PAT June, 2021; 17(1): 30-39 ISSN: 0794-5213
Online copy available at *www.patnsukjournal.net/currentissue*
Publication of Nasarawa State University, Keffi

Effects of Topography on some Properties of Soils along a Toposequence in Federal University, Dutse, Jigawa State, Nigeria

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Abstract
This study was to assess the influence of topography on soil properties along a toposequence in Federal University Dutse Research Farm, Jigawa State, Nigeria. Three representative pedons upper, middle and lower slope were studied. Soil samples were collected randomly from each soil layer and replicate three times. Data obtained were subjected to analysis of variance (ANOVA) using Minitab (version 19) software package. The results revealed that the colour surface of upper and middle slope was dark yellowish brown (10YR3/4) while the lower slope was dark grayish brown (10YR4/4). The texture of the surface horizon varied, the upper slope had sandy loam while the middle and lower slope had sandy clay loam with bulk density values ranging from 1.42, 1.43 to 1.46 g cm^{-3} at surface for upper, middle and lower respectively. The pH was acidic to neural with mean values of 5.62, 5.65 to 6.97 for all the profiles. Total nitrogen was low 0.07, 0.07 and 0.08 gkg^{-1} exchangeable bases were medium to high and cation exchange capacity was low and significantly different at middle slope 6.44 cmol (+) kg^{-1}. Available phosphorus was rated low, middle slope 0.08 mgkg^{-1} was found significantly different from the upper and lower slope.
Keywords: Soil, Morphological properties, Landscapes, slope positions and Toposequence

Introduction
For soil to be productive it depends on its physical and chemical properties. These properties are as a result of interaction among soil forming factors and processes (Esu, 2010). Soil properties differed significantly among soil types and across positions reflecting differences in climate and parent material (Elias, 2019). Topography has effect on soil morphological, physical and chemical properties and also influence the pattern of soil distribution over landscape even when soil are developed from the same parent material (Suleiman, *et al*., 2017). The distribution of clay contents, sand and soil pH on a landscape affects the position of the slope in an area. Differences in soil properties due to slope position differ due to degree of deposition and transportation of soil materials (Shemele and Armayahu, 2013). Some part of the University farm consist of slope terrain which are used for crop production The variability of the soil properties may affect the distribution of the water and influence fertility status of the soil (Brandy and Weil, 2005). On the other hand sloppy terrain contributes to degradation and washing away of top soil which in turn reduce the productive capacities of soils. Therefore, understanding soil properties and their distribution over a landscape is important for sustainable agriculture and preserves the potential of a soil. Information gathered from the soil analysis of data obtained from the toposequence is useful in explaining status of soil properties of an area. Therefore, this study was undertaken to evaluate the effect of topography on morphological, physical and chemical properties of soils of toposequence in the research farm of Federal University Dutse, Jigawa State.

Materials and Methods

The Study Site Is Located At University Research Farm of Federal University Dutse, Jigawa State on latitude 11^0 46' 39N and longitude 9^0 20 3E. The area falls within Sudan savannah agro-ecological zone. The climate of Jigawa State falls within wet and dry season, generally hot semi-arid tropics. The rainy season starts at the end of May and lasts till September with maximum rainfall in August. The average annual rainfall is 650 mm, whereas the mean minimum and the mean maximum temperature are 32 to 41°C (Bidoli *et al*., 2012). The site has approximately a total of 46.11 hectares, some parts of the land is used for cultivation of crops such as millet, sorghum, cowpea and groundnut. Others part of the farm is used for rearing large and small ruminants, the remaining parts are used for grazing. The vegetation consists of short grass and shrubs.

Field Survey

A reconnaissance survey was carried out in the study area before the actual field work. Soil characteristics were determined along a toposequence using a Munsell soil colour chart. The toposequence was divided into three namely upper, middle and lower slopes. Three profile pits (1.5 x 2 meters) one in each slope category, were excavated on the toposequence, the geographical poisoning system (GPS) was used to take the coordinates. Physiographic position, topography and colour were used to create soil boundaries. Soil profiles were described according to Soil Survey Staff (2014) and soil samples were collected from every identifiable horizon while collection of bulked sample was made from each horizon for laboratory analysis.

Laboratory Analysis

Particle size analysis was carried out using Bouyocous hydrometer method (Gee and Bauder, (1986), sodium hexametaphosphate was used as dispersing agent. The soil texture was obtained using The USDA textural triangle. Bulk and particle density was measured by (Blake and Hartge, 1986) method .The value of porosity was calculated from particle and bulk density using the relationship P= (1- Bd/Pd x 100), where P = porosity, Bd = Bulk density, Pd = Particle density. Soil pH was determined using a glass electron pH meter in soil: water ratio of (1:2.5). Electrical conductivity was obtained by (Jackson, 1967) 20 ml of distilled water was added to the solution of 1: 2.5 soil water suspension used for pH determination. Cations exchange capacity (CEC) was determined by 1N NH_4OA_C solution buffered at pH 7. The absorbed$NH_4^+$was washed with 100 ml alcohol to remove excess $NH_4$to replace by 100 ml 1 N K_2SO_4 then analysed the displaced NH_4 with an auto analyser (Chapman, 1965). Exchangeable bases (Ca^{2+}, Mg^{2+}, K^+ and N^+) were extracted by 1 N neutral ammonium acetate (NH_4OA_C) solution and amount of Ca and Mg in solution measured by atomic absorption spectrophotometry, while K and Na were determined by using a Flame Photometer (ISRIC/FAO. 2002). Available P was measured by Bray 2 method (Bray and Kurtz, 1945). Organic carbon was obtained by (Wakley and Black (1965) method of wet combustion involving oxidation of organic matter with potassium dichromate ($K_2Cr_2O_7$) and sulphuric (H_2SO_4) acid. Total nitrogen was analysed by the micro-Kjeldahl digestion and distillation procedures as described by Bremer and Mulvaney (1982).

Statistical Analysis

Significant differences in chemical properties among slope positions were measured using analysis of variance (ANOVA) Minitab (version 19) software package (Pennsylvania, USA). Means were separated by the Tukey HSD test procedure at 5% level of significance.

Results and Discussion

Morphological characteristics

The selected morphological characteristics of the soils are presented in table 1. The soil colour of upper slope varied from dark yellowish brown (10 YR 3/4) at surface overlain by brown (7.5YR 4/4) to light yellowish brown 10YR 6/4) at subsurface. The Ap horizon was free of mottled indicated it was well drain. The middle slope had dark grayish brown at surface (10YR 4/2) overlain by brown (10YR 5/3), yellowish brown (10YR 5/6 and reddish brown (7.5 YR 6/6) at subsurface. The lower slope had dark yellowish brown. (10 YR 4/2) at surface overlain several shades of yellowish brown (10YR 5/4), (10YR 5/6) to brown 7.5 YR4/4) at subsurface. The colour differences was due to biological processes which was influenced by organic matter and topography (Lawal *et al.,* 2014) Weak sub angular blocky structure was observed at soil surface and changes to moderate sub angular blocky at subsurface across the profiles. The subsurface of all profiles are poorly structured because of illuviation that accumulates clay particles at B-horizons. Very friable to friable consistency was observed across the soil profiles,

Table 1: Selected morphological properties of the three soil profiles in the study area

Depth (cm)	Horizon	Colour moist	Structure	Consistency moist	Texture feel	HB
0-10	Ap	10YR3/4	W SB	VFR	SL	CS
10-44	B	7.5YR4/4	W SB	VFR	SL	DS
44-88	Bt_1	10YR5/4	M SB	FR	SCL	D
88-150	Bt_2	10YR6/4	M SB	FR	SCL	D
0-11	Ap	10YR4/2	W SB	FR	SCL	WS
11-49	B	10YR5/3	M SB	FR	SCL	W
49-90	Bt_1	10YR5/6	W MB	FR	SCL	D
90-150	Bt_2	7.5YR6/6	M SB	FR	SCL	D
0-13	Ap	10YR4/4	W SB	VFR	SL	CW
13-50	AB	10YR5/4	W MSB	VFR	SCL	W
50-92	Bt_1	7.5YR4/4	M SB	FR	SCL	D
92-150	Bt_2	10YR5/6	M SB	FR	SCL	D

W= Weak; SB= Sub-angular blocky; M= Moderate; VFR= Very friable; FR= Friable; Texture field feel method: SL= Sandy loam; SCL= Sandy clay loam; Horizon boundary: CS=Clear and smooth; DS= Diffuse smooth; CW= Clear and wavy; D= Diffuse; W= Wavy

Physical characteristics

The surface texture of the study area is sandy loam except for the middle slope which is sandy clay loam and the subsurface horizons are classified as sandy clay loam (Table 2).Sand ranged from 70-64%, 72-62% and 73-68% for upper, middle and lower slopes respectively and decreases in soil depth in a regular trend. The highest percentage of sand was observed in lower slope, this could be attributed to the movement of sand particles caused by wind, gravity and run-off water. The result agreed with the report of (Esu *et al*., 2008) that movement of soil particles by run-off water and gravity affect soil distribution over a landscape. Generally, the study area was dominated by sand; the high percentage of sand may be due to the parent material rich in quartz mineral (Brandy and Weil, 2008). The trend of the distribution was in the following order, lower slope,> middle slope > upper slope. Clay ranged from 20-34%, 22-30% and 24-35% at upper, middle and lower slope and increase slightly with depth in all the profiles. The bulk density of the soil profiles varied from 1.42-1.56 g cm^{-3}, 1.46- 1.65 g $cm^{-3}$and 1.43-1.50 g cm^{-3} for upper, middle and lower slope respectively. The values of the bulk density at subsurface is higher than the values of surface and increased with depth. This could be as a result of natural compaction of subsurface soils caused by the overlying horizons and distribution of organic matter content (Malgwi and Abu, 2011; Abyneh, 2005). As the organic matter of the soils decreased, the bulk density increased and the soils pore space was also reduced. Plants perform best in bulk densities lower than 1.4 and 1.6 for clayed and sandy soils respectively (Sharu *et al*., 2013). The total bulk density of all the soils profile falls below the ideal value for crop production < 1.2 -1.8 gcm^3 (Brandy and Weil, 2008). The particle density of surface horizons in upper and middle is higher than lower slope and increased irregular with depth, This is related to soil compaction as a results of intensive farming and may also be linked with nature of the parent material. The values ranged from 2.86-2.67 gcm^3, 2.83-2.64 gcm^3 and 2.61-2.90 gcm^3 at soil surface and subsurface respectively. The porosity values ranged from 50.35 -45.69%, 48.40-43.19% at surface and subsurface respectively. The values at surface horizon is higher compare to subsurface horizon and showed decreasing trend with soil depth signifying more activities of microorganism on surface soils which increased aggregation. Porosity of 45- 50% volume are good for agricultural soils(FAO, 2006).The porosity values recorded in all surface of soil profiles falls below the ideal porosity value.

Table 2: Selected physical properties of the three soil profile of the study area

Depth (cm)	Horizon	Particle size Distribution (%) Sand	Silt	Clay	Textural class	BD (g cm^{-3})	PD (g cm^{-3})	Porosity (%)
0								
10-44	B	70	10	20	SL	1.45	2.67	45.69
44-88	Bt_1	66	12	32	SCL	1.47	2.50	41.20
88-150	Bt_2	64	22	34	SCL	1.56	2.60	40.20
						1.48	2.63	44.00
0-11	Ap	72	6	22	SCL	1.46	2.83	48.40
11-49	B	70	8	20	SCL	1.50	2.64	43.19
49-90	Bt_1	60	10	24	SCL	1.58	2.60	39.23
90-150	Bt_2	62	4	30	SCL	1.65	2.50	34.00
0-13	Ap	73	10	24	SL	1.43	2.61	50.15
13-50	AB	71	9	26	SCL	1.45	2.90	46.01
50-92	Bt_1	65	12	26	SCL	1.48	2.85	44.15
92-150	Bt_2	68	6	35	SCL	1.50	2.58	43.19

BD= Bulk density; PD= Particle density; SL= Sandy loam; SCL= Sandy clay loam

Chemical characteristics

The soil pH are moderately acidic to neutral, the mean pH values of the soils were 6.97, 5.65 and 5.62 for upper, middle and lower slopes respectively (Table 4). The pH was observed to decrease or increase irregular with increasing depth. Based on the ratings of Chude *et al.,* (2011), a pH range of 5.6- 7.2 are ideal for availability of most plant nutrient. This is also in conformity with Suleiman *et al.,* (2017) stated that pH ranged at these values influenced the uptake of minerals and provides the best condition for growing crops. There was variation in soil levels from the statistical analysis. Upper slope had mean of 6.97 indicated neutral and was statistically higher (5%) than that of middle and lower slope. The electrical conductivity was low in all the horizons and the values were < 0.1 dS m^{-2} signifying the soils was non-saline (Scianna *et al*., 2007) The exchangeable bases of the soils indicated that calcium (Ca^{2+}) was dominant cations followed by Magnesium (Mg^{2+}), potassium (K^{+}) and sodium (Na^{+}) (Table 3). Chude *et al*. (2011) revealed that exchangeable Ca and Mg contents are the principle cations found in the soils. Ca and Mg were moderate and higher in lower slope compare to upper and middle slope indicating the movement of nutrients contents from upper to lower slope. There was significant difference in Ca and Mg contents of the soils. Lower slope had the highest values of Ca and Mg contents with mean values of 5.44-1.09 cmol (+) kg^{-1} and was found significantly different from upper and middle slope. K was also moderate in all the profiles, with the highest value of 0.25cmol (+) kg^{-1} at upper slope. This is due to application of fertilizer at upper slope which increase K availability. K mean values of the soils differed significantly (5%) in the three soil profiles. Upper slope (0.25 cmol (+) kg) was highly significantly different from middle and lower slope (0.11- 0.14 cmol (+) kg).Na was rated low in all the profiles reason has been stated earlier with values of electrical conductivity. The trend of distribution of cations in good agricultural soils are in order of ca^{2+}> mg^{2+}> k^{+}> Na^{+} and any changed happened from this trend can cause nutrients imbalance problems for plants (Adegbite *et al.*, 2019). The CEC of the soils were categorized under medium with the mean values of 6.69, 6.44 and 6.81 cmol (+) kg^{-1} at upper, middle and lower slope respectively (Table 4). The CEC showed slight variation with depth and higher at surface soils. Middle slope was found to be statistically different from upper and lower slope and has the lowest mean (6.44 cmol (+) kg). This could be related to movement and leaching of some exchangeable cations by water as a result of slope positions. The mean values of organic matter were 1.03, 1.21 and 0.81% at upper, middle and lower slope respectively. Organic matter is generally low in all the soils, according to nutrient ratings by FAO (2006b). The values were higher in the surface soils compare to subsurface soil due to fallen of leaves, plant residues and twigs which increase microorganism activities. Based on findings of Fikadu *et al.*, (2018) reported that organic matter is higher on surface soils when compare to subsurface. The low organic matter may be as a result of the removal of crop residues carried out by the farmers in the farm which if left can decomposed and form organic material (Sharu *et al.*, 2013). Also continues cultivation and land clearing can lead to depletion of organic matter contents. Studies from (Habtamu *et al.*, 2009) shown that continues cultivation and removal of crop residue had tremendously effect on organic matter and total nitrogen contents under cultivated land as compared to uncultivated land. There was no significant difference between the organic matter levels of the soils. The total nitrogen mean values ranged from 0.07, 0.07and 0.08 gkg^{-1}at upper, middle and lower slope. The total nitrogen values of the soils changed irregularly with soil depth. Total nitrogen values were low, implying that organic matter is the source of nitrogen in the soils (Abagyeh, 2017). Statistically there was no significant difference in the total nitrogen values within the three soil profiles. The mean values of available phosphorus were 2.08, 0.08 and 2.50 $mgkg^{-1}$ at upper, middle and lower slope. The values was rated low across the soil profiles, middle slope (0.08%) at (5%) was found significantly different from the upper and lower slope.

Table 3: Selected chemical properties of the three soil profile of the study area

Depth (cm)	Horizon	pH	EC (dS m^{-1})	Exchangeable bases cmol (+) kg^{-1} Ca	Mg	K	Na	CEC Cmol (+) kg^{-1}	OC (%)	OM (%)	Total N (gkg^{-1})	Av. P (mgkg^{-1})
0-10	Ap	7.2	0.14	5.45	1.05	0.18	0.12	6.80	10.31	1.78	0.09	3.10
10-44	B	6.8	0.01	5.39	0.96	0.24	0.15	6.74	0.70	1.20	0.09	2.30
44-88	Bt_1	6.9	0.03	5.35.	0.82	0.28	0.18	6.63	0.58	0.99	0.06	1.20
88150	Bt_2	4.5	0.05	5.29	0.77	0.32	0.24	6.62	0.10	0.17	0.07	1.74
0-13	Ap	5.2	0.03	5.41	1.04	0.17	0.12	6.74	0.69	1.83	0.08	0.10
13-50	B	5.6	0.01	5.36	0.79	0.11	0.13	6.39	0.60	1.31	0.07	0.09
50- 92	Bt_1	6.1	0.02	5.31	0.87	0.08	0.16	6.42	0.40	0.77	0.08	0.08
92150	Bt_2	5.7	0.01	5.24	0.72	0.09	0.19	6.24	0.52	0.94	0.07	0.06
0-11	Ap	5.5	0.02	5.491.	1.15	0.22	0.13	6.99	0.73	1.26	0.10	3.3
11-49	AB	5.4	0.01	5.46	1.12	0.15	0.11	6.84	0.52	0.90	0.09	2.6
49-90	Bt_1	6.4	0.01	5.43	1.09	0.12	0.12	6.76	0.46	0.79	0.08	2.9
90-150	Bt_2	5.2	0.01	5.39	1.00	0.09	0.18	6.66	0.81	0.31	0.06	1.2

Table 4: Summary of statistical values of chemical properties of the studied soil

Slope type	pH	EC (Ds m^{-1})	Ca	Mg	K	Na	CEC cmol (+) kg^{-1}	OC (%)	OM (%)	Total N gkg^{-1})	Av.P (Mgkg^{-1})
Upper slope	6.97a	0.07a	5.37b	0.90b	0.25a	0.17a	6.69a	0.60a	1.03a	0.07a	2.08a
Middle slope	5.65b	0.01a	5.34b	0.85b	0.11b	0.15a	6.44b	0.55a	1.21a	0.07a	0.08b
Lower slope	5.62b	0.01a	5.44a	1.09a	0.14ab	0.13a	6.81a	0.63a	0.81a	0.08a	2.50a
SE (+)	0.204	0.014	0.013	0.057	0.035	0.010	0.043	0.138	0.137	0.016	0.358

Means followed by the same letter are statically similar at 5% level of significance according to tukey test

Conclusion

The study shows that topography had significant effect on soil colour, particle size distribution, bulk density and porosity, particularly surface horizon. The pH of the soils was found to be moderately acidic to neutral, which is favourable for most plants nutrients available in the soil. Statistically the pH of the upper slope has the highest value and showed significant difference among the soil profiles, indicating current status of soil environment in term of topographic position and land use. Exchangeable bases (Ca, Mg, K and Na) were rated medium and presently adequate to sustain crop production. Lower slope had the highest content of Ca and Mg and showed significant difference from upper and middle slope. Organic matter, total N, and available P are low, for better agricultural sustainability management, soil organic matter should be given priority as its plays vital role in soil physical, chemical and biological properties. Also incorporation of organic residues and application of fertilizer should be encouraged preventive measures should be tackle to avoid bush burning.

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