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EFFECT OF SOIL DEPTH AND TOPOGRAPHY ON PHYSICAL AND CHEMICAL PROPERTIES OF SOIL ALONG FEDERAL COLLEGE OF FORESTRY, IBADAN NORTH WEST, OYO STATE

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ABSTRACT

Soil properties along a toposequence is a key to sustainable crop and soil productivity, hence the need to study the effect of toposequence and soil depth on physical and chemical properties of soil around Federal College of Forestry, Ibadan, Oyo-State. Four profile pits were dug along the toposequence in Federal College of Forestry, Ibadan, Oyo-State. Soil samples were collected from three soil depth (0 - 30 cm, 30 - 45 cm, and 45 - 60cm) from four profile pits that was dug along the toposequence, (crest, sedentary, middle and valley bottom) for analysis of physical, morphological and chemical properties following standard procedures at the laboratory. The results showed that the consistency of the soil in profile pit 1 (crest) is slightly sticky and slightly plastic compared to soil in profile pit 2 (sedentary) that is predominantly non-plastic while profile pit 3 and 4, (middle/creep and valley bottom) are non-plastic, non-sticky, slightly sticky. The highest total porosity values was recorded at the valley bottom of the forest (57.74 %), followed by middle of the forest (53.21 %) while the least was by crest of the forest (51.7 %). The highest saturated hydraulic conductivity was recorded at the crest of the forest (15.91 cm hr^{-1}) and the least by valley bottom of the forest (8.44 cm hr^{-1}). Likewise bulk density values at the crest of the forest (1.28 g cm^{-3}) was the highest compared to valley bottom of the forest (1.12 g cm^{-3}). The highest (52 mg kg^{-1}) and the lowest (1 mg kg^{-1}) available P values were recorded at the valley bottom layers of the forest land soils and sedentary of the forest land soils, respectively. The highest exchangeable Ca was found in the valley bottom of forest soils (4.44 cmol kg^{-1}) at the upper topographic position, whilst the lowest values were recorded at the crest layers of forest soils (1.2 cmol kg^{-1}) at the middle topographic positions. Thus, it was concluded that the soils position on the topography affects the composition of the soil at each sampling point. This indicated that landscape in the study area affects the process of soil formation. Therefore, integrated soil fertility management and soil conservation measures are required in all topographic positions to maintain soil physicochemical properties.

Key words: Toposequence, soil profile, physical properties, chemical properties

INTRODUCTION

Topography is one of the major factors of soil formation that influences the way soils develop. It is both an internal and external factor of pedogenesis that influences soil formation (Wang *et al*., 2001). Biswas (1997) described the influence of topography in soil formation as the up and down nature of soil surface. He described the topography as a relative elevation or in-equalities of land surface considered collectively. Soil slope is the incline of the surface of the area to the horizon. Topography influences soil formation through its effects on drainage, run off, soil erosion and microclimate. Topography also relates to the configuration of the land surfaces and is described in terms of differences in elevation, slope and landscape position, also it relates to the underlying parent rock in the basement complex (Oluwatosin and OjoAtere, 2001). Topography also gives rise to toposequence of related soils from the same parent materials about the same age and occupying under similar climatic conditions but have differences in their characteristics due to change in slope (Brady and Weil, 2007). Stoop, (1978) observed a high degree of variability in crop stands and low average of productivity on the West African landscape and noted that crop field tends to decrease from fertile valley bottom soil to generally infertile up lands. (Oluwatosin and OjoAtere, 2001) noted that in spite of these reported that variability in soil properties and crops yield along the toposequence, recommendation for agronomic practices are often made to farmers without due consideration for specific topographic locations that might influence the management options such as fertilizer rate and types, tillage operations and herbicides application. This brings about sharp variation to crop yield. Moorman, (1981) noted that an understanding of the basic soil is essential for developing soil management practices that will maintain the productive potential of the soil. There is the movement of water from the crust of a toposequence to the valley bottom and this influences the distribution of soil organic matter, microorganisms, vegetation and chemical properties, thus affecting such physical properties of soil as bulk density and hydraulic conductivity (Ksat) at different level of the toposequence. Consequently, estimations of rates of water movement through soil and underlying strata is pertinent in many soil management decisions.

The physical and chemical properties of soil are influenced by slow positions from the upper slope, middle slope and lower slope and are characterized by variations in the horizon within each of the slope position and profile. Each of the slopes is affected at different levels as parent materials are eroded from the upper slope downwards, nutrient elements, water and gradience also moves downward and accumulates at the lower slope. This action continues and brings about variations in the soils over a period of time. Differences in soil properties due to slope position differ due to degree of detachment, transportation and deposition of soil materials. Understanding soil properties and their variation is important for their sustainable utilization and proper management. The concept of slope position which involves processes that cause properties differentiation along hill slopes and among soil horizons have improved evaluating the interaction pedogenic and geomorphic processes. Also, differences in soil formation along hill slope result in differences of plant and litter production and decomposition (Wang *et al*., 2001).

Effective land use management for crop production on a landscape therefore requires knowledge of both physical and chemical properties of the soil at different slope positions. Despite the potentials to produce some cash crops and food crops on the land, farmers are facing problems of declining productivity and nutrient loss through the action of erosion.

In the study area, topography shows its impact through its effect on drainage, runoff, soil erosion and microclimate. To improve the nature of agricultural production, there is the need to identify soil related problem that impedes plant growth. The starkly realities of the twenty first century is that, human population are increasing while the food supply is likely to decline because of degradation and urbanization (Oluwatosin and OjoAtere, 2001). Thus, to survive as a species; there is need to improve the deficiency and sustainability with which the soil resources can be managed. Therefore, the objective of the study was to examine the variation of soil morphological and chemical properties along a toposequence along Federal College of Forestry, Ibadan North West Local Government Area of Oyo State.

MATERIALS AND METHODS

Study Location

The experiment was carried out at the Federal College of Forestry (FCF), Ibadan, Oyo State. FCF lies on latitude 07^{o}23$^{'}$N and longitude 03^{o}15$^{'}$E. The climatic conditions of the area are tropically dominated by rainfall pattern from 1400 mm - 1500 mm the average temperature is about 32^{o}C, relative humidity of 80-85 and ecological climatic of the area experience rainfall with two distinct season, dry season from November to March and rainy season from April to October.

Soil Sampling Technique

Four profile pits were dug along the toposequence (crest, sedentary, middle and valley bottom) in the study area. The profile pits were excavated to a depth of 2 m having 1 m width and 2 m length dimension. Soil morphological descriptions were done using guidelines of the survey staff (1992). From each soil layer, undisturbed samples were collected with metal cylinders of 6cm height and 3cm internal diameter. The soil was secured with a piece of calico tied round the cylinder and was also held firmly with a rubber band and the core samples were properly label for identification. Likewise, disturbed soil samples were also collected from each identified horizons in the profile pits (i.e. soil depth 0 - 30 cm, 30 – 45 cm, and 45 – 60 cm) from bottom to the top with the aid of hand trowel and the soil was temporarily stored in labeled polythene bags for movement into the laboratory for analysis.

Laboratory analysis

The collected samples were air dried at room temperature in the laboratory before passing through a 2 mm diameter sieve. From a sub sample of the sieved soil, the Soil pH was determined with pH meter using glass electrode in 1:1 soil to water ratio (Udo and Ogunwale, 1986), another sample was extracted with 1 *N* NH_4OAc while Na and K were determined in the extract using flame photometer whereas Mg and Ca were determined with Atomic Absorption Spectrophotometer (AAS). Organic carbon was determined by the walkey-black wet oxidized procedure (SSSA, 1992). Particle size distribution was determined using hydrometer method (Bouyoucos, 1962). Extractable Micronutrients were determined with AAS, Total nitrogen was determined using micro-Kjeldahl method while Available Phosporus was determined using Bray-1 method (Nelson and Sommers, 1996). Bulk density was determined by core-sampling method (Baruah and Barthakur, 1997). Total porosity was computed from the measurements of soil dry bulk density (ρb) and soil particle density ($P\rho$) as:

$$1 - \frac{\rho b}{P\rho} \text{ x } 100\ \% \text{ ....}[1]$$

RESULTS

Soil Depth and Topography Effects on Soil Physical Properties

Effect of topography on the morphology of soils at the study area

Morphological description of soil along Federal College of Forestry is as presented in table 1. From the result, crest, sedentary, middle and valley bottom are 90cm deep with Ap horizon 0-30cm, Bt1, 30-60cm and Bt2 60-90cm. The texture of the soil in the four profile pit is sandy loam, loamy sand and sandy clay loam. The consistency of the soil in profile pit 1 (crest) is slightly sticky and slightly plastic. In profile pit 2 (sedentary) is predominantly non-plastic. While profile pit 3 and 4, (middle/creep and valley bottom) are non-plastic, non sticky and slightly sticky. The boundary of the soil at the studied area is between distinct and clear wavy boundary.

Table 1: Morphological Description of the Soils Studied

Pro file No	Depth (cm)	Texture	Structure	Consistency	Boundary	Features
Profile Pit 1						
	0-30	LS	Wfcrsbk	Ss	D	Fine root
Crest	30-60	SL	Msbk	Sp	D	Fine root
	60-90	SL	Scrsbk	Sp	Cwb	Few fine root
Profile Pit 2						
	0-30	SCL	Wfcrsbk	NS	D	Presence of all types root
Sedentary	30-60	SL	Msbk	NS	D	Many medium roots
	60-90	SCL	Scrsbk	NS	Cwb	Devoid root
Profile Pit 3						
	0-30	LS	Msbk	NP	D	Fine roots
Middle	30-60	SCL	Scrsbk	NS	D	Fine roots
	60-90	SCL	Platy	SS	Cwb	Few fine roots
Profile Pit 4						
	0-30	LS	Mfcrsbk	NP	D	Medium fine root
V/bottom	30-60	SL	Scrsbk	NS	D	Fine roots
	60-90	SCL	Scrsbk	SS	Cwb	Few fine roots

Key: LS=loamy sand,SL=sandy loam, SCL=sandy clay loam, Wfcrsbk=weak, fine crumb, subangular blocky, Scrsbk=strong coarse subangular blocky, Wmcrsbk=weak, moderate, crumb subangular blocky, Scabk= strong, coarse angular blocky, Msbk = moderate subangular blocky, mfcrsbk = moderate fine crumb subangular blocky, NS=non-sticky, SS=slightly sticky, NP=non-plastic, SP=slightly plastic, D=distinct, Cwb=clear wavy boundary.

Effect of Topography on the Particle size distribution of soils at the studied area

The effect of Topography on the Particle size distribution of soils at the studied area is as presented in table 2. The percentage of sand, clay and silt in the 0 – 30 cm horizon is 81.6 %, 12.1% and 6.3 % at the crest; 30 – 60 cm is 81.6 %, 12.1 % and 6.3 %while at 60 – 90 cm is 76.6 %, 18.1 % and 5.3 %.

Table 2. Effect of Topography on the Particle size distribution of soils at the studied area

Profile No	Depth (cm)	Sand (%)	Clay (%)	Silt (%)	Textural Class
Crest	0-30	81.6	12.1	6.3	Loam sand
	30-60	81.6	12.1	6.3	Sand loam
	60 above	76.6	18.1	5.3	Sand loam
Sedentary	0-30	73.6	21.1	5.3	Sand clay loam
	30-60	78.9	15.3	5.8	Sand loam
	60- above	75.6	14.1	10.3	Sand loam
Middle	0-30	86.9	10.3	1.8	Loam sand
	30-60	70	26.3	3.7	Sand clay loam
	60 above	69.9	21.3	8.8	Sand clay loam
Valley Bottom	0-30	82.8	11.8	5.4	Loam sand
	30-60	74.7	17.7	7.6	Sand loam
	60 above	68.7	21.7	9.4	Sand clay loam

Effect of Topography on Bulk Density, Saturated Hydraulic Conductivity and Total Porosity

The effect of topography on bulk density, saturated hydraulic conductivity and total porosity of soils in the study area is as presented in table 3. The highest bulk density values was recorded at the crest of the forest (1.28 g cm^{-3}), followed by sedentary of the forest (1.26 g cm^{-3}), followed by middle of the forest (1.24 g cm^{-3}), and least by valley bottom of the forest (1.12 g cm^{-3}). The lowest bulk density recorded at the valley bottom of the forest land soils could be attributed to the relatively high organic matter contents, whereas the highest bulk density in the crest of the forest land soils might be the result of compaction from repeated cultivation, low organic matter and weight of the overlying soil material.

Table 3: Physical properties of the soils in the study area

Profile pits	Bulk density (g/m^3)	Total porosity (%)	Saturated hydraulic conductivity (cm hr^{-1})
Crest	1.28	51.7	15.91
Sedentary	1.26	52.45	12.84
Creep/middle	1.24	53.21	10.12
Valley bottom	1.12	57.74	8.44

Soil Depth and Topography Effects on Soil Chemical Properties

Effect of Topography on Soil pH

The effect of topography on soil pH is as presented in table 4. The lowest pH (H_2O) was registered at the sedentary (4.32) of the forest land soils in the upper topographic position, while the highest was recorded at the 30-60 cm layers of the crest land soils at the lower topographic position.

Effect of Topography on Soil Organic Carbon and Total Nitrogen

The effect of topography on soil organic carbon and total nitrogen is as presented in table 4. The highest organic carbon content was recorded at the crest of the forest land soils, whilst the lowest was observed at the valley bottom of the forest soils.

Effect of Topography on Available Phosphorus

The effect of topography on available phosphorus is as presented in table 4. The highest (52 mg kg^{-1}) and the lowest (1 mg kg^{-1}) available P values were recorded at the valley bottom layers of the forest land soils and sedentary of the forest land soils, respectively. This clearly shows the significant contribution of the soil organic matter content to the P pool of the soils in the study area.

Effect of Topography on Exchangeable Cation

The effect of topography on exchangeable cation is as presented in table 4. The highest exchangeable Ca was found in the valley bottom of forest soils (4.44 cmol kg^{-1}) at the upper topographic position, whilst the lowest values were recorded at the crest layers of forest soils (1.2 cmol kg^{-1}) at the middle topographic positions. This shows the existence of some erosion from the upper topographic position and subsequent deposition at the lower position and downward leaching of this cation within the soil system. The trends observed for the other exchangeable bases, however, were not consistent. In the studied soils, Ca and Mg were the dominant cations. This is in agreement with the finding of Fassil and Yamoah (2009) who indicated that in neutral Vertisols the exchangeable cations are mainly occupied by Ca and Mg and to small extent by K and Na.

Effect of Topography on Extractable Micronutrients

The effect of topography on extractable micronutrients is as presented in table 4. As a whole, the highest mean extractable micronutrients were recorded at the surface layer of the forest land soils at the upper topographic positions, whilst the lowest values were observed in the bottom layers of forest land soils at the middle topographic positions. The highest values of micronutrients at the surface layer of the forest land could be the result of the high organic matter content, while the lowest values of micronutrients in the bottom layers of the of forest land soils could be associated to high soil pH which might be due to the accumulation of basic cations.

Extractable Fe ranged from 35 to 67 mg kg^{-1}.

Table 4: Chemical properties of the soils in the study area

Profile Depth (cm)	pH (H_2O) (2:1)	Organic compounds			A.P (mg kg^{-1})	Exchangeable Acidity	Exchangeable cations ($Cmol^{-1}$)				Extractable Micronutrients (mg kg^{-1})			
		O.C (g kg^{-1})	O.M (g kg^{-1})	T. Nit. (g kg^{-1})		Al + H	Na	K	Ca	Mg	Mn	Fe	Cu	Zn
Crest	6.06	9.9	17.2	0.7	10	1.9	7.0	0.23	1.7	6.33	104	47	13	5
	6.75	15.0	25.8	1.3	17	2.0	7.4	0.28	1.2	5.84	28	43	11	6
	6.12	18.0	31.0	1.6	17	1.75	7.6	0.79	1.25	7.89	21	38	10	5
Sedentary	4.32	28.1	48.5	2.4	1	1.5	7.8	0.49	1.35	5.51	142	67	10	1
	4.64	33.5	57.8	2.9	5	1.8	7.8	0.51	1.35	4.85	110	48	9	3
	5.04	34.1	58.8	2.9	11	1.3	7.9	2.61	3.29	14.8	18	39	10	3
Creep	6.45	32.9	56.7	2.8	32	1.4	6.2	1.02	2.45	8.06	48	46	11	5
	5.9	30.3	52.3	2.6	19	1.1	7.8	0.82	2.64	9.62	9	35	9	4
	5.2	31.1	53.7	2.7	8	1.0	7.6	7.36	1.75	8.63	5	38	8	1
Valley Bottom	5.96	35.5	61.2	3.1	52	0.7	6.7	2.23	4.44	14.8	35	43	9	4
	5.75	30.9	53.3	2.7	5	1.35	7.4	0.43	2.64	9.29	10	37	9	3
	5.65	33.7	58.1	2.9	5	1.85	0.6	2.17	1.4	46.46	8	43	7	4

DISCUSSION

The texture of the soil in the four profile pit is sandy loam, loamy sand and sandy clay loam. The consistency of the soil in profile pit 1 (crest) is slightly sticky and slightly plastic. In profile pit 2 (sedentary) is predominantly non-plastic. While profile pit 3 and 4, (middle/creep and valley bottom) are non-plastic, non-sticky and slightly sticky. The boundary of the soil at the studied area is between distinct and clear wavy boundary. At sedentary, the percentage of sand, clay and silt in the 0 – 30 cm horizon is 73.6 %, 21.1 % and 5.5 %, for 30 – 60 cm is 78.9 %, 15.3 % and 5.8 % while at 60 – 90 cm is 75.6 %, 14.1 % and 10.3 %. At the middle or creep, the percentage of sand, clay and silt in the 0 – 30 cm horizon is 86.9 %, 10.3 % and 1.8 %. For 30 – 60 cm is 70 %, 26.3 % and 3.7 %. While at 60 – 90 cm is 69.9 %, 21.3 % and 8.8 %. At the valley bottom, the percentage of sand, clay and silt in the 0 – 30 cm horizon is 82.8 %, 11.8 % and 5.4 %. At 30 – 60 cm is 74.7 %, 17.7 % and 7.6 % while at 60 – 90 cm is 68.7 %, 21.7 % and 9.4 %. The highest bulk density values were recorded at the crest of the forest (1.28 g cm^{-3}), followed by sedentary of the forest (1.26 g cm^{-3}), followed by middle of the forest (1.24 g cm^{-3}), and least by valley bottom of the forest (1.12 g cm^{-3}). The lowest bulk density recorded at the valley bottom of the forest land soils could be attributed to the relatively high organic matter contents, whereas the highest bulk density in the crest of the forest land soils might be the result of compaction from repeated cultivation, low organic matter and weight of the overlying soil material. The lowest bulk density observed in soils of the forest land could be attributed to the high organic matter contents as was also reported by Eyayu *et al*. (2009) and Mojiri *et al*. (2012). The bulk density of the studied soils was fallen with the specified range as was suggested by White (1997) who revealed that bulk density is < 1 g cm-3 in high organic matter soils to 1.2 and 1.8 g cm-3 in sands and compacted horizons in clayey soils and it is largely affected by land uses and soil depth.

The highest saturated hydraulic conductivity was recorded at the crest of the forest (15.91 cm hr^{-1}) followed by sedentary of the forest (12.84 cm hr^{-1}), followed by middle of the forest (10.12 cm hr^{-1}) and least by valley bottom of the forest (8.44 cm hr^{-1}).

The highest total porosity values were recorded at the valley bottom of the forest (57.74 %), followed by middle of the forest (53.21 %), followed by sedentary of the forest (52.45 %), and least by crest of the forest (51.7 %). These differences might be occurred due to the differences in bulk density. The highest total pore space at the valley bottom and crest of the forest land could be accredited by high organic matter contents and low bulk density as was also reported by Gupta (2004) and Brady and Weil (2008) who revealed that the amount of pore spaces and soil organic matter have inversely related to bulk density. All factors that affect soil pore spaces will also have effects on bulk density.

The lowest pH (H_2O) was registered at the sedentary (4.32) of the forest land soils in the upper topographic position, while the highest was recorded at the 30-60 cm layers of the crest land soils at the lower topographic position. The lowest pH at the surface layer of the forest land could be the result of high organic matter content, while the highest pH in the bottom layer of the cultivated land could be the result of accumulation of basic cations. The range of soil-water pH interpretation was suggested by Jones (2003), the pH of the studied soils found between slightly acidic to neutral.

The highest organic carbon content was recorded at the crest of the forest land soils, whilst the lowest was observed at the valley bottom of the forest soils. The highest total nitrogen content was recorded at the valley bottom (3.1 g kg^{-1}) of the forest land soils, whilst the lowest was observed at the crest (0.7 g kg^{-1}) of the forest soils. The highest (52 mg kg^{-1}) and the lowest (1 mg kg^{-1}) available P values were recorded at the valley bottom layers of the forest land soils and sedentary of the forest land soils, respectively. This clearly shows the significant contribution of the soil organic matter content to the P pool of the soils in the study area. In line with this, the positive effects of soil organic matter on available P, by forming organophosphate complexes that are more easily assimilated by plants and anion replacement of H_2PO from adsorption sites, were reported in different studies (Abebe and Endalkachew, 2012; Nega and Heluf, 2013; Yihenew and Getachew, 2013). As per available P ratings of Cottenie (1980), the available P content of the studied soils falls in the range of very low to very high across the profile pits and soil depth along the toposequence. Murphy (1968), Tekalign *et al*. (2002) and Abebe and Endalkachew (2012) also reported low availability of P in most soils including alfiisols and attributed this to the effects of copious crop harvest, erosion, fixation and low accumulation of soil organic matter content.

The highest exchangeable Ca was found in the valley bottom of forest soils (4.44 cmol kg^{-1}) at the upper topographic position, whilst the lowest values were recorded at the crest layers of forest soils (1.2 cmol kg^{-1}) at the middle topographic positions. This shows the existence of some erosion from the upper topographic position and subsequent deposition at the lower position and downward leaching of this cation within the soil system. The trends observed for the other exchangeable bases, however, were not consistent. The highest Fe value was found at the 0 - 30 cm soil depth of the sedentary forest land at the upper topographic position, whereas the lowest Fe was found at the 30-60 cm soil depth of the cultivated land at the middle topographic position.

Extractable Mn ranged from 5 - 142 mg kg^{-1}. The highest Mn was recorded at the sedentary soil of the forest land at the upper topography and lowest at the 60 - 90 cm soil depth of the creep/ middle of the forest land at the lower topographic position. It seems that the Fe highest values were related to the presence of high organic matter content. As per the ratings were suggested by Lindsay and Norvell (1978), most of the studied soils were medium to high contents of Fe and Mn. They were adequate for plant growths which are above the critical limit 4.5 mg kg^{-1} for Fe and 1 mg kg^{-1} for Mn. Extractable Cu varied from 7 - 13 mg kg^{-1}. The highest Cu was recorded at the crest of the forest land at the upper topography and lowest at the valley bottom layers of the forest land at the lower topography. Extractable Zn ranged from 1 - 6 mg kg^{-1}. The rating was proposed by Lindsay and Norvell (1978), the value of extractable Zn was found in the range of adequate for normal plant growth which is above the critical limits (1 - 5 mg kg^{-1}) for Zn.

CONCLUSION

The available data revealed that topography is independent of soil development. Each slope position is not interrelated as a successive stage of soil development. The soil in the study area as a whole is developing in response to the action of the environmental factors acting on the particular parent material. Differences in soil properties were caused by drainage condition, transportation of eroded material and mobile chemical constituents. Soil differentiation with slope position was not the result of pedogenic process driven by differences in moisture, leaching and vegetation but also due geomorphic process that cause erosion in some places and deposition in others. A combination of morphological evident with physical, chemical and mineralogical laboratory data suggested that landscape position affect soil development as it was observed on the differences in pedons of difference landscape positions. It was observed that the soils position on the topography affects the composition of the soil at each sampling point. This indicated that landscape in the study area affected the process of soil formation. The predominant pedogenic process that might have affected the process of soil formation are weathering and leaching of the exchangeable bases. The soils at the upper slope are observed to be easily washed away after formation because of the sloppiness of the area hence the reason for the low fertility observed from the upper slope. However, these materials washed from the upper slope are gradually sorted out and deposited along the topography studied and this is evidenced with the higher concentration of the organic matter along the toposequence down to the valley bottom.

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