR-P1 = Tambukareli Profile 1

level of organic matter (1.8%) was found in profile IPD-P1 while the minimum level of organic matter (01%) was recorded in KTR-P1. The organic mean value for all studied horizons was 1.25%. All studied soils had low level of organic carbon [34]. Organic matter for topsoil and subsoil ranged between 1.74% to 3.1% in all pedons. The maximum level of organic matter was 3.1% in topsoil of pedon DML-P1 while the minimum level among horizons was 1.72% in KTR-P1. The low levels of organic carbon implicated low level of organic matter as the earlier determines the least. Despite of the dark colour of observed soils low level of organic carbon and organic matter are enhanced by limited occurrence of decomposition in semi-arid areas due to scarce distribution of vegetation resulting from low rainfall [13].

All studied profiles and within horizons had low level of available phosphorus [35]. The topsoils of studied pedons had phosphorus ranging from 0.6 mg/kg to 2.1 mg/kg in profiles SJR-P1 and KTR-P1 respectively. The lowest recorded available phosphorus in all horizons was 0.5 mg/kg in profile SJR-P1 and TKR-P1. The mean value for all horizons' available phosphorus was 1.37 mg/kg. The low level of P in studied soil is an outcome of P fixation performed under the influence of acidity and alkalinity in the formation of insoluble compounds as well as the influence of parent materials featured with low [36].

Total nitrogen was ranging between 0.03% to 0.09% in all horizons of studied pedons. The mean value for total nitrogen was 0.06%. The level of nitrogen was decreasing from topsoil to subsoil and downward consecutive horizons. Generally, nitrogen level in all horizons of studied profiles were rated low based on description by Tenga et al. [37]. Low level of nitrogen in vertisols is caused by denitrification resulting from poor drainage [13].

Exchangeable Ca ranged between 15.6 to 42.6 cmol (+)/kg. The topsoils of profiles IPD-P1, ITG-P1 and SJR-P1 had high level of Ca ranging between 15.6 to 19.4 cmol (+)/kg while the topsoils of DML-P1, KTR-P1 and TKR-P1 had very high level of Ca ranging between 20 to 35.7 cmol (+)/kg. The level of Ca was increasing from topsoils to lower horizons in all studied pedons in which all the below topsoils had very high level of Ca which was > 20 cmol (+)/kg. The studied soils had high rates of Ca mainly due to large deposits of gypsum beneath the soils [6,13]. Exchangeable Mg ranged between 0.4 cmol (+)/kg to 13.4 cmol (+)/kg with a mean value of 7.8 cmol (+)/kg. The topsoils of IPD-P1, DML-P1, ITG-P1 and KTR-P1 had very high level of Mg including 10.2, 13.4, 9.7 and 11.6 cmol (+)/kg respectively and level of Mg was observed to decrease form topsoil to lower horizons. Profiles SJR-P1 and TKR had high (2.5 cmol (+)/kg) and medium (0.5 cmol (+)/kg) as described by [ILACO [38]. All horizons in profiles IPD-P1, DML-P1, ITG-P1, KTR-P1 and SJR-P1 had very high level of Mg ranging between 13.4 to 5.4 cmol(+)/kg. The level of Mg in all studied profiles was therefore sufficient to support a variety of crop production.

The level of exchangeable K ranged between 0.8 to 17.4 cmol (+)/kg with a mean value of 4.88 cmol(+)/kg. The topsoils of all studied profiles had very high level of K ranging between 1.2 to 14 cmol(+)/kg while the level of K was increasing from topsoil to lower horizons. TKR-P1 differed with other profiles in which the level of K was decreasing from topsoil to subsoils and beneath horizons having a range of high to very high level of K.

The level of Na in all studied profiles was rated between low to very low as all were found below 0.85 cmol (+)/kg. The topsoils of the studied profiles including IPD-P1, DML-P1, ITG-P1, KTR-P1, SJR-P1 and TKR-P1 had Na levels of 0.85, 0.46, 0.09, 0.9, 0.3 and 0.1 cmol (+)/kg respectively while subsoils horizons had not exceeded 0.83 cmol (+)/kg of sodium content and it was observed that the level of exchangeable sodium was decreasing from topsoil to lower horizons. The low level of Na influenced the low level of Exchangeable Sodium Percentage (ESP) in which all profiles had low level of ESP ranging between 0.1% to 2.5% in which this implies that the studied soils are non-saline [39]. The study soils had varied range of cation exchange capacity (CEC) that ranged between 25.80 cmol (+)/kg to 55.70 cmol (+)/kg with a mean value of 39.36 cmol (+)/kg. All the horizons of the studied soils profile had high to very high level of CEC in which such levels indicate higher levels of mixed clay mineralogy [30,35]. The topsoils of profiles IPD-P1, DML-P1, ITG-P1, KTR-P1, SJR-P1 and TKR-P1 had high CEC levels having 33.2, 42.9, 26.8, 50.8, 35.5 and 25.8 cmol (+)/kg respectively. The CEC rates were observed increasing from top soil to lower horizons. The subsoils of profiles IPD-P1, DML-P1, ITG-P1, KTR-P1, SJR-P1 and TKR-P1 had CEC rating between 55.7 cmol (+)/kg. to 26.4 cmol (+)/kg and the lowest level (25.8 cmol (+)/kg) was recorded in topsoil of pedon TKR-P1.

Electrical conductivity of all studied pedons were low (<1.7 ms/cm). Electrical conductivity ranged between 0.18 ms/cm as a minimum to 0.8 ms/cm as maximum level. The topsoils of pedons IPD-P1, DML-P1, ITG-P1, KTR-P1, SJR-P1 and TKR-P1 had EC levels of ranging between 0.2 to 0.8 ms/cm while the subsoils ranged between 0.2 to 0.8 mc/cm as well. The low levels of electrical conductivity mean soils are none saline [14,18].

3.4 Extractable Micronutrients

The extracted micronutrients including Zn, Mn and Fe of the studied profiles are presented in Table 4. Extractable Zn varied between 0.09 to 0.79 mg/kg with a mean value of 0.45 mg/kg. Topsoils of studied profiles had Zn level ranging between 0.9 to 74 mg/kg while subsoils had a range between 0.19 to 0.79 mg/kg. In IPD-P1 profile Zn ranged between 0.51 to 0.28 mg/kg which is rated as low. In profile DML-P1 Zn ranged from 0.73 to 0.29 which is rated as medium to low level and in profile ITG-P1 ranged from 0.09 to 0.32 mg/kg. in pedons KTR-P1, SJR-P1, and TKR-P1 the level of Zn ranged between 0.22 to 0.74 mg/kg, 0.24 to 0.75mg/kg and 0.41 to 0.79 mg/kg all rated low to medium level.

In terms of Manganese (Mn), study profiles had a range of 9.65 to 46.30 mg/kg with a mean value of 24.94 mg/kg. topsoils of studied profiles IPD-P1, DML-P1, ITG-P1, KTR-P1, SJR-P1 and TKR-P1 had Mn levels of 10.85, 15.7, 28.5, 39.6, 27.7 and 37.1 mg/kg respectively. The subsoils of all studied pedons, Mn was ranging between 12.63 to 35.3 mg/kg. The existing levels of Mn are adequate for plant growth [30]. Extracted Fe varied among profiles and horizons ranging between 0.4 to 3.7 mg/kg with a mean value of 1.9 mg/kg rated as low to high [4]. Topsoils had Fe ranging between 1.3 to 1.9 mg/kg while subsoils ranged between 1.8 to 3.3 mg/kg rated as high [40]. Lower horizons of all studied profiles had lowest levels of extracted Fe ranging between 0.4 to 0.6 mg/kg rated as between low to medium [41].

Table 3. Chemical properties of studied soils

Pedon	Horizon	Depth (cm)	pH		OC	OM	N	Av. P	Exch. bases and CEC (cmol $_{(+)}$/kg)					EC ms/cm	ESP
			H_2O	KCL	%			mg/kg	Ca	Mg	K	Na	CEC		
IPD-P1	Ap	0-30	7.3	6.1	1.6	2.6	0.08	1.9	19.4	10.2	2.7	0.85	33.2	0.2	2.5
	Bss1	30-60	7.6	6.4	1.5	2.6	0.07	1.1	22.7	9.8	3.9	0.83	37.2	0.6	2.2
	Bss2	60-90	7.6	6.3	1.3	2.2	0.05	0.8	22.9	9.7	4.1	0.81	37.5	0.6	2.1
	Bss3	90-120	7.8	6.3	1.2	2.1	0.05	0.6	24.9	5.4	3.9	0.72	34.9	0.8	2.1
DML-P1	Ap	0-30	6.9	5.9	1.8	3.1	0.07	2	27.8	13.4	1.2	0.46	42.9	0.5	1.1
	Bss1	30 – 60	7.1	5.3	1.3	2.2	0.06	1.9	28.3	11.4	2.1	0.39	42.2	0.4	0.9
	Bss2	60 – 90	7	6	1.1	1.9	0.06	1.8	29.9	10.5	3.3	0.38	44.1	0.4	0.9
	Bss3	90 – 120	7.3	5.6	1.1	1.9	0.05	1.7	27.3	10.1	3.4	0.34	41.1	0.2	0.8
ITG-P1	Ap	0 – 30	7.9	6.7	1.7	2.9	0.09	1.8	15.6	9.7	1.4	0.09	26.8	0.8	0.3
	Bss1	30 – 60	7.9	6.7	1.0	1.7	0.07	0.9	18.4	8.5	1.5	0.05	28.5	0.7	0.2
	Bss2	60 – 90	8.1	7.1	1.0	1.8	0.05	8	20.2	8.3	1.9	0.08	30.5	0.6	0.3
	Bss3	90 – 120	8.1	7.1	1.1	1.9	0.03	0.6	20.9	7.1	2.1	0.04	30.1	0.6	0.1
KTR-P1	Ap	0 – 30	7.6	6.3	1.1	1.8	0.08	2.1	35.7	13	1.2	0.9	50.8	0.25	1.8
	Bss1	30 – 60	8	7	1.0	1.7	0.06	1.1	40.2	11.6	3.1	0.8	55.7	0.2	1.4
	Bss2	60 – 90	8.2	6.7	1.0	1.7	0.06	0.8	39.8	9.7	4.1	0.7	54.3	0.2	1.3
	Bss3	90 – 120	7.9	6.7	1	1.7	0.08	0.7	42.6	8.2	4.2	0.7	55.7	0.18	1.3
SJR-P1	Ap	0 – 30	6.7	5.3	1.1	1.9	0.06	0.6	18.4	2.5	1.4	0.3	35.5	0.2	0.8
	Bss1	30 – 60	7.8	6.5	1.2	2.1	0.05	0.5	20	9.2	1.7	0.3	46	0.2	0.7
	Bss2	60 – 90	7.9	6.8	1.2	2.1	0.04	0.5	24.6	8.8	1.7	0.09	50.3	0.3	0.2
	Bss3	90 – 120	8	6.7	1.2	2.1	0.05	0.3	27.3	7.4	1.7	0.09	52.2	0.4	0.2
TKR-P1	Ap	0 – 30	6.4	5	1.6	2.7	0.08	1.1	20	0.4	5.3	0.1	25.8	0.2	0.4
	Bss1	30 – 60	6.8	5.8	1.3	2.3	0.08	0.9	25	0.4	1	0.02	26.4	0.8	0.3
	Bss2	60 – 90	7.1	6	1.2	2.1	0.07	0.8	28.9	0.8	0.9	0.02	30.6	0.7	0.1
	Bss3	90 – 120	7.3	5.6	1.4	2.4	0.06	0.5	30.3	1.1	0.8	0.04	32.2	0.6	0.1

Note: OC = organic carbon; OM = Organic matter; N = Nitrogen; Av. P = Available phosphorus; CEC = Cation exchange capacity; EC = Electrical conductivity; ESP = Exchangeable Sodium Percentage; IPD-P1 = Ipande Profile 1; DML-P1 = Damwelu Profile 1; ITG-P1 = Itigi Profile 1; KTR-P1 = Kitaraka Profile 1; SJR-P1 = Sanjaranda Profile 1; TKR-P1 = Tambukareli Profile 1

Table 4. Extractable micronutrients status of studied soils

Pedon	Horizon	Extractable Micronutrients (mg/kg)		
		Zn	**Mn**	**Fe**
IPD-P1	Ap	0.51	10.85	1.6
	Bss1	0.45	24.35	1.8
	Bss2	0.32	26.02	1.7
	Bss3	0.28	11.35	0.4
DML-P1	Ap	0.61	15.7	1.7
	Bss1	0.73	12.63	2.2
	Bss2	0.36	6.65	3.2
	Bss3	0.29	37.1	0.4
ITG-P1	Ap	0.09	28.5	1.9
	Bss1	0.19	35.3	2.2
	Bss2	0.32	28	3.7
	Bss3	0.31	10.96	0.7
KTR-P1	Ap	0.74	39.6	1.8
	Bss1	0.45	35.2	2.4
	Bss2	0.51	37.12	3.3
	Bss3	0.22	46.3	0.6
SJR-P1	Ap	0.56	27.7	1.3
	Bss1	0.69	22.04	3.3
	Bss2	0.75	15.7	3.5
	Bss3	0.24	13.6	0.6
TKR-P1	Ap	0.41	37.1	1.6
	Bss1	0.79	20.76	2.2
	Bss2	0.48	19.01	3.7
	Bss3	0.56	37	0.6

Table 5. Morphological, diagnostic features and classification based on USDA soil Taxonomy

Pedon	Diagnostic epipedon and subsurface horizon	Other diagnostic features	Order	Suborder	Great group	Subgroup	Family
IPD-P1	Ochric epipedon, Calcic horizon	Semi-arid, gently sloping, very deep, clayey, mildly alkaline, wider deep cracking structure, sticky during wet, very had during dry season.	Vertisols	Torrerts	Gypsitorrests	Chromic Gypsitorrests	Very fine clayey, gently sloping, mild alkaline, non-acidic, isohyperthermic, chromic gypsitorrests
DML-P1	Ochric epipedon, Calcic horizon	Semi-arid, gently sloping, very deep, clayey, neutral to mildly alkaline, wider deep cracking structure, sticky during wet, very had during dry season.	Vertisols	Torrerts	Calcitorrerts	Chromic Calcitorrests	Very fine clayey, mildly alkaline, non-acid, isohyperthermic, chromic calcitorrests
ITG-P1	Ochric epipedon, Calcic horizon	Semi-arid, gently sloping, very deep, clayey, slightly acidic to moderate alkaline, wider deep cracking structure, sticky during wet, very had during dry season.	Vertisols	Torrerts	Gypsitorrests	Chromic Gypsitorrests	Fine clayey, acidic, moderate alkaline, isohyperthemic, chromic gypsitorrests
KTR-P1	Ochric epipedon, Calcic horizon	Semi-arid, gently sloping, very deep, clayey, slightly acidic to moderate alkaline, wider deep cracking structure, sticky during wet, very had during dry season.	Vertisols	Torrerts	Calcitorrerts	Chromic Calcitorrests	Very fine clayey, acidic, moderate alkaline, isohyperthermic, chromic calcitorrests
SJR-P1	Ochric epipedon, Calcic horizon	Semi-arid, gently sloping, very deep, clayey, neutral to moderate alkaline, wider deep cracking structure, sticky during wet, very had during dry season.	Vertisols	Torrerts	Gypsitorrests	Chromic Gypsitorrests	Fine clayey, moderate alkaline, isohyperthermic, chromic gypsitorrests

Pedon	Diagnostic epipedon and subsurface horizon	Other diagnostic features	Order	Suborder	Great group	Subgroup	Family
TKR-P1	Ochric epipedon, calcic horizon	Semi-arid, gently sloping, very deep, clayey, slightly acidic to neutral, wider deep cracking structure, sticky during wet, very had during dry season.	Vertisols	Torrerts	Gypsitorrests	Chromic Gypsitorrests	Fine clayey, acidic, isohyperthermic, chromic gypsitorrests

3.5 Soil Classification and Fertility Levels

The assessed soil morphology, properties both physical and chemical were utilized by the study to feature the diagnostic horizons and other attributes corresponding to soil classification as by soil Taxonomy [5]. The classification results are presented in Table 5.

4. CONCLUSION

The studied soils had adequate depth, optimum texture and penetrable to most crop roots. All study areas landscapes are gentle slopes therefore allows mechanizations though limited to high clayey ratio. The pH level ranging between slightly acidic to moderate alkaline provide a conducive condition for growth of a wide range of crops and plants. Organic matter and organic carbon are generally low in the studied soils due to limited decomposition of plants in semi-arid areas necessitating adding of organic manure for better crop production. Study soils had low level of nitrogen and therefore needs fertilization with N component or growing crops with nitrogen fixation ability as pulses particularly chickpeas and others. P, K and Zn were found low in all profiles and therefore for a good condition for growth of fertilizers, the soils need to be fertilized with P and K fertilizers along with Zn based on existing status of the specific soil sites. Exchangeable and CEC bases were found adequate to support growth of a variety of crops. The six selected soil profiles were classified based on USDA soil taxonomy in which profile IPD-P1 was vertic chromic gypsitorrests, profile DML-P1 was vertic chromic calcitorrests, profile ITG-P1 was vertic chromic gypsitorrests, profile KTR-P1 was vertic chromic calcitorrests, profile SJR-P1 was vertic chromic gypsitorrests and profile TKR was vertic chromic gypsitorrests.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Author has declared that no competing interests exist.

REFERENCES

1. Lufega SM, Msanya BM. Pedological characterization and soil classification of selected soil units of Morogoro District, Tanzania. International Journal of Plant & Soil Sciences. 2017;16 (1) :1-12.
2. Debie E, Yayeh T, Anteneh M. The role of sustainable soil management practices in improving smallholder farmers' livelihood in the Gosho watershed, Northwest Ethiopia. Cogent Food & Agriculture. 2022;8(1) :1-22.
3. Dudek M, Waroszewski J, Kabala C, Labaz B. Vertisols properties and classification in relation to parent material differentiation near strzelin (SW Poland). Soil Science Annual. 2019;70(2):158-169.
4. Basga SD, Temga PJ, Tsozue D, Danbe N, Nguetnkam JP. Morphological, mineralogical and geochemical features of topomorphic vertisols used for sorghum production in North Cameroon. Eurasian Journal of Soil Science. 2018;7(4):346-354.
5. USDA. Soil Taxonomy: A basic system of soil classification for making and interpreting soil surveys. Washington DC; 1999.
6. Nyaombo JJ. The effect of selected agronomic practices on chickpea (*Cicer arietinum* L.) production on vertisols and farmers' livelihood in Itigi District, Tanzania. PhD Thesis. University of Dar es Salaam, Institute of Resources Assessment; 2023.
7. Rahim IS, Wahba MM, Amal MA. Micromorphological characteristics of vertisols in Egypt. Internal Journal of Research in Management. 2015;5(6):1-7.
8. Neenu S, Ramesh K, Ramana S, Biswas AK, Rao S. Growth and yield of different varieties of chickpea (*Cicer arietinum* L.) as influenced by the phosphorus nutrition under rainfed conditions on vertisols. International Journal of Bioresources and Stress Management. 2014;5(1):53-57.
9. Khan OZ, Naseer A, Shahbaz M, Faisal S, Mushtaq K. Assessing the factors affecting the yield of chickpea in Thal, Punjab, Pakistan. J Innov Bio-Res. 2017; 1(1):46-51.
10. Nawange DD, Verma HD, Hemlata V. Growth and yield performance of Kabuli chickpea (*Cicer arietinum* L.) genotypes under different planting geometry and fertility levels in Vindhya plateau region.

International Journal of Agriculture Sciences. 2018;10(5):5291-5293.

11. Chala G, Obsa Z. Effect of organic and inorganic fertilizers on growth, yield and yield components of chickpea (Cicer arietinum) and enhancing soil chemical properties on vertisols at Ginchi, Central Highlands of Ethiopia. Journal of Biology, Agriculture and Healthcare. 2017;17(23): 28-34.
12. URT. Soils of Tanzania and their potential for agriculture development. Mlingano Agricultural Research Institute, Ministry of Agriculture, Food Security and Cooperatives, Tanzania; 2006.
13. Nyaombo JJ, Majule AE. Characterization of vertisols fertility status and their implications on chickpea (*Cicer arietinum* L.) farming in semi-arid areas of Itigi District in Tanzania. Indonesian Journal of Agricultural Research. 2023;5(2): 109-120.
14. Kileo R, Rao G, Salim S. Grain legumes strategies for ESA: Tanzania-chickpea. International Crops Research Institute for Semi-Arid Tropics. 2019;118-122.
Available:https://www.researchgate.net/publbication/33257810.
15. Nyaombo JJ. Pulses Farming; An adaptive strategy to climate change in arid and semi-arid areas regions: A case study of Itigi District in Singida Region, Tanzania. Intech Open; 2022.
Available:http://dx.doi.org/10.5772/intechopen.100739.
16. Chichaybelu M, Girma N, Fikre A, Gemechu B, Mekuriaw T, Geleta T. et al. Enhancing chickpea production and productivity through stakeholders' innovation platform approach in Ethiopia; 2021.
Available:https://doi.org/10.1007/978-981-15-8014-7_7.
17. Giday O, Gibreakidan H, Berhe. Soil fertility characterization in vertisols of south Tigray, Ethiopia. Advances in Plants & Agriculture Research. 2015;2(1):7-13. Tripolskaja L, Asakaviciute R. Effects of fertilizers on pulse crop productivity and nitrogen assimilation on acid soil. Journal of Plant, Soil and Environment. 2019; 65(11):536-540.
18. Tripolskaja L, Asakaviciute R. Effects of fertilizers on pulse crop productivity and nitrogen assimilation on acid soil. Journal of Plant, Soil and Environment. 2019; 65(11): 536-540.
19. Ooro PA, Birech RJ, Malinga JN, Thuranira E, Digo C, Taiy R. Influence of Crop Rotation and Soil Fertility Management Strategies on Water Use Efficiency of Wheat in a Changing Climate in Njoro Sub-County in Kenya. J. Exp. Agric. Int. 2020;42(8):59-76.
Accessed on:2024 May 29
Available:https://journaljeai.com/index.php/JEAI/article/view/1707
20. Chabi FO, Dagbenonbakin GD, Agbangba CE, Oussou B, Amadji GL, Ahoton EL, Saïdou A. Soil Fertility Level and Cropping Practices Determining Soybean Yield in Northern East and Center of Benin. Int. J. Plant Soil Sci. 2019;30(6):1-10.
Accessed on:2024 May 29
Available:https://journalijpss.com/index.php/IJPSS/article/view/1038
21. Goudarzi T, Tabrizi L, Nazeri V, Etemadi M. Nutrient distribution in various tissues of Licorice (*Glycyrrhiza glabra* L.) and the influence of soil fertility on the levels of its bioactive compounds. Industrial Crops and Products. 2024;209:118073.
22. FAO. Guideline for soil description, Fourth edition. Rome: Italy. 2006.
23. Munsell Color Company. Munsell soil color charts Co. Inc; 1992.
24. Alonso-Azcarate J, Moreno-Maroto. Evaluation of the USDA soil texture triangle through Atterberg limits and an alternative classification system. Applied Clay Science. 2022;10.
25. FAO. Standard operating procedure for soil organic carbon: Walkley-Black method, Titration and colorimetric method. Rome: Italy; 2019.
26. Sila A, Hengl T, Terhoeven-Urselmans T. Soil Spectroscopy tools and reference models; 2014.
27. Towett EK, Shephered KD, Sila A, Betemariam A, Cadisch G. Mid-infrared and total X-Ray fluorescence spectroscopy complementarity for assessment of soil properties. Soil Science Society of America Journal. 2015;79:1375-1385.
28. Nelson DW, Sommers LE. Organic carbon in soils. In Methods of Soil Analysis. Part 2, Agronomy Monography No. 9. (Eds. by Miller R. H. and Keeney, D. R.) American Society of Agronomy, Madison Wisconsin. Pp. 1982; 570-571.
29. Lindsay WL, Norvell WA. Development of DTPA soil test for zinc, iron, manganese, and copper. Soil Science of America Journal. 1978;42:421-428.

30. Msanya BM, Mwasyika TA, Amuri N, Semu E, Mhoro L. Pedological characterization of Dodoma capital city District, Tanzania. Soil morphology, physio-chemical properties, classification and soil fertility trends. Annals of Advanced Agricultural Sciences. 2018;2(4):59-73.
31. FAO. World reference base for soil resources: International soil classification system for naming soils and creating legends for soil maps. Rome – Italy; 2015.
32. Mwasyika, T. Influence of soil fertility on mineral nutritive quality of cereals and vegetables grown on typical soils of Dodoma capital District, Tanzania. Sokoine University of Agriculture; 2015.
33. Zebire D, Ayele T, Ayana M. Characterizing soils and the enduring nature of land uses around lake Chamo basin in south – west Ethiopia. Journal of Ecology and Environment. 2019;43(15): 01-32.
34. Powlson DS, Poutlon PR, Glendining MJ, Macdonald AJ, Goulding WT. Is it possible to attain the same soil organic matter content in arable agricultural soils as under natural vegetation? Outlook on Agriculture. 2022;51(1):91-104.
35. Landon JR. Tropical soil manual. Eds, Booker Tade Ltd.; 1984.
36. Juita N, Sudarsono, Iskandar. The role of soil minerals in red and black vertisol in Jeneponto regency. IOP Conference series: Earth and Environmental Science; 2020.
37. Tenga JJ, Msanya BM, Semoka JM, Semu E Mwango SB. Pedological characterization and classification of some typical soils in three agro-ecological settings of south-Eastern Tanzania. International Journal of Scientific & Engineering Research. 2018;9(2):692-702.
38. ILACO. Agricultural compendium for rural development in the tropics and subtropics. Elsevier Publishing Company, Amsterdam; 1981.
39. Pierre TJ, Primus AT, Simon BD, Philemon ZZ, Hamadjida G, Monique A. et al. Characteristics, classification and genesis of vertisols under seasonally contrasted climate in the Lake Chad Basin, central Africa. Journal of African Sciences; 2018.
40. Bunemann EK, Bongiorno G, Bai Z, Creamer R, Deyn GD, Goede R et al. Soil quality – A critical review. Soil Biology and Biochemistry. 2018;120:105-125.
41. Lihong H, Lu Z, Zhang J, Chakravarty B, Jin L, Cao X. Nutrient and specification enhancement of fortified Asian noodles by chickpea flour substitution and transglutaminase treatment. International Journal of Food Properties. 2021;24 (1):174-191.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/118266