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Effect of Land Use Types and Slope Gradient on Soil Physico-Chemical Properties in Upper Eyiohia River Watershed Afikpo North, Southeastern Nigeria

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A field study was conducted to determine soil physico-chemical variations under different land use types and slope gradient and generate data for management options in the study area. The watershed was delineated into two topographical units (Upstream and downstream sub catchment watershed), important land use types (cultivated, grazing and forest lands) were identified. Three composite soil samples were collected on each land use in both upstream and downstream to a soil depth of 30 cm and replicated three times to determine selected physical and chemical properties. Data generated from laboratory result were subjected to statistical analysis of variance. Result on Selected physicochemical properties as affected by land use type indicates that Bulk density (BD),Total Porosity (TP), Available Water Capacity(AWC), Field Capacity (FC), manganese (Mn) and zinc (Zn) were significantly different (p<0.05) between land use types, while Sand, Silt, BD, Particle Density (PD), Total Porosity, Available Phosphorous, manganese, zinc and cupper were significantly different (p<0.05) between upstream and downstream sub catchment watershed. Exchangeable bases (,Calcium (Ca) and potassium (K)), Cation Exchange Capacity, organic carbon and total nitrogen is rated low in the studied area and are presently inadequate to sustain the current land use.

Keywords: GIS, Land use, Physico-chemical properties, Slope gradient, Soil quality

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INTRODUCTION

Soil characteristics and distribution of soil types is necessary for planning and implementing sustainable land use, rehabilitation of degraded lands and implementing sound research on soil fertility (Alemayehu et al., 2010; Dinku et al., 2014). Scientific investigations have revealed that low fertility of the soils is the primary constraint to increased crop yields (Ogbodo, 2010). In order to evaluate the quality of our natural resources and their potential for sustainable use, detailed information on soil properties are required (Teshome et al., 2016). It is therefore, very useful to study and understand the properties of soils and their distribution over an area in order to develop management plans for an efficient utilization of soil resources (Abay et al., 2015). All soils are naturally variable in inherent properties across vegetation and underlying hydrology, with their properties changing across gradient and vertically down the soil profile (Mbagwu, 1995; Sheleme, 2011; Teka et al., 2015).

Land use and soil management practices influence the soil nutrients and related soil processes, such as erosion, oxidation, mineralization, and leaching (Liu et al., 2010). As a result, it can modify the processes of transport and re-distribution of nutrients. In non-cultivated land, the type of vegetative cover is a factor influencing the soil organic carbon content (Liu et al., 2010; Okebalama et al., 2017). Moreover, land use change often brings about considerable alterations and decline in soil fertility, thus leading to soil quality degradation after the cultivation of previously untilled soils (Neris et al., 2012).

Temporal and spatial variations in the geomorphic and hydrologic processes in the soil is an integral part of land use types and slope positions, in addition, change in land use and management practices could influence the physical, chemical as well as the biological properties of the soil (Yifru and Taye, 2011). Land use can influence soil chemical, physical and biological Properties because of different anthropogenic activities, namely tillage, livestock trampling, harvesting, planting, application of fertilizer (Getahun et al., 2014; Ketema and Yimer, 2014).

A study conducted in Nigeria (Maniyunda and Gwari, 2014) has shown that silt and clay soil fractional contents increased while sand decreased along slope gradient. Many studies have also considered the overall effect of land use and their management on soil properties (Yihenew and Getachew, 2013; Fikadu et al., 2013) and have compared croplands, forestlands and grazing lands and found that significant changes on selected physical and chemical properties of soil in the southeastern highlands of Ethiopia. Another study by Alemayehu and Sheleme (2013) also found comparable higher organic carbon (OC), total nitrogen (TN) under grassland as compared to cultivated land use types. Similarly, according to (Yihenew and Getachew, 2013), human managed land uses like cultivated and grazing land use types had more deleterious effects on soil electric conductivity (EC), pH, soil organic carbon (SOC), TN and on the overall activities of soil macro faunal in the soil. Different soil properties encountered along slope gradient will affect the patterns of plant production, litter production and decomposition, which have effects on carbon and nitrogen contents of soils (Mulugeta et al., 2012). Soil properties such as clay content and its distribution with depth, sand content and pH have been shown to be highly correlated with landscape position (Wang et al., 2000). The slope position determines or influences the chemical, physical and biological properties of the soil (Salako et al., 2006). Moreover, it also determines not only the intensity of erosion and sediment redistribution but also the local drainage capacity of the area. Slope accelerates soil disturbance through erosion and affects the soil properties considerably (Afshar et al., 2010).

In the study area, there are three major land use types (cultivated, forest and grazing lands) commonly managed by smallholder farmers. The farmers have owned fragmented land with different farm management system, which further creates soil property variation in the area. Therefore, understanding such comprehensive and multifaceted interaction on the soil would have a meaningful concern on the soil physico-chemical properties in upper Eyiohia river watershed. More importantly, understanding and evaluation of the overall situation of the soil as influenced by localized anthropogenic and geomorphic variables may be imperative in designing a sound land use for sustainable agriculture and landscape management in the area. Afikpo North where the watershed is located is the second most densely populated local government areas after the state capital Abakaliki in Ebonyi state, southeastern Nigeria with large farm size (Lagunju, 1996). However, severe soil fertility depletion and productivity decline, shrinking crop yields and ecological damages including erosions losses, leaching, reduced water retention, increased water run-off, flood and gullies are some of the adverse effects of the uncontrolled land-use and agricultural intensification in the state (Ofomata, 2011). These problems might worsen in future due to the fragile, heavily weathered and leached nature of the soils of this area upon attendant uncontrolled population pressures.

The decline in soil fertility is exacerbated by soil erosion, which is aggravated by steep slopes, poor vegetation cover and continuous cropping. Thus, different positions along slope gradient require different management practices. This is due to the complex nature of such relationship and interaction due to the sensitive impact of slope (topography) on the soil properties, which makes this relationship and interaction (slope and land use) site specific. In line with this, the magnitude and pattern of soil properties variation within specific geomorphology of the land in the study area is still unanswered.

However, the biophysical and the socio-economic setting of the farmer's experience in managing their land are quite different spatially as well as temporally in the area. In addition, evidence from previous studies in the area is less adequate to describe the extent of soil properties variation associated with land use types and slope gradient. Therefore, the objective of this study is to evaluate the soil physico-chemical variations under different land use types and slope gradient and generate data for management options in upper Eyiohia river watershed Afikpo North, southeast, Nigeria.

MATERIALS AND METHODS

Description of the Study Site

Upper Eyiohia river watershed lies between longitude 7^{o}5'1"E and 8^{o}0'0"E and latitudes 5^{o}5'5"N and 6^{o}0'0"N within the Afikpo syncline of the Cross River basin of the Benue Trough (Figure 1). The watershed occupies an area of 54,200 ha (542 km^2) and is made up of 35 communities. Afikpo is a hilly area despite occupying a region low in altitude, which rises 106.68m above sea level (Whiteman, 1982).

Geomorphology, Soil and Climate

The study area consists of highly undulating sandstone ridges and shale low lands, trending in a NE-SW direction (Ukaegbu and Akpabio, 2009). The geology of northeast of Afikpo basin consists of two major lithostratigraphic units , namely, the sandstone ridges and low-lying shales, each of which forms significant component of the Middle Albian Asu River Group and Turonian Ezeaku. The area is also marked by two significant angular unconformities; one inter formational between the Asu River Group and Ezeaku Formation, and the other intraformational within the Ezeaku Formation (Ukaegbu and Akpabio, 2009). The soil belongs to two dormant soil groups Nitosols (NT) and Gleysols (GL) (IUSS WRB, 2014**)**. The mean annual rainfall in the area ranges between 1200 -2022 mm and the minimum and maximum temperatures are 25.0°C and 27.2°C, respectively. Relative humidity is 80% during the rainy season but declines to 60% in the dry season (ODNRI, 1989). The climate is tropical when compared with winter, the summers have much more rainfall. According to Koppen and Geiger (2007), this climate is classified as Aw. The driest month is December (12) with 10 mm of rain (Figure 2). In September (09), the precipitation reaches its peak with an average of 309 mm. March (03) is the warmest month of the year. The temperature in March averages 29.0 °C. At 25.6 °C on average, August (08) is the coldest month of the year

Delineation of Watershed

The Digital Elevation Model (DEM) was used to delineate watershed boundary and stream network through 'Hydrology tool' using ArcGIS 10.1 software package to establish the upstream and downstream sub topographic units in the watershed (Figure 3). The DEM metadata was downloaded from open topography which shows high and low elevation terrain above sea level which has huge implication in determining surface run off and variability in physico-chemical properties of the soil along slope gradient.

Soil Sampling and Characterization

The land use and management practices within the watershed was characterized by virtual observation and delineated by mapping and measurement on both upstream and downstream sub-catchment watershed. Soil samples were collected from each of the identified major land use land cover change (LULCC) categories to determine selected physical and chemical properties. The soil samples were taken to soil laboratory in Department of Soil science and Environmental Management, Ebonyi State University, Abakaliki, to determine selected physical and chemical properties. The purpose was to examine the variability in soil properties as affected by land use types and slope gradient. The watershed was delineated into two topographical units (upstream and downstream sub catchment watershed). Each of the topographical position were geo-referenced with a hand held global positioning system (GPS) receiver which also gave the altitude of sampling points and the distance from one another. In upstream and downstream, important land use types (cultivated, grazing and forest lands) were identified for soil characterization and sampling. Thus, in each land use type in upstream and downstream, three composite soil samples were collected to a depth of 30 cm and replicated three times and a total of eighteen soil samples were collected (Figure 4) to determine selected physical and soil chemical properties.

Laboratory Analysis and Procedure

Soil Physical Properties

The soil physical properties determined were soil texture, bulk density (g cm^{-3}), water holding capacity i.e., field capacity at 1/3 bar and the permanent wilting point (PWP) at 33 bars, Particle density (PD) and Total porosity (TP). Soil Bulk density was determined using the Blake and Hartge (1986) method. Total porosity (TP) was calculated from bulk density values with particle density (P_D) of 2.65gcm^{-3}. Soil texture was determined and analyze for as described by Bouyoucos (1951) hydrometer method using sodium hexametaphosphate (calgon) as dispersant. Available water capacity (AWC) was calculated as the differences between water as

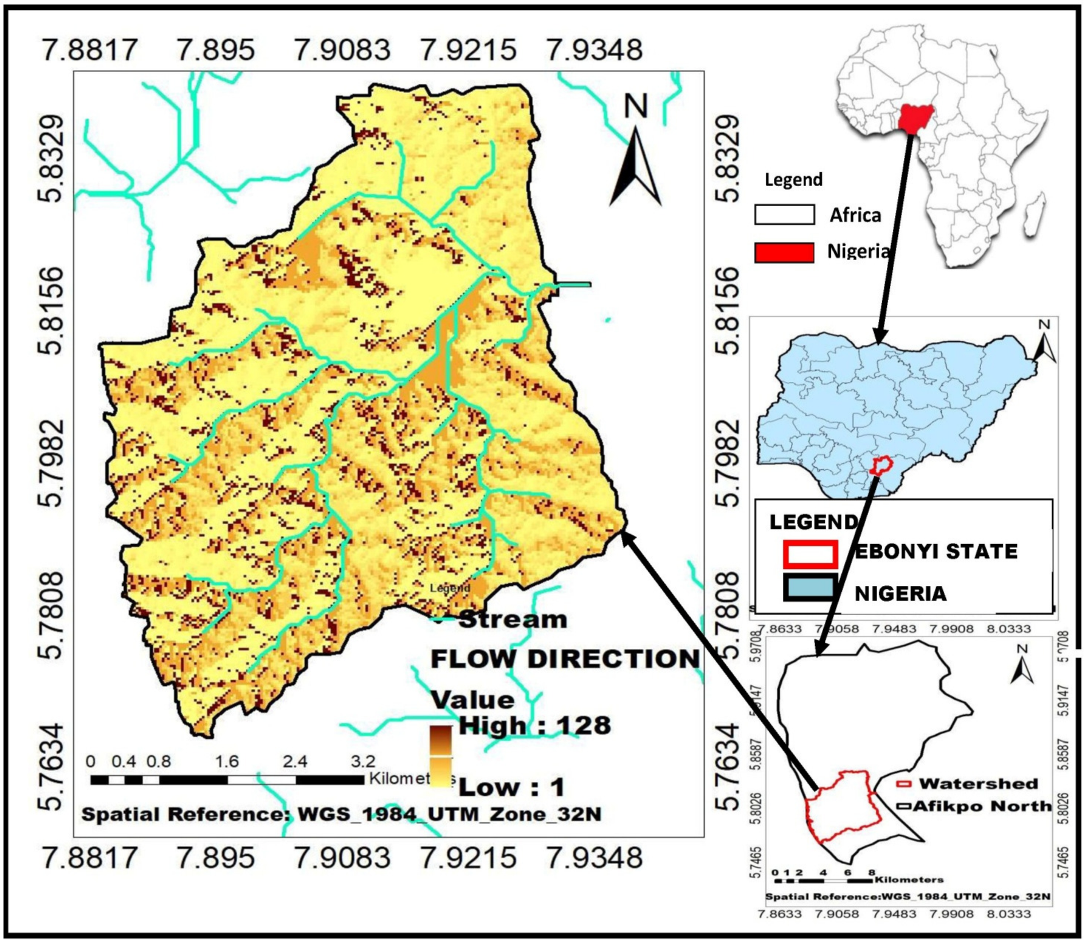
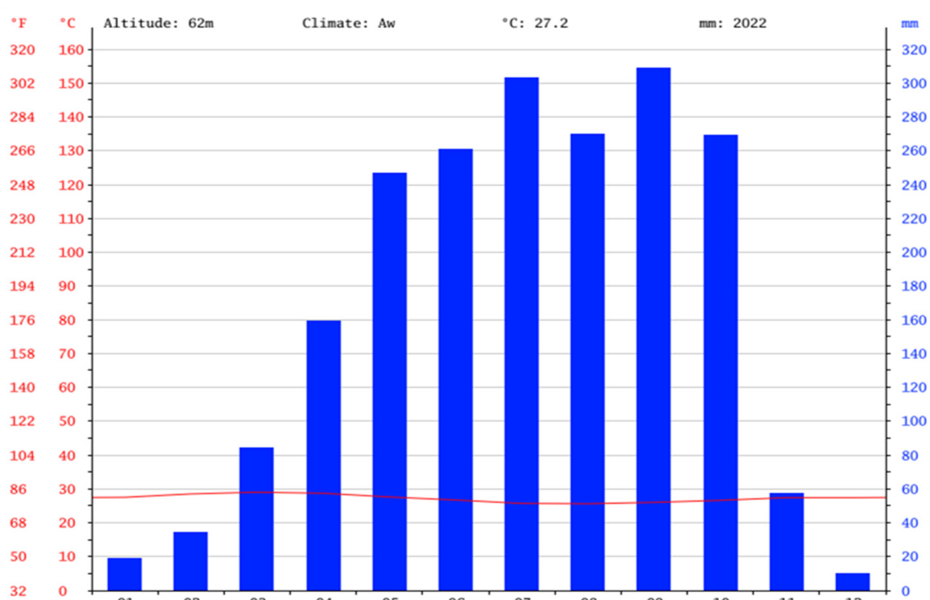


Figure 1: Map of study area showing the study watershed



Source: Koppen and Geiger, 2007

Figure 2: Climograph of the study area

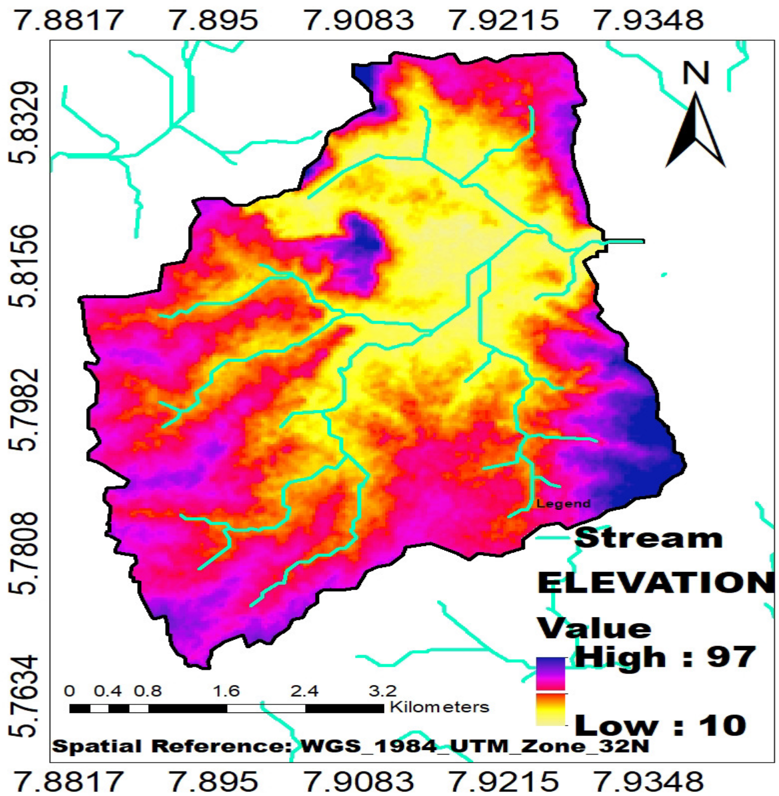


Figure 3: Digital Elevation model of Upper Eyiohia Watershed

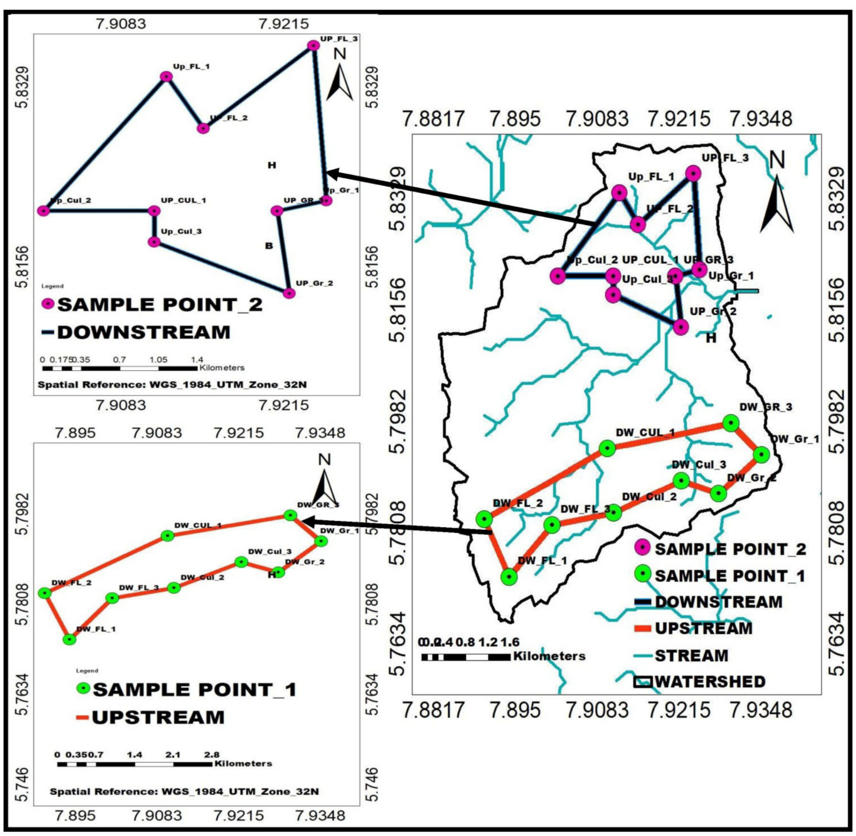


Figure 4: Soil sample area map

retained at field capacity (FC) and permanent wilting point (PWP) and was determined using the saturation water percentage-based on estimation models of Mbagwu and Mbah (1998). Particle density (PD) was determined by the wet-sieving method of Kemper and Rosenau (1986)

$$TP\ [1-(B_D/P_D] \times 100$$

$$PD = \frac{\text{Weight of soil retained on sieve} - \text{weight of sand}}{\text{Total Sample Weight} - \text{Weight of sand}}$$

Soil Chemical Properties

Soil pH- in water (pH-H_2O) was determined using pH meter, organic carbon (OC: %) was determined according to Nelson and Sommer (1982**)** procedure, Total nitrogen (TN %) was determined using micro-kjedhal procedure according to Bremner (1996)**.** The content of available phosphorus (AP mg kg^{-1}) was determined using the Bray-2 method as described in Page et al. (1982). Exchangeable bases (Ca, Mg, Na, K: cmol kg^{-1}) and cation exchange capacity (CEC: cmol kg^{-1}) were determined using atomic absorption method and flamephotometer to extract sodium and potassium (Ohiri and Ano, 1985)**.** In the leachate, exchangeable calcium and magnesium were determined using the titration method as described by Mba (2004)**,** the extractable micronutrients: Zn, Cu, Fe and Mn were extracted using 0.1M HCl solution Osiname et al. (1973) and determined on an atomic absorption spectrophotometer at appropriate wavelength.

Geographical and Statistical Analysis

ArcGIS 10.1 software spatial statistical and hydrology analysis extension tools were used to generate the maps. T-test analysis was run on the soil physical and chemical parameters using SPSS statistical software package (version 20) to determine significant difference among means in upstream and downstream and to detect significant variation in mean as affected by land use types at 5% significant level.

RESULTS

Soil Physical Properties under different Land use Type

Results indicate that the soils are sandy loam in texture across land use type with mean sand, silt and clay fractions of 53%, 30% and 17% receptively and there was no significant difference (P>0.05) among land use types in particle size distribution of the soil (Table 1). The mean values of bulk density (BD) and particle density (PD) were 1.38 g cm^{-3} and 4.4 g cm^{-3} respectively while total porosity (TP) by volume was 48%. There was significant difference (P<0.05) in BD and TP among land types with the highest mean BD values (1.4 g cm^{-3}) in the cultivated fields and grazing lands and the lowest (1.29 g cm^{-3}) in the forest lands. The mean water holing capacity (WHC) of the soil at field capacity (1/3 bar), permanent wilting point (PWP 33 bar) and available water capacity (AWC) were 22, 11 and 10 which is rated as low and showing no significant difference between land use types.

Soil Chemical Properties under different land use types

Results shows that the mean organic carbon, total nitrogen and available phosphorous were 1.42%, 0.10% and 19.8 mg kg^{-1} and showing no significant difference between land use types (P>0.05). Organic carbon and total nitrogen are rated as low while available phosphorus is rated high according to Hazelton and Murphy (2007) rating. The mean soil pH value is 4.64 and shows no significant difference between land use types and showing very strongly acidic

Cation Exchange Capacity (CEC) and Exchangeable bases under different land use types

Results indicate that the mean cation exchange capacity (CEC), calcium (Ca) and potassium (K) were 6.9 cmol kg^{-1}, 3.5 cmol kg^{-1} and 0.1 cmol kg^{-1} which is rated as low based on Landon (1991) rating and showing no statistical difference between land use types (P>0.05). The mean values of magnesium (Mg) and sodium (Na) were 1.9 cmol kg^{-1} and 0.1 cmol kg^{-1} which is rated as medium according to Landon (1991) rating and showing no significant difference between land use types.

Micronutrient under different land use types

The mean values of iron (Fe) and manganese (Mn) were 33.3 and 53.6 mg kg^{-1} which is rated as high according to FAO (2006) rating and showing significant difference (P<0.05) between land use types. The highest mean Fe value was observed in the cultivated (40.1 mg kg^{-1}) and grazing lands and the lowest (25.9 mg kg^{-1}) in the forest lands. However, the highest mean values of Mn were recorded in cultivated lands (66 mg kg^{-1}) and grazing lands and the lowest in forest lands (39.2 mg kg^{-1}). On the contrary, the mean values of zinc (Zn) and cupper (Cu) were 0.99 and 0.98 mg kg^{-1} which is rated as medium and low respectively, although zinc shows significant difference (P<0.05) between land use types

Table 1: Selected soil physico-chemical properties as affected by land use type

Parameter	Forest land	Cultivate land	Grazing land	Mean	SE	P-value	F-value	Sign (0.05)
Physical properties								
Sand (%)	52.56	51.56	56.23	53.46	1.95	0.600	0.529	ns
Silt (%)	32.07	30.40	27.07	29.85	2.926	0.779	0.254	ns
Clay (%)	15.37	18.03	16.70	16.70	1.89	0.849	0.166	ns
BD (g cm^{-3})	1.29	1.41	1.44	1.38	0.023	0.05	3.683	*
PD (g cm^{-3})	4.50	4.43	4.30	4.41	0.201	0.922	0.081	ns
TP (V %)	51.47	46.95	45.85	48.08	0.854	0.039	4.053	*
Water holding capacity								
• FC (1/3 bar)	20.74	20.59	25.07	22.13	2.110	0.481	0.769	ns
• PWP (33 bar)	9.52	9.85	14.17	11.18	1.542	0.411	0.943	ns
• AWC	11.22	10.74	10.90	10.90	0.347	0.820	0.202	ns
Chemical properties								
• pH –H_20	4.87	4.37	4.68	4.64	0.175	0.509	0.707	ns
• OC (%)	1.64	1.42	1.18	1.42	0.218	0.691	0.379	ns
• TN (%)	0.127	0.09	0.084	0.103	0.016	0.534	0.655	ns
• AP (mg kg^{-1})	23.92	19.82	20.60	19.82	1.653	0.574	0.577	ns
Cation exchange capacity and bases (cmol kg^{-1})								
• CEC	5.8	5.46	5.84	5.70	0.193	0.182	1.911	ns
• Ca	3.73	3.23	3.63	3.53	0.195	0.555	0.613	ns
• Mg	1.83	1.99	2.13	1.98	0.105	0.523	0.678	ns
• Na	0.12	0.13	0.07	0.11	0.016	0.309	1.271	ns
• K	0.12	0.11	0.11	0.11	0.007	0.971	0.029	ns
Micronutrients (mg kg^{-1})								
• Fe	25.95	40.07	33.99	33.27	0.771	0.000	28.103	*
• Mn	39.23	66.9	54.75	53.67	2.952	0.006	7.320	*
• Zn	0.25	1.80	0.11	0.99	0.72	0.046	4.072	*
• Cu	0.46	1.49	0.99	0.98	0.210	0.167	2.024	ns

AP= Available Phosphorous, OC=Organic Carbon, TN=Total Nitrogen, Ca=Calcium, Mg=Magnesium, K=Potassium, CEC=Cation Exchange Capacity, SE=Standard Error, ns=not Significant, *= 5% significance significant level, BD=Bulk Density, TP=Total Porosity, FC=Field Capacity, PWP=Permanent Wilting Point, AWC=Available Water Capacity, Fe= Iron, Mn=manganese, Zn=Zinc, Cu= Cupper

with the highest mean value in cultivated lands (1.80 mg kg^{-1}) and lowest in grazing fields (0.11 mg kg^{-1}) and forest areas.

Selected physico-chemical Properties of soils as affected by slope gradient

Soil Physical properties across slope gradient

Results indicate that the soils are sandy loam in texture with mean sand, silt and clay fractions of 53%, 30% and 17%respectively showing significant difference ($P<0.05$) between upstream and downstream (Table 2). The highest mean sand fraction (57.4%) was observed in the upstream and the lowest in the downstream (49.5%). On the contrary, the highest mean silt fraction (35.3%) was in the downstream and the lowest (24.35) in the upstream. The mean clay fraction is 16.70% showing no significant difference between upstream and downstream. The mean bulk density and particle density were 1.38 and 4.41 g cm^{-3} for upstream and downstream respectively with significant difference ($P<0.05$) respectively between the two slope gradients. The highest mean BD value

Table 2: Selected soil physico-chemical properties as affected by slope gradient

Parameter	Upper stream	Down stream	Mean	SE	P-value	F-value	Sign (0.05)
Physical properties							
Sand (%)	57.40	49.51	53.45	1.686	0.033	5.472	*
Silt (%)	24.35	35.33	29.84	2.522	0.045	4.736	*
Clay (%)	18.24	15.15	16.70	1.809	0.406	0.729	ns
BD (g cm^{-3})	1.45	1.31	1.38	0.020	0.003	12.225	*
PD (g cm^{-3})	3.82	4.99	4.41	0.129	0.000	23.659	*
TP (V %)	45.44	50.73	48.08	0.784	0.004	11.367	*
Water holding capacity							
• FC (1/3 bar)	21.32	22.85	22.08	1.507	0.184	1.453	ns
• PWP (33 bar)	11.28	11.08	11.18	1.584	0.950	0.004	ns
• AWC	10.04	11.77	10.90	0.262	0.872	0.010	ns
Chemical properties							
• pH –H_20	4.44	4.84	4.64	0.171	0.261	1.359	ns
• OC (%)	1.15	1.69	1.42	0.206	0.207	1.728	ns
• TN (%)	0.09	0.11	0.103	0.016	0.474	0.538	ns
• AP (mg kg^{-1})	18.03	24.86	21.45	1.425	0.029	5.738	*
Cation exchange capacity and bases (cmol kg^{-1})							
• CEC	5.50	5.96	5.73	0.209	0.845	3.274	ns
• Ca	3.22	3.84	3.53	0.180	0.104	2.973	ns
• Mg	2.08	1.88	1.98	0.104	0.349	0.932	ns
• Na	0.09	0.13	0.11	0.016	0.251	1.421	ns
• K	0.11	0.11	0.11	0.006	0.986	0.000	ns
Micronutrients (mg kg^{-1})							
• Fe	31.49	35.05	33.37	1.56	0.271	1.299	ns
• Mn	44.90	62.44	53.67	3.39	0.01	6.789	*
• Zn	0.28	1.69	0.98	0.237	0.009	8.968	*
• Cu	0.50	1.46	0.99	0.196	0.026	6.016	*

AP= Available Phosphorous, OC=Organic Carbon, TN=Total Nitrogen, Ca=Calcium, Mg=Magnesium, K=Potassium, CEC=Cation Exchange Capacity, SE=Standard Error, ns=not Significant, *= 5% significance level, BD=Bulk Density, TP=Total Porosity, FC=Field Capacity, PWP=Permanent Wilting Point, AWC=Available Water Capacity, Fe= Iron, Mn=manganese, Zn=Zinc, Cu= Cupper.

(1.45 g cm^{-3}) was recorded in the upstream compared to the lowest (1.31 g cm^{-3}) in the downstream. The highest mean value of particle density (4.99 g cm^{-3}) was in the downstream and the lowest (3.82 g cm^{-3}) in the upstream. The mean value of total porosity by volume is 48% indicating free and better drainage system network in the soil and showing significant difference (P<0.05)) between upstream and downstream with highest mean value (51%) in downstream and lowest (45%) in upstream.

The mean water holing capacity (WHC) of the soil at field capacity (1/3 bar), permanent wilting point (PWP 33 bar) and available water capacity (AWC) were 22, 11 and 10 respectively which is rated as low based on FAO (2006b) rating and showing no significant difference (P>0.05) between upstream and downstream.

Soil Chemical Properties across slope gradient

Results indicate that the mean values of soil pH, organic carbon and total nitrogen were 4.64, 1.42%, and 0.10% respectively and showing no significant different between upstream and downstream (P>0.05) while soil pH showing very strongly acidic (4.64). The mean value of available phosphorous is 21.45 mg kg^{-1} and shows significant difference between upstream and downstream with highest mean value (20.8 mg $kg^{-1)}$ in the downstream compared to the lowest (18 mg kg^{-1}) in the upstream.

Soil Exchangeable bases across slope gradient

The mean values of soil cation exchangeable capacity, calcium, magnesium, sodium and potassium are 5.73, 3.53, 1.98, 0.11 and 0.11cmol/kg respectively and showing no significant different between upstream and downstream.

Soil micronutrient across slope gradient

The results indicate that the mean values of manganese (Mn), zinc (Zn) and cupper (Cu) were 53.7, 0.98 and 0.99 mg $kg^{-1}$and showing significant difference ($P<0.05$) between upstream and downstream with highest mean Mn value (63.4 mg kg^{-1}) in the downstream compared to the lowest (44.9 mg kg^{-1}) in upstream. The highest mean Zn value (1.69 mg kg^{-1}) was in the downstream compared to the lowest (0.28 mg kg^{-1}) in the upstream sub watershed. Cupper also showed highest mean value (1.46 mg kg^{-1}) in downstream and the lowest (0.5 mg kg^{-1}) in upstream. However, the mean value of Iron (Fe) is 33.3 mg $kg^{-1}$and showing no significant different between the upstream and downstream.

DISCUSSION

Soil Physico-chemical Properties under different Land use Type

The similarity in texture class (Table 1) across all land use types reflects homogeneity in parent materials (chiefly sandstone) and the fact that texture is inherent property of the soil that cannot be changed by land use in short period of time (Akamigbo, 2010). Various authors (Okolo et al., 2015; Ukaegbu et al., 2015; Nwite and Okolo, 2017) have previously reported predominance of sand fraction in soils of different land uses in southeastern Nigeria. The lower bulk density recorded in forestland compared to cultivated and grazing land could be due to higher amount of organic matter content and litter cover leading to increase in soil volume with no effect on soil weight. This is similar to findings in Takele et al. (2015) and Amanuel et al. (2018). They reported that the differences in soil organic matter and less disturbances in forestland resulted to the lower bulk density in the soils of the forestland compared to the cultivated and grazing lands.

On the contrary, the highest mean value of TP under forest lands and the lowest under grazing lands suggesting the trampling effect of cattle increasing bulk density while at the same time reducing total porosity and water infiltration. This might be due to soil bulk density and soil total porosity which is inversely related which has huge implications for runoff and soil erosion losses since the upstream of the study area (Southern part) are in the area of high elevation than the downstream (Figure 3). The findings are in agreement with Lemenih et al. (2005) and Selassie (2005) who reported progressive increase in bulk density due to deforestation, grazing and continuous cultivation. Okolo et al. (2015) have previously reported increase in BD as a result anthropogenic activities in Enyigba area of southeastern Nigeria.

The low water holding capacity and plant available water content of the soil is consistent with the high TP and sandy nature of the soil which may contribute to increased runoff and soil erosion hazards. High content of sand fraction in soils of southeastern Nigeria has been previously reported by various authors (Okolo et al., 2015; Ukaegbu et al., 2015; Nwite and Okolo, 2017). The higher mean Av. P content in the soil may be attributed to the addition of supplement (agro-chemicals) to enhance soil fertility (Ekukinam, 2010). The incorporation of manure and crop residue has been shown to increase the amount of organic acids that increase the rate of desorption of phosphate and thus improve the available P and other nutrients content in the soil (Ogbodo, 2012). Plant available P content is usually very low due to apparent removal of P from the soil solution and also the inherent soil type (Randall et al., 2001; Tsado 2008; Tsado et al., 2014). However, the widespread occurrence of P deficiency in most arable lands in Nigeria has led to the intensive use of P fertilizers (Tsado et al., 2012). The range of mean available phosphorus is not consistent with the findings of Ekundayo (2004) who reported mean value of 10 mg kg^{-1} soil of south-eastern Nigeria.

Low organic carbon and total nitrogen in the study area could be attributed to continuous cultivation without fallow, and high rate of mineralization due to high temperature (tropics) and crop removal during harvest by farmers without proper incorporation of crop residue into the soils. Higher organic carbon content was recorded in forest soils and this could be due to undisturbed state of the ecosystem. This is similar to the findings of Berihu et al. (2017), Assefa et al. (2017) and Amanuel et al. (2018). They reported that organic and total nitrogen varied between land use types with higher value in forestlands compared to other land uses (cultivated land, grazing land and eucalyptus plantation). Very strongly acidic level of the soil in the study area could be as a result of depletion of basic cations to drainage in runoff generated from accelerated soil erosions from upstream to downstream areas (Figure 3). Mbah et al. (2017) and Okenmuo et al. (2018) have previously reported similar pH range in soils of southeastern Nigeria.

Low CEC, Ca and K in the study area have been previously reported for most Nigerian soils (Abua et al., 2010; Uzoho et al., 2007; Mbah et al. 2017) and attributed to soil erosion losses by the high tropical rainfall as well as low content in the underlying parent material. The high level of manganese may further lead to acidification and Mn toxicity in the study area if not controlled. Ogbodo (2013) had identified the most serious negative impact associated with acidification in soil of Southeastern Nigeria as aluminum (Al) and manganese (Mg) toxicity. High Mn in the study area implies that Mn content is above the critical available range of 3 to 5 mg kg^{-1} reported by Lindsday and Norveil (1978). These figures suggest that Mn content of the soils is high and cannot be a limiting factor to successful crop production in the study area. The high concentrations of Iron (Fe) on the soils of cultivated and grazing lands (Table 1) could be explained due to higher organic wastes from domestic and motor repair commercial dealers as the population density in these areas appears higher. Study has shown that due to significant anthropogenic encroachment, Iron (Fe) can be washed into nearby water bodies, cultivated areas and other openings where they can form a major source for bioaccumulation (Sutherland and Tolosa, 2001). It could also be associated to sewage sludge and cattle rustling activities usually applied by the farmers to the soil as a source of added soil organic matter for cultivated crops. However, the acidic nature of the soil of the study area (Ultisol) with low pH enhances predominance of Al and Fe ions in the soil solution. High concentration of Mn in cultivated lands and grazing lands could be due to the presence of car wash outfits that has the potential of continual release of effluents containing oil, paint and varnish oils, petrols, diesel, detergents and dissolved dust particles. Other possible sources of Mn on the soils of grazing land could be through application of insecticide (inorganic fertilizer) to control paste attacking cattle by the cattle breeders containing Mn in the form of MnSO4, MnO or as an addition to micronutrient fertilizers. There was irregular distribution of zinc across land use types, Mustapha et al. (2011) also reported similar irregular distribution of zinc in the land use in Gombe state, Nigeria.

Selected physico-chemical Properties of soils as affected by slope gradient

The dominance of sand content, particularly in the upstream implies that the soil is highly limited both in nutrient and water retention (Lal 1987; Salako et al., 2006; Teka et al., 2015). The highest mean value of particle density in the downstream and the lowest in the upstream (Table 2) possibly suggests the presence of relatively less binding agents in the downstream which therefore increased soil particle density. In line with this, Achalu et al. (2012) revealed that decrease in clay fraction increase particle density through its positive effect on soil aggregation.

The low water holding capacity and plant available water content of the soil in the upper stream is attributed to the sandy nature of the soil which might contribute to increased overflow and soil erosion risk. Thus, at downstream, the higher clay content enhanced soil water retention. This is similar to the findings of Salako et al. (2006) who reported high clay content down slope. Variation in the mean value of soil pH, organic carbon and total nitrogen between upstream and downstream lies in the differences of land use practice and fertilizer application between upstream and downstream. Soil organic carbon and total nitrogen were higher in downstream compared to the upstream. This is contrast with the findings of Wanshnong et al. (2013). They reported higher organic carbon and total nitrogen content in the upper slope compared to the lower slope. No significant different between upstream and downstream in soil exchangeable bases in the study area, similar findings has however been reported by Musa and Gisilanbe (2017) when comparing the effect of three slope positions on exchangeable bases properties of the soil in Adamawa state, Nigeria and showed no significant difference. Understanding soil properties and their variation is important for their sustainable utilization and proper management. The highest mean values of Mn, Zn and Cu recorded in the downstream compared to the upstream could be linked as a result of slope gradient, which involves processes that cause soil properties differentiation along hill slopes, this is in agreement with the findings of Gessler et al. (2000) and Teka et al. (2015). They reported that soil properties on a slope differ due to degree of detachment, transportation and deposition of soil materials accelerated by soil erosion.

CONCLUSIONS

In Upper Eyiohia River watershed Afikpo North, the growing population and more intensive land use and slope gradient have resulted in sharp declines of soil fertility by continuous removal of grain and vegetation, and erosion. Significance mean difference seen in selected soil physico-chemical parameters of the soil under different land use types is as a result of different management and conservation practices on each land use type chiefly linked to land use land cover change over time, others include population pressure and shortage of cultivable land. Significance mean differences detected in selected soil physico-chemical as affected by slope gradient (upstream and downstream) show a strong relation to variation in degree of slope as upstream showing steep slope compared to the downstream which is slopping and has particularly caused significant difference in selected physicochemical properties between upstream and downstream. This is mainly due to differences in soil surface removal, transportation and deposition. Exchangeable bases (Ca and K), CEC, organic carbon and total nitrogen is rated low in the studied area and are presently inadequate to sustain the current land use. There should be variation in nutrient management along the slopes with emphasis on differences in specific nutrient elements along slope gradients.

The results of the finding can assist decision-makers in identification of priority areas and providing a basis for a comprehensive management and sustainable land-use intervention/policy and enhancing watershed rehabilitation and productivity to improve the livelihoods of the community. It is therefore recommended that since organic carbon, total nitrogen, calcium, potassium and cation exchange capacity are low in the study area, build-up of these nutrients in the soils is urgently required. This study has shown the relationship between soil properties and slope position on a slope gradient and how slope position can affect the physical and chemical properties of soil across a landscape. Measures to improve their replenishment may include; cultivation across slope, agroforestry, farm fallow, prevention of indiscriminate burning of vegetation and encourage practices of incorporating organic residues into the soil.

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