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CHARACTERIZATION AND MANAGEMENT OF SOILS OF AMANGWU-EDDA, EBONYI STATE FOR SUSTAINABLE RICE PRODUCTION

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Abstract
The study was conducted at Amangwu-Edda in Afikpo-South Local Government Area (LGA) of Ebonyi State, Nigeria, to characterize the soils of the area and give management options for sustainable rice production. Two hundred and fifty hectares of land was surveyed using the rigid grid method, based on the differences and similarities of the morphological properties. Three (3) different mapping units were identified, and soil profile pits dug and described morphologically, then samples were collected based on horizon differentiation from bottom to top. The samples were prepared and subjected to routine laboratory analysis for selected physical and chemical properties. Data generated were analysed using suitable statistical tools. The analytical results showed that the percent clay had mean values of 26.47% for soil mapping unit 1, 31.80% for soil mapping unit 2, and 25.73% for soil mapping unit 3. The soil pH was strongly acidic (3.8 – 4.9) in all the soil mapping units studied. The coefficient of variation showed that pH (H_2O) had low variation in all the soil mapping units, while organic carbon (OC) and total nitrogen (N) had high variation in all the soil mapping units. A low to moderate variation was recorded for percent sand, silt and clay for the three soil mapping units. Management options for yield increase and sustainable rice production were suggested for rice growers in the study area.

Keywords: Characterization, Management, Sustainable, Rice, and Production

Introduction
Rice is the world's most strategic commodity crop for food security; it is an important stable food for over half of the world population, an economic security crop for rice producing countries *vis-a-vis* rice export. About 90% of rice produced globally is from Asian countries. According to FAO (2017), top seven countries in rice production are as follows; China (30%), India (22%), Indonesia (8%), Bangladesh (7%), Vietnam (6%), Thailand (4%), and Myanmar (3%). During the pre-green revolution era, rice production was at 220mt, however in 2017, total rice production was at 729mt to feed the world growing population (IRRI, 2019). The inability to meet rice consumption needs through local production in sub-Saharan Africa has resulted in high cash outlays for importation. Oladiran (2010) estimated that Nigeria imported about 22b kg of rice to meet local requirements in the last decade; therefore, making sustained research efforts towards increasing local production is very imperative. Recent policies have placed emphasis on increasing local rice production in order to reverse import trends, and free up limited foreign reserves for use in other sectors. This cannot be achieved without properly characterizing the soils in a given area for specific land use type. The information collected from soil characterization helps in the development of land use plans, which evaluates and predicts the effects of the land use on the environment (Isitekhale *et al.,* 2014).

According to Onweremadu *et al.* (2007), characterization of soils of a given location allows the acquisition of soil and soil-related data which are very needful in the sustained soil resource utilization. Similarly, soil resource cannot be maximised without detailed information and understanding of the soils characteristics (Idoga *et al.,* 2005). Therefore, the need to adequately collect information about soil resources is very important due to challenges arising from misuse of soil resources and the consequent environmental degradation. Characterizing the soils subjected to rice production would help meet our food demand by increasing productivity, as this would help identify the nutrients deficient in the soils for rice production and give management measures to remedy the identified deficiencies. The Significance of this study was to enhance the knowledge and understand different morphological, physical and chemical properties of soils in order to propagate judicious and sustainable use of the soil resources under rice production. The major objective of this study was to evaluate the morphological, physical and chemical characteristics of the soils of Amangwu-Edda rice field at Afikpo-South LGA of Ebonyi State for sustainable rice production.

Materials and Methods

Study Area

The study was conducted at Amangwu-Edda in Afikpo South LGA of Ebonyi State, South-East Nigeria, located between latitude 5° 53″ and 5° 46′ N and longitude 7° 48′ and 7° 56′ E. It is bounded in the North, East and West by Ohazara, Afikpo North and Ivo LGAs of Ebonyi State and in the South by Ohafia LGA of Abia State. The area has a tropical climate with dry and wet seasons. The mean annual temperature amounts to 27°C and 31°C for minimum and maximum respectively, with bimodal rainfall pattern. The mean annual minimum rainfall is 1800mm while the mean maximum rainfall is 2000mm spread between April to early November. There is short spell in August referred to as 'August break'. At onset of the rainfall, it is violent and torrential lasting for 1-2 hours. The relative humidity (80%) is highest during the rainy season, and declines to 60% in the dry season, especially the north-easterly harmattan (Ofomata 1975). According to Keay (1959), the study site is within the boundary between the dry Forest Zone and the derived Savannah Zone, but the greater proportion in the derived Savanna Zone. The land use is mainly crop farming based on rainfall.

Pedological Study

A reconnaissance survey was carried out before field operations to familiarize ourselves with the study area. Two hundred and fifty hectares (250ha) of land which were demarcated with the aid of Global Positioning System (GPS) Receiver Garmin Ltd Kansas, USA was surveyed. The overall micro-relief of the surveyed areas consists of slightly undulating to gently sloping terrain of not more than 4% gradient. A detailed soil survey using the rigid grid format was conducted. Transverses were cut along a properly aligned base line at 100m intervals, while Auger borings were made at 25cm interval to a depth of 100cm. Morphological (colour, texture, structures, consistency and inclusions) features were fully described and used to establish soil boundaries and units. Based on similarities and differences from these morphological features, three mapping units were delineated, and three profile pits dug in each mapping unit measuring 2m x 1m x 2m, for mapping unit I, while those in the remaining two mapping units could not get to the required depth because of the water table. Sampling points were geo-referenced using handheld GPS receiver (Model: Garmin).The morphological characteristics of each profile pits were described according to the guidelines for profile pit description outlined in Soil Survey Manual (Soil Survey Staff, 2006). The pedons were clearly demarcated based on depths of genetic horizons and sampled horizon by horizon, starting from bottom to avoid contamination. All the soil samples collected from the profile pits were transported to soil science laboratory of National Root Crops Research Institute (NRCRI), Umudike, air dried, gently ground, and sieved using a 2mm sieve, preparatory for laboratory analysis. Samples for total N and OC were passed through a 0.5mm sieve. A representative profile pit was selected from the three profile pits in each delineated mapping unit.

Laboratory Analysis

Particle size distribution (PSD) was measured by Bouyoucous hydrometer method after the procedure of Gee and Bauder (1986).Soil pH was determined using the Jenway 3510 pH meter in both distilled water and 0.1N KCl. It was read off at a ratio of 1:2.5 for soil in distilled water and 1:2.5 for soil in 0.1N KCl solution (Thomas, 1996). Total N was determined by Kjeldahl digestion method (Bremmer 1996). Available phosphorus was determined using Bray II method as described by Olson and Sommers (1982). OC was determined by wet digestion method (Nelson and Summers, 1982). Thereafter, organic matter was derived by multiplying OC by 1.724 (Van Bemulline's correlation factor). Exchangeable base were extracted with 1N NH_4O_{AC} solution, with exchangeable calcium and magnesium obtained by EDTA titration. Exchangeable potassium and sodium were estimated by flame photometry (Jackson, 1962). Exchangeable acidity was determined by 0.1N potassium chloride extraction method (Mclean, 1982). Percentage base saturation was determined using the formula;

$$\%\text{BSat} = \frac{\text{Total Exchangeable Base (TEB)}}{\text{ECEC}} \text{x} \frac{100}{1}$$

Data Analysis

Coefficient of variation (CV) as used by Wilding (1994) was utilized to estimate the degree of variability existing among soil properties in the study site. Percentage coefficient of variation was determined thus;

$$\text{CV (\%)} = \frac{\text{Standard Deviation}}{\text{Mean}} \text{ X } 100$$

Results and Discussion

Soil morphological properties

The morphological characteristics of the soils in the soil mapping units studied are shown in Table 1. The soils were all matured based on the evidence of argillic horizons and lessivage in the entire soil mapping units studied. The processes of eluviation, lessivage and illuviation observed were responsible for high clay content at the Bt than Ap horizon in the mapping units (Chukwu, 1997). The soil colour showed that the mapping units have different colour matrix as follows; In mapping unit I, the soil colour brown 7.5YR 4/6 when moist at Ap horizon, was reddish brown 5YR 4/6 when moist at the AB horizon, and grayfish yellow brown 10 YR 7/1, 4/1 when moist at the sub-surface horizons. In mapping unit II, the soil colour brown 7.5YR 4/3 when moist at the Ap horizon, and grayish brown 7.5YR 5/2 when moist at the sub-surface horizon. However, mapping unit III had a soil colour of dark gray 7.5 YR 4/1 when moist, and grayfish brown 7.5YR 5/1 in the entire horizons. The soil colour observed in all the mapping units is in conformity with the findings of Lekwa and Whiteside (1986) who worked on similar soils. The drainage condition, parent material and physiographic position may have influenced the soil colour matrix of the mapping units studied, the effect of colour variation also further agrees with the findings of Esu *et al*. (2008). It was observed that the mapping units have sub angular blocky structure in all the horizons except for the Ap horizon of mapping unit I that had crumb structure. Majority of the horizons had an abrupt and smooth boundary, while few horizons had a clear and smooth boundary. The Ap horizons of the entire mapping units had many fine roots. Mapping unit I is very deep and well drained, while mapping units II and III are also deep but poorly drained. The deep nature of the soils in all the mapping units can be attributed to the nature of the parent materials of the soils, which FMANR(1990), had reported earlier, This can also be attributed as a result of the loose nature of the parent material, and environmental factors. The textural class of the study area appears loamy in composition with some clay and silt concentration. Mapping unit I had a texture of loam (L) at the Ap and AB horizon, silt loam at the Bt_1 horizon, clay loam at the Bt_2 and Bcg horizons, while silty clay loam was observed at the Bt_{3g} horizon. However, soil mapping unit II had loam (L) at the AP and Bt horizons, while AB and B horizon recorded clay (C) and clay loam (CL) respectively. Mapping unit III had loam (L) at the Ap horizon, silt loam at the AB and Bt horizon, while BC horizon had silty clay loam (SCL). However, the textural classes of the mapping units agree with (Brady and Weil, 2007) that attributed differences in soil texture to the factors of soil formation.

Table 1: Morphological properties of the mapping units Studied

Horizon	Depth (cm)	Matrix Colour Moist	Texture	Structure	Consistency moist	Boundary	Roots	Drainage
			Mapping	**unit 1**				
Ap	0-30	Brown (7.5 YR 4/6)	L	1cr	vfr	a,s	m1rts	Well drained
AB	30-75	Reddish brown (5 YR 4/6)	L	2fsbk	frm	a,s	f2rts	Well drained
Bt1g	75-115	Grayish yellow brown (10 YR 7/1)	SL	3msbk	frm	a,s	f1rts	Well drained
Bt2g	115-161	Grayish yellow brown (10 YR 4/1)	CL	3msbk	vfrm	a,s	-	Well drained
Bt3g	161-180	Light Gray (10 YR 7/4)	SCL	3msbk	frm	a,s	m1rts	Well drained
Bcg	180-200	Very pale brown (10 YR 7/1)	CL	3msbk	frm	-	-	Well drained
			Mapping	**unit 11**				
Ap	0-24	Brown (7.5 YR 4/3)	L	3msbk	frm	c,s	m1rts	Poorly drained
ABg	24-62	Brown (7.5 YR 5/3)	C	3msbk	vfrm	a,s	c1rts	Poorly drained
Bg	62-96	Grayish brown (7.5 YR 5/3)	CL	3msbk	frm	a,s	-	Poorly drained
Bcg	96-120	Strong brown (7.5 YR 5/6)	L	2fsbk	vfrm	-	-	Poorly drained
			Mapping	**unit 111**				
Ap	0-14	Dark gray (7.5 YR 4/1)	L	1fsbk	Fr	c,s	m1rts	Poorly drained
ABg	14-45	Grayish brown (7.25 YR 5/1)	SL	2msbk	Fr	a,s	m1rts	Poorly drained
Bg	45-70	Grayish brown (7.5 YR 6/1)	SL	2msbk	vfrm	c,s	f1rts	Poorly drained
BCg	70-125	Pinkish gray (7.5 YR 6/1)	SCL	3msbk	vfrm	-	-	Poorly drained

Boundary: a = abrupt, b = broken, c = clear, d = diffuses, s = smooth, w = wavy, I = irregular. When a dash (-) it represent the property is not recorded
Structure: sbk = sub angular blocky, sg = single grained, c = coarse, cr = crumb, f = firm, m = medium, 1 = weak, 2 = moderate, 3 = strong
Consistency: sfm = slightly firm, frm = firm, vfrm = very firm, v fr = very friable, fr = friable
Texture: SCL = silty clay loam, SL = silt loam, L= loam, C= clay, CL= clay loam
Remarks: rts = roots, m = many, c = common, f = few, 1 = fine, 2 = medium, 3 = coarse

Physical properties

The results of the laboratory analyses on some soil physical properties are presented in Table 2. The results shows that percent sand ranged from 19.80-49.80% for soil mapping unit I, 29.80-39.80% for mapping unit II, and 15.80-29.80% for soil mapping unit III. However mapping unit III recorded the least mean value of 23.80%, while mapping unit II had the highest mean value of 34.05% of sand. The distribution of sand had no regular trend in value with depth for all the soil mapping units apart from mapping unit I that decreased with depth as observed by Onweremadu *et al.* (2009). The coefficient of variation showed that mapping unit I and III recorded a moderate variability with values of 35.94% and 24.74% respectively, while mapping unit II had low variability with value of 13.64%. The silt distribution showed that mapping unit I had a range value of 30.40%-50.40%, while 24.40%-46.40% and 46.40%-52.40% were recorded for mapping unit II and III respectively. Mapping unit II recorded the least mean value of 34.90%, and mapping unit III had the highest mean value of 50.40%, which is an indication that it possesses the highest percent of silt fraction. The percent silt as shown in the soil profiles had no particular trend of distribution with depth in all the mapping units. It was observed that mapping units I and II recorded a moderate variability with values of 21.51% and 31.86% in percent silt respectively, while mapping unit III had a low variability (5.61%) in percent silt. High silt content could be as a result of parent material and rate of pedogenesis. It was also observed that the percent clay was high in the sub horizons than the Ap horizon, but had no particular trend of distribution with depth in mapping units I and II, while in mapping unit III, it increased with depth. The clay distribution showed a value range of 19.80%-33.80% for mapping unit I, 17.80%-47.80% for mapping unit II, and 31.80-32.80% for mapping unit III. Mapping unit III recorded the least mean value of 25.75%, and mapping unit II had the highest mean value of 31.80%, which is an indication that it possesses the highest percent of silt fraction. Nuga *et al.* (2008) suggested that this higher clay content observed in the sub-surface horizon in the mapping units can be as a result of illuviation and faunal activities taking place in the area. The coefficient of variation showed that mapping unit I had moderate variability (21.19%), mapping unit II had high variability (50.09%) and mapping unit III had low variability (14.97%). The moderate to high variability recorded in mapping units I and II can be attributed to eluviations, illuviation and erosion effect on the site. The higher value of silt and clay fractions over the sand fraction in the mapping units studied is an indication that the mapping units have high native fertility, and can retain nutrient (Onyekwere *et al.,* 2011). This implies that mapping units studied can retain enough moisture for rice production. These attributes shows that these mapping units are most ideal for sustainable rice production. The electrical conductivity (EC) had value range of 5.66-13.45ds/m with a mean value of 10.91ds/m, for mapping unit I, 9.95-15.00ds/m with a mean value of 18.55ds/m for mapping unit II, and 12.04-15.93ds/m with a mean value of 18.55ds/m for mapping unit III. There was no pattern of distribution with depth in all the mapping units. The result showed a moderate variability (28.89%) at the soil mapping unit I, and low variability (18.55% and 12.75%) for the mapping units II and III respectively. The EC values of all the mapping units exceeded 4ds/m regarded as the lower limit of EC content in soils (Onyekwere *et al.,* 2001), an indication that all the mapping units were probably saline and had soluble salts. The variability in EC could be attributed to variability in salinity. Salinity will vary in the soil profiles primarily from the process of leaching and topographic effects. Surface topography plays a significant role in influencing spatial EC variation (Corwin and Lesch, 2005). He also noted that slope will determine the level and location of runoff and infiltration, which will influence the variation in water content and salinity. For sustainable rice production to be achieved in the mapping units studied, irrigation needs to be applied to enable fresh water to flush out the excess salts that led to the high salinity observed in all the soil mapping units studied.

Table 2: Physical Properties of the mapping units Studied

Horizon	Depth	Sand	Silt	Clay	Textural Class	Electrical Conductivity
(cm)		(%)				(dS/m)
Mapping unit 1						
Ap	0-30	45.80	32.40	21.80	L	5.66
AB	30-75	49.80	30.40	19.80	L	13.45
Bt1	75-115	25.80	50.40	23.80	Sil	12.02
Bt2	115-161 33.80	34.40	31.80	CL		12.52
Bt3	161-180 19.80	46.40	33.80	SiCL		8.47
BC	180-200 25.80	46.40	27.80	CL		13.33
Mean		33.47	40.07	26.47		10.91
CV		35.94	21.51	21.19		28.89
		MV	MV	MV		MV
Mapping unit 11						
Ap	0-24	39.80	42.40	17.80	L	12.04
AB	24-62	29.80	24.40	47.80	CL	9.95
Bt1	62-9	30.80	26.40	43.80	CL	14.75
Bt2	96-120	35.80	46.40	17.80	L	15.00
Mean		34.05	34.90	31.80		12.93
CV		13.64	31.86	51.09		18.55
		LV	MV	HV		LV
Mapping unit 111						
Ap	0-4	29.80	46.40	23.80	L	12.04
AB	14-45	23.80	52.40	23.80	SiL	12.83
Bt1	45-70	25.80	50.40	32.80	SiL	15.93
Bt2	70-125	15.80	52.40	31.80	SiCL	12.92
Meean		23.80	50.40	25.73		13.43
CV		24.74	5.61	14.97		12.75
		MV	LV	LV		LV

L=Loam, SL=Silt Loam, CL=Clay Loam, SiCL=Silty Clay Loam, C=Clay, CV=Coefficient of Variation, LV=low variation, MV=moderate variation, HV=high variation

Chemical properties

The result of the soil chemical properties of the mapping units studied is shown in Table 3. The soil pH (H_20) had value range of 3.8 - 4.9, with a mean value of 4.4 for soil mapping unit I, 4.3 - 4.7, with a mean value of 4.6 for mapping unit II, and 3.8 - 4.8, with a mean value of 4.3 for mapping unit III. This shows that soils of the entire mapping units were strongly acidic. The soil pH (H_20) had an irregular trend with depth in the entire mapping units. However, low variability was observed with values of 9.21% for mapping unit I, 4.21% for mapping unit II, and 11.68% for mapping unit III. These pH values were below the critical value of pH 5.0 recommended for the production of most crops in the soils of the south east Nigeria (Enwezor *et al.,* 1990). Though rice can tolerate pH level observed in the mapping units studied, but for sustainable production of rice to be achieved in these mapping units, there is need to incorporate organic materials in the soils, to reduce the soil acidity. According to Onyekwere *et al*. (2014), addition of organic fertilizer to soil reduces soil acidity, because organic fertilizer has some liming effect to the soil. The percent OC was generally low with the values ranging from 0.10 - 0.88%, with a mean value of 0.42% for mapping unit I, 0.17 - 1.31%, with a mean value of 0.75 for mapping unit II, and 1.37 - 1.94%, with a mean value of 1.13 %. The organic carbon distribution, decreased down the depth in all the mapping units except for mapping unit III that had an irregular trend with depth. However it was observed that the Ap horizons recorded the highest percent OC in all the mapping units studied. OC showed high variability at the mapping unit I (87.46%), mapping unit II (86.91%) and mapping unit III (58.72%). This result could be attributed to soil type, vegetative cover, availability of organic material and its rate of mineralization. The low organic carbon content in all the mapping units studied can be attributed to any or all of the following; inadequate supply of organic litter, bush burning, long dry season, and intensive mineralization during the rainy season (Dogie *et al*., 2008). Maintenance of a satisfactory organic matter status is essential to the production of most of the nitrogen and half of the phosphorus taken up by unfertilized crops (Von Uxekull 1986), including rice. The low OC of the soil were assumed to have contributed in part of the low soil pH. Feller (1993) reported that environmental factors determine OC content and variations in tropical soils. Total nitrogen content was generally low in all the mapping units, having value range of 0.10 - 0.41%, with a mean value of 0.16% , 0.05 - 0.28%, with a mean value of 0.17% for soil unit II, and 0.10 - 0.32%, with mean value of 0.17% for mapping unit III . The total N distribution had an irregular trend with depth in mapping units I and II, except for mapping unit III that decreased down the depth. High variability was recorded in all the mapping units. The variability and low nitrogen status of the soil mapping units studied can be attributed to crop harvest and subsequent bush and residue burning of land during dry season, as this hastens volatilization of available nitrogen, thereby depletes the soil total N. This result is in line with the findings of Sims (1990). The total N content of the mapping units studied is a reflection of the OC content of the soils. The low level also could be attributed to the intense cultivation of the soils, which normally increases the rate of mineralization of organic matter, thus negatively affecting the level of soil total N content (Senjobi, *et al.,* 2013). This result implies that there should be an increase in rice yield in these mapping units upon application of nitrogen fertilizer. The available phosphorus in the mapping units studied had value range of 13.70 - 40.90mg/kg with mean values of 24.30mg/kg for mapping unit I, 13.20 - 30.10mg/kg with a mean value of 22.45mg/kg for mapping unit II, and 16.20 - 47.90mg/kg with a mean value of 28.82mg/kg for mapping unit III. Mapping unit III had the highest value which can be attributed to organic matter (nutrient minerals) deposit. Mapping units I and III had irregular distribution of available phosphorus with depth, while it decreased down the horizon in mapping unit II. An indication that the mapping units studied have high mean values of available phosphorous. The coefficient of variation showed that moderate variability was recorded in mapping units I and II with values of 41.01% and 32.58% respectively. Mapping unit III recorded a high variability (50.11%). This phenomenon may be due to the phosphorous fixing capacity and their subsequent slow release by soils containing relatively high level of Fe and Al oxides (Coleman *et al.,* 1990). The exchangeable Calcium of the mapping units studied had value range of 2.40 - 4.02cmol/kg, with a mean value of 3.09cmol/kg for mapping unit I, 2.40 - 4.00cmol/kg with a mean value of 3.30cmol/kg, for mapping unit II, and 1.60 - 3.20cmol/kg with a mean value of 2.40% for mapping unit III. There was irregular trend in distribution of exchangeable Calcium with depth in the entire mapping units studied. The exchangeable Calcium recorded moderate variability in all the soil mapping units studied, the values are as follows: mapping unit I (20.20%), soil mapping unit II (20.70%) and soil mapping unit III (25.53%). All the mapping units studied had exchangeable Ca mean values below 4cmolkg^{-1} regarded as lower limit of exchangeable Ca in soils (Onyekwere *et al.,* 2001). The exchangeable Potassium content of the mapping units studied had value range of 0.14 - 0.46cmol/kg, with a mean value of 0.34cmol/kg for mapping unit I, 0.31 - 0.35cmol/kg with a mean value of 0.33cmol/kg, for mapping unit II, and 0.31 - 0.42cmol/kg with a mean value of 0.36% for mapping unit III, an indication that the mapping units have moderate potassium content. There was irregular trend in distribution of exchangeable potassium with depth in all the mapping units studied. The exchangeable potassium recorded moderate variability in mapping units I (38.99%) and low variability in mapping units II (5.33%) and III (12.48%). There will be a positive response in yield increase of rice upon the application of potassium fertilizer in the mapping units studied. Similarly, the Effective Cation Exchangeable Capacity (ECEC) had value range of 10.21 - 23.02cmol/kg, with a mean value of 17.97cmol/kg for soil mapping unit I, 10.05 - 17.33cmol/kg with a mean value of 17.97cmol/kg, for soil mapping unit II, and 13.88 - 19.80cmol/kg with a mean value of 17.26% for soil mapping unit III. There was irregular trend in ECEC distribution with depth in all the soil mapping units studied. The ECEC recorded moderate variability in soil mapping units I and II with the following values: mapping unit I (24.04%) and mapping unit II (22.48%), while soil mapping unit III had a low variability value of 11.79%. The low ECEC content of the mapping units studied can be attributed to leaching of most basic cations from the exchangeable complex dominated by exchangeable acidity (Donahue *et al*., 1990). Also, high rainfall duration and intensity may have increased leaching of basic cations (Oti, 2007), even in clayey soil of the same agro-ecology. However, ECEC level can be attributed to the soil parent material. The percent base saturation (BS) of the mapping units had value range of 24.63 - 50.64%, with mean value of 32.67% for mapping unit I, 27.18 - 52.24%, with a mean value of 38.12% for mapping unit II, and 23.27 - 30.78%, with a mean value of 26.74% for mapping unit III. There was irregular trend in % BS distribution with depth in all the mapping units. The percent base saturation recorded moderate variations (mapping unit I, 28.82 % and mapping unit II, 27.49 %), while low variability is recorded by mapping unit III (11.79%). The variability could be attributed to leaching and effect of runoff on basic cations.

Table 3: Chemical Properties of the Mapping Units Studied

Horizon	Depth (cm)	pH(H_20)	OC ←(%)→	TN	Av.P ($Mgkg^{-1}$)	Ca ←	Mg	Na (Cmol kg)	K →	EA	ECEC	Bsat (%)
Upper slope												
Ap	0-30	4.1	0.88	0.31	40.90	2.80	1.60	0.54	0.23	5.04	10.21	50.64
AB	30-75	4.9	0.84	0.41	15.90	3.60	1.60	0.39	0.32	11.24	17.15	34.46
Bt1	75-115	4.5	0.51	0.10	27.20	2.50	1.20	0.20	0.46	13.34	17.70	24.63
Bt2	115-161	4.7	0.12	0.10	13.70	3.20	2.00	0.56	0.46	16.80	23.02	27.02
Bt3	161-180	3.8	0.10	0.22	20.20	2.40	1.60	0.27	0.41	11.68	16.36	28.61
BC	180-200	4.6	0.10	0.10	27.29	4.02	1.20	0.16	0.14	12.48	18.00	30.67
Mean		4.43	0.42	0.16	24.30	3.09	1.53	0.35	0.34	11.76	17.97	32.67
CV		9.21	87.46	53.41	41.01	20.2	19.64	64.48	38.99	32.67	24.04	28.82
		LV	HV	HV	MV	MV	LV	MV	MV	MV	MV	MV
Middle slope												
Ap	0-24	4.7	1.31	0.14	30.10	3.20	1.60	0.13	0.32	4.80	10.05	52.24
AB	24-62	4.3	1.31	0.28	26.00	2.40	1.20	0.17	0.35	11.04	15.16	27.18
AB	62-96	4.5	0.20	0.20	20.50	3.60	1.80	0.19	0.31	11.00	16.90	34.91
BC	96-120	4.7	0.17	0.05	13.20	4.00	2.00	0.29	0.32	10.72	17.33	38.14
Mean		4.55	0.75	0.17	22.45	3.30	1.65	0.20	0.33	9.39	14.86	38.12
CV		4.21	86.91	57.96	32.58	20.70	20.70	34.91	5.33	32.62	22.48	27.49
		LV	HV	HV	MV	MV	MV	MV	LV	MV	MV	MV
Foot slope					0.32							
Ap	0-14	3.9	1.94	0.32	19.20	1.60	1.20	0.42	0.34	10.32	13.88	25.65
AB	14-45	3.8	0.80	0.15	16.20	3.20	2.00	0.37	0.37	13.36	19.30	30.78
Bt_1	45-70	4.6	0.42	0.12	32.00	2.00	1.20	042	0.31	12.96	16.89	23.27
Bt_2	70-125	4.8	1.37	0.10	47.90	2.80	1.60	037	0.42	13.84	19.03	27.27
Mean		4.28	1.13	0.17	28.82	2.40	1.50	039	0.36	12.62	17.28	26.74
CV		58.72	58.24	50.11	30.43	25.53	7.01	13.03	12.48	14.51	11.79	11.68
		LV	HV	HV	HV	MV	MV	LV	LV	LV	LV	LV

OC=Organic Carbon, TN = Total Nitrogen, Av.P = Available Phosphorus, K = Potassium, EA = Exchangeable Acidity, ECEC = Effective Cation Exchangeable Capacity, BSat,=BaseSaturation, CV=Coefficient of Variation, LV=low variation, MV=moderate variation, HV=high variation

Conclusion

Based on the analytical result of the mapping units studied, it was observed that most of the soil nutrients were low. Therefore, for sustainable rice production to be achieved in these mapping units, farmers should increase the organic carbon base of the mapping units by incorporating rice husk, harvested residue and other organic input. The following rate of NPK fertilizer are recommended for rice production in the mapping units; 80kg N, 40kg P_2O_5, 40kg K_2O ha^{-1} sourced from Urea, Single Super Phosphate and Muriate of Potash respectively. Farmers should also embrace environmental friendly practices, and avoid indiscriminate bush burning that destroys the soil biological system, and also leads to volatilization of some soil nutrients.

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