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Evaluation of Soil and Organic Matter of a Watershed along River Aya, Ogoja Reach, Cross River State, Nigeria

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ABSTRACT

Watersheds are believed to transport organic matter and washed nutrients from high lands and deposits along the flood plains, making the area soils fertile. The certainty that watershed flood plains are highly fertile makes farmers in developing countries clamour for farm lands around watershed flood plains. This could be mere speculation if a soil from a particular flood plain is not subjected to laboratory analytical tests. A watershed basin along river Aya, at Ogoja reach is one of such flood plains. Soils were taken from 3 different areas within a particular farm in the watershed basin and tested for soil constituents and organic matter content. All the soil classes were found to be light to medium in texture varying between sandy clay loam at the surface level of 0-15 cm and few classes of clay loam at the 15-30 cm soil depth with some variation in silt and clay along the depth of the soil profile. Sand ranged from 50.2% at land surface to 32.9% at bottom site; Silt had higher weighted average of 27.6% compared to 26.6% weighted average at Midland site; clay increase with increase in slope varying from 22.5% at the surface to 32.7% in the lower horizon. Soil reactivity (pH) on study site was slightly acidic with values ranging from5.35 to 6.46. Bulk density had averages of 1.19 g/cm^{3}for Highland site, 1.43g/cm^{3}midland and 1.20g/cm^{3}Lowland site respectively. All the weight ranges are favourable for farming and conducive to normal root distribution of crop plants. The three macronutrients (N, P, K) values fluctuated among the sites but all fall under "medium" category by fertility standard ratings. This result showed that not all watershed soils are exceptionally fertile as believed by rural farmers that could have classify the soil fertility standard to be "very high".

Key words: Watersheds, River Aya, Evaluation, Soil constituents, Organic matter content

1. INTRODUCTION

Land and water are ecologically linked in a natural system called a catchment, drainage basin, or watershed. A watershed is the area of land that drains into a body of water such as a river, lake, stream or bay, or, a watershed which captures rainfall and other precipitation and funnels into a lake, stream or wetland.

A watershed is an area of land that captures rainfall and other precipitation and funnels it to a lake or stream or wetland, [1]. A watershed is an area of land that drains to a lake, river, wetland, or other waterway. When precipitation occurs, water travels over forest, agricultural or urban/suburban land areas before entering a waterway. Water can also travel into underground aquifers on its way to larger bodies of water. Together, land and water make up a watershed system [2].

Watersheds act as a filter for runoff that occurs from precipitation and snowmelt, providing clean water for drinking, irrigation, and industry. Most watersheds which convey its waters along flood plains are believed to transport washed nutrients and are deposited around the water course lands thereby making the area soils to be highly fertile. Due to their high levels of soil nutrients and natural irrigation, floodplains are often used for agriculture [3].

Watershed floodplain lands and adjacent waters are believed to combine and form a complex, dynamic physical and biological system found in nowhere else. When portions of floodplains are preserved in their natural state, or restored to it, they provide many benefits to both human and natural systems. Some are static conditions, such as providing aesthetic pleasure and some are active processes, such as reducing the number and severity of floods, helping handle storm water runoff and minimizing non-point water pollution. For example, by allowing floodwater to slow down, sediments settle out, thus maintaining water quality. The natural vegetation filters out impurities and uses excess nutrients [4].

Stable watersheds are generally characterized by forest vegetation, a thick humus layer that protects the soil from the impact of precipitation, high infiltration rates, low runoff rates, and low soil erosion and sediment transport rates in upland areas, a stable stream channel, high quality water, and a healthy aquatic community [5].

Floodplains are the low-lying areas of land where floodwater periodically spreads when a river or stream overtops it banks. It is also described as the flat area that starts at river's edge and continues to the beginning of surrounding highlands. Riparian vegetation along stream banks and in the floodplain reduces the velocity of floodwaters, lessening the erosive force of the flood and capturing nutrient-laden sediment [6, 7].

Floodplains are a particularly rich zone for biodiversity and agricultural soils. In many parts of the world, annual flooding of the floodplain is welcomed, as it renews the soil's fertility for farming. Floodplain soils absorb water during the wet season, then slowly releases moisture to plants and into the stream. This buffers the effect of peak runoff and keeps plants growing and streams flowing longer. Stream bank vegetation also helps cool surface water temperatures, and creates important habitat for fish, waterfowl, and other wildlife species.

Waters bring moisture and a surge of new nutrients into the floodplain. Many settlements were originally built in or near floodplains because of access to drinking water and high soil fertility for farming. Over time, many riverside communities have chosen to control flooding by building upstream dams and levees, and by straightening the course of the river. Such drastic alternations protect developed lands from flooding. Floodplains support many riparian species, which depend on regular small-scale flooding of farming systems.

Stable watershed upland water courses slows down the flow through wetlands that intercept rainwater closer to where it falls, before large volumes of water reach the river. Water stored in floodplain and wetland soils is slowly released back to the surface over a longer period of time. That reduces flood volumes and keeps the river flowing longer into the dry season [8, 9].

Floodplains have accounted for the development of many societies through agriculture due to the silt deposit that characterized them. Hence, they are often regarded as the most biologically productive and diverse ecosystem on earth [9]. These prolific lands in terms of agriculture are highly and intensively cultivated giving rise to what is known as floodplains or Fadama agriculture. Floodplains occupy a significant portion of the earth's South America, and a greater proportion of tropical Asia giving rise to many socio-economic activities such as farming, fishing and even recreation. According to [10], article on West Africa Sahelian floodplain Recession Agriculture (Mali), the floodplain of River Senegal, Niger, Sokoto, Kafu, Phongolo and Tema in Semi-and-zones of South and East Africa, the organization observes that such productive land have helped indigenous communities to develop sequential use in relation to inundation and recession of flood waters-promotion, forestry, crop cultivation, fisheries and livestock with annual inundation patterns.

Floodplain agriculture accounts for the wealth and livelihood of some desert countries like Egypt, North Sudan and Uganda where the controlled flooding of the Nile River provides large expands of fertile land for agricultural activities along the Nile Valley making them self-sufficient in the growing and exporting of many crop products to other African countries. Thailand, China and other countries along the Ganges River Plain are reckoned with as the World's largest exported of rice due to floodplain cultivation [11-13]. Apart from agriculture and fishery, floodplains are known to be attributed to biodiversity, uniqueness, naturalness and cultural heritage. The physical hydrological functions include nutrient retention and recycling, ground water recharge, flood control, sediment retention, erosion control, water treatment, climate stabilization, ecosystem stability and stabilization of other systems [14].

In Nigeria, the importance of floodplains led to the development of Agricultural in rural areas around the floodplain basins referred to as Fadama agriculture which has become critical to the survival and economic development of the rural areas of semi-arid Northern Nigeria where rainfall is scarce and highly variable [15]. The successes recorded in Fadama agriculture leads to periodical review of its operations (which started with Fadama1, Fadama II and presently operating the phase of Fadama III) for better management and performance.

The general objective of the study were to assess the physical and chemical characteristics of watershed soils from a farm in River Aya basin at Ogoja reach; determine the soils organic matter contents and compare with FAO standards for soil fertility.

2. MATERIALS AND METHODS

2.1 Study Area

Ogoja is a Local Government Area in Cross River State, Nigeria. Its headquarters is Ogoja town in the northeast of the area near the A4 highway at 6°39′17″N 8°47′51″E at coordinates: 6°30′N 8°40′E. It has an area of 972 km² and a population of 171, 901 at the 2006 census [16].

The area is drained by river Aya and and its tributaries such as Monaya, Edline to almost every part of the study area. River Aya and its tributaries constitutes what [17], calls the “Aya system” which is a sub-river basin of Cross River basin [18] (Figure 1). Among its course, the river is confluence by 4th and 3rd orders tributaries. The flow regime naturally follows the run-off and climatic controls characterized by a single minimum flow and a short water period under three to four months. River Aya water course produced many floodplains which transcend across many communities in Cross river State in Nigeria with many basins, which farmers use as productive agricultural areas. The area has an average rainfall of 1750 mm to 2000 mm per annum with two distinctive seasons (wet and dry). The wet season begins from April and end in October to give way to the dry season with high temperatures in March and rainfall peaks occurring between July and September[19, 20].

The people are engaged in basic agriculture with the cultivation of annual and cash crops such as Yams, cassava, cocoyam, maize, rice, etc on the fertile floodplains, many of them also engaged in fishing and hunting along the gallery forest[17].

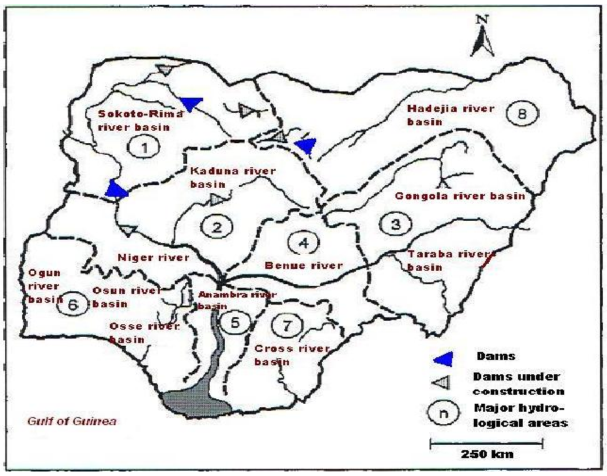

Fig. 1a Hydrological Map of Nigeria Showing. Cross River Basin (7)
Source: (Eze and Joel, 2010)

Fig. 1b Cross River Basin Showing River Aya at Ogoja

2.2 Soil Sampling Site

The watershed area at Ogoja is a blend of different land situations. Soil surface varies from being flat to being sloppy, undulating and rolling in topography. The direction of the slope of the land is towards South-east of river Aya. The average slope varies from 1 to 5%. The cultivated land sites selected for study were classified into three (3) sites and named as; Highland (HL), Middle land (ML) and Low land (LL) for convenient distinction from each other. The names are mainly based on visual observation of elevation and slope.

The farm lands in for the study are situated near the river/stream bank having access to water for vegetable cultivation by irrigation in the dry season, and Maize, Sugar cane and fruit orchards during rainy season.

2.2.1 Collection of Soil Samples from Site

The soil samples were collected in the dry season from designated sites (HL),(plate 1), (ML)(plate 2),and (LL)(plate 3). Three samples each were taken from the three sites with the help of hand auger at 2 range depths (0 -15, 15-30 cm), to obtain eighteen (18) samples.

Plate 1. Highland site.

Plate 2. Middle land site.

Plate 3. Low land site

2.3 Laboratory Analysis

Soil samples were air dried and analyzed for texture, bulk density, soil reactivity (pH), organic carbon and some macronutrients(organic matter contents) using standard laboratory methods [21, 22].

3. RESULTS AND DISCUSSION

3.1 Result

The laboratory result of the soil textural classes into percentages (%) of sand, silt and clay are tabulated as shown in Table (1). The soil physico - chemical properties of pH, bulk density, organic carbon and those of Nitrogen (N), Phosphorus (P) and Potassium (K) are shown in Table (2).

Table -1 Site Soil Texture Classes

Site	Depth(cm)	Sand (%)	Silt (%)	Clay (%)	Textural class
HL_1	0 -15	50.2	26.3	23.5	Sandy Loam
	15-30	40.6	28.7	30.7	Sandy Clay Loam
HL_2	0 -15	49.8	25.6	24.6	Sandy Clay Loam
	15-30	41.3	28.5	30.2	Clay Loam
HL_3	0 -15	50.1	27.4	22.5	Sandy Loam
	15-30	42.3	29.2	28.5	Sandy Loam Clay
	***WA**	**45.7**	**27.6**	**26.7**	
ML_1	0 -15	45.6	24.9	29.5	Sandy Clay Loam
	15-30	43.4	27.6	29	Clay Loam
ML_2	0 -15	46.5	25.4	28.1	Sandy Clay Loam
	15-30	42.3	27.9	29.8	Sandy Clay Loam
ML_3	0 -15	44.6	26.1	29.3	Sandy Clay Loam
	15-30	44.1	27.4	28.5	Sandy Clay Loam
	WA	**44.4**	**26.6**	**29.0**	
LL_1	0 -15	35.2	29.3	35.5	Clay Loam
	15-30	32.9	34.7	32.4	Loamy Clay
LL_2	0 -15	34.2	34.9	30.9	Loamy Sand Clay
	15-30	33.5	35.6	30.9	Loamy Sand Clay
LL_3	0 -15	34.1	33.6	32.3	Loamy Clay
	15-30	33.2	34.1	32.7	Loamy Clay
	WA	**33.9**	**33.7**	**32.5**	

WA=Weighted Average

3.2. Discussion

3.2.1. Soil texture

The soils of all the classes were found to be light to medium in texture varying between sandy clay loam at the surface level of 0-15 cm and few classes of clay loam at the 15-30 cm soil depth with some variation in silt and clay content along the depth of the soil profile (Table, 1). Considering the variation in texture at different depths, it was observed that High land (HL) and Middle land (ML) had almost similar composition, having a common lighter texture of sandy clay loam in almost all depth from surface to the bottom (0 to 30 cm).

Table -2 Physico - Chemical Indicators of the Organic Matter

Site	Depth(cm)	pH	Bulk density (g/cm^3)	Organic Carbon (%)	N (mg/l)	P (mg/l)	K (mg/l)
UL1	0 -15	6.4	1.45	0.55	0.20	10.6	0.30
	15-30	6.46	1.38	0.37	0.18	4.8	0.19
UL2	0 -15	6.3	1.44	0.53	0.22	10.4	0.43
	15-30	6.38	1.36	0.35	0.16	4.8	0.22
UL3	0 -15	6.32	1.48	0.51	0.21	8.6	0.41
	15-30	6.41	1.37	0.33	0.17	5.9	0.21
	WA	**6.38**	**1.19**	**0.44**	**0.19**	**7.52**	**0.29**
ML1	0 -15	6.28	1.46	0.52	0.23	11.7	0.41
	15-30	6.35	1.40	0.34	0.18	7.90	0.33
ML2	0 -15	6.33	1.47	0.54	0.24	12.2	0.45
	15-30	6.44	1.39	0.36	0.20	6.10	0.35
ML3	0 -15	6.40	1.46	0.51	0.23	11.9	0.47
	15-30	6.52	1.38	0.33	0.19	8.70	0.36
	WA	**6.39**	**1.43**	**0.43**	**0.23**	**9.75**	**0.40**
LL1	0 -15	5.80	1.47	0.41	0.25	12.8	0.51
	15-30	6.00	1.42	0.32	0.21	6.60	0.42

LL2	0 -15	5.35	1.48	0.42	0.23	13.6	0.55
	15-30	6.22	1.39	0.34	0.20	7.00	0.48
LL3	0 -15	5.72	1.49	0.44	0.24	13.5	0.56
	15-30	6.18	1.36	0.31	0.21	9.30	0.51
	WA	**5.88**	**1.20**	**0.37**	**0.22**	**10.47**	**0.51**

WA = Weighted Average

However, mapping units of the Low land (LL) had slightly heavy texture dominated by loamy clay throughout the 0-30 cm layers. Among the 3 main sites, sand percentage ranged from 50.2% at the (HL) surface to 32.9% at the (LL) bottom; this means the percentage of sand kept decreasing along the slope of the watershed (Figure 2 and 3). Silt had a higher weighted average of 27.6% in (UL) site compared to 26.6% weighted average at (ML) site. In (LL) site silt increased in composition to weighted average percentage of 33.7%, as highest among the 3 sites of the study (Table 1) (Figure 3). The clay content was found to increase down the depth of the profile with increase in slope from soil surface varying from 22.5% at the surface to as high as 32.7% in the lower horizon (Figure 4). This is probably due to translocation of finer particles under the influence of high intensity rainfall of the area with relatively less compacted soils at the surface.

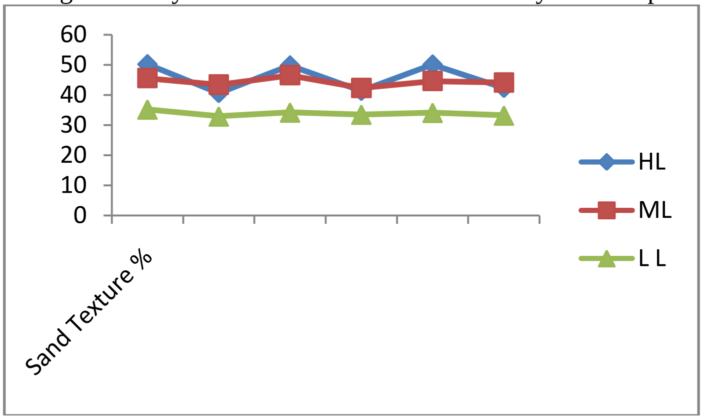

Fig. 2 Sand Content by Percentage in the three study sites

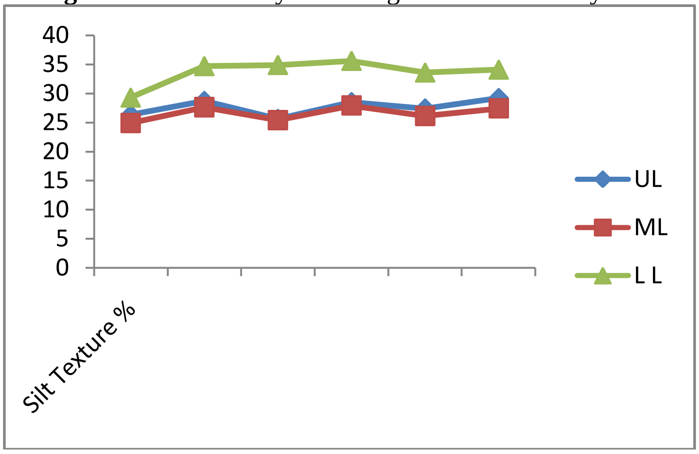

Fig. 3 Silt Content by Percentage in the three study sites

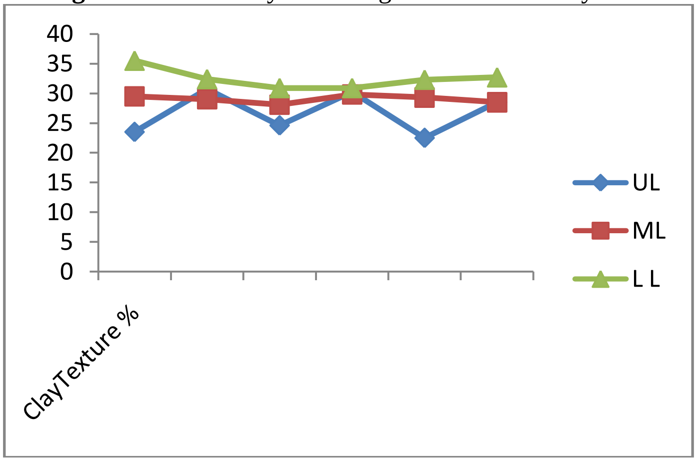

Fig. 4 Clay Content by Percentage in the three study sites

3.2.2. Physico-chemical indicators of the organic matter

Soil Reactivity (pH): The Highland soils were slightly acidic with respect to the lowland soils (Table 2). Soil reactivity varied from 5.35 in (LL) to 6.46 in (HL). Out of these, the surface soils had higher pH across the soil profile for all classes. The higher acidity in the surface layer may be attributed to the loss of considerable amount of organic content along with the high intensity rainfall through the surface/subsurface run-off.

The pH values also followed a trend of variation in the reverse order, LL >ML > HL, showing that the lowland soils are more acidic than those of upland soils. However, all the acidity levels are favourable for crops farming [23], (Table 3).

Bulk Density: The bulk density of the soil in different classes fluctuated between 1.36 to 1.49 g/ cm^3 in different soil layers (Table, 2). The highland (HL) soil values trend between 1.36 to 1.48 g/ cm^3, Middle land(ML) ranged between 1.38 to 1.47 g/ cm^3, and lowland(LL) had 1.36 to 1.49g/cm^3 range like that of (HL); but the weighted averages differs in that (HL) had 1.19 g/cm^3,(ML) 1.43g/cm^3, and (LL) 1.20g/cm^3 respectively. This result indicates bulk density was higher in (ML) site. This may be attributed to slightly uniform spread of clay content among the 3 main study site by percentage composition (Table, 2).

Table -3 Critical limits for interpreting levels of soil fertility, salinity, and Sodicity Parameters

	pH	**Saline Soil**	**Sodic Soil**
Ultra acid	>3.5	ECe	>4.0 ds/m^2
Extremely acid	3.5-4.4	ESP	>8.5
Very strong acid	4.5-5.0	pH	>0.3
Moderately acid	5.5-6.0		> 0.3
Slightly acid	6.1-6.5		>12

Source: Omar, (2011).

The depth wise variation of bulk density in different classes though didn't differ markedly, but an overall picture indicates that the bulk density of the soil varied in the order ML> LL > HL. However, the bulk density of soil of all classes is in the favourable range for farming activities [24, 21], and is conducive to normal root distribution of crop plants (Table 2).

Organic Carbon: Organic carbon content was found to gradually decrease down the depth of soil (Table, 2). The values ranged between 0.55% to 0.33% in the surface layer downward within the 0-30 cm range of depth in the (HL) site, 0.54 to 0.33% in (ML) and 0.44 to 0.31 in (LL). Decreasing trend of organic carbon down the depth of the soil is a well established fact as the organic matter content, normally becomes highest in the surface layer contributed by the residues of flora and fauna, which gradually decreases down the depth of the soil. Lower organic carbon content by downward trend could also be as a result of comparatively lower clay content and erosion [25].

Organic Matter Content: The organic matter content analyzed are Nitrogen (N), Phosphorus (P) and Potassium (K). The organic content for organic matter of soils are measured according to classes or ratings. Thus, (N) obtained from highland (HL) site ranged between 0.16 – 0.22mg/l; middle land (ML) 0.18 -23mg/l and lowland had a range between 0.20 – 0.25mg/l and by weighted average (ML) has 0.23mg/l indicating the highest site in N content, followed by (LL) with 0.22mg/l while (LL) had 0.19mg/l (Figure 5). When these values are compared with standard rating for categorizing soil fertility parameters as shown in Table (4) [26]; the N content in all the site (HL, ML and LL) falls within a soil rated with medium content of N; although going by individual site assessment, site (LL) recorded 0.25mg/l at the range depth (0-15cm) point (Table 2).

Phosphorus (P) recorded a range of 4.8 – 10.6mg/l in (HL), 6.1 – 11.9mg/l in (ML) and 6.6 – 13.5mg/l in (LL) site. Comparatively by weighted average, (LL) site had the highest content with 10.47mg/l, followed by (ML) with 9.75mg/l while (HL) had 7.52mg/ l (Table 2). This means the P content increased with increase in slope from upland downward into the lowland (Figure 6). The standard rating showed P content in (LL) is rated as “medium” while (HL) and (ML) falls within “low” content (Table 4).

Table -4 Classes or Ratings Considered for some Soil Parameters

Parameters	**Categories or Ratings**				
	V. low	**Low**	**Medium**	**High**	**V. high**
Soil OM (%)	< 0.86	0.86-2.59	2.59-5.17	>5.17	-
Total N (%)	<0.05	0.05-0.12	0.12-0.25	>0.25	-
Av. P (mg/kg^{-1})	<5	5-9	10-17	18-25	>25
K (cmol(+) kg^{-1}	<0.2	0.2-0.3	0.3-0.6	0.6-1.2	>1.2
Na (cmol(+)kg^{-1}	<0.10	0.1-0.3	0.3-0.7	0.7-2.0	>2.0
Ca (cmol(+)kg^{-1}	<2.0	2-5	5-10	10-20	>20
Mg (cmol(+)kg^{-1}	<0.3	0.3-1.0	1.0-3.0	3.0-8.0	>8.0
CEC (cmol(+)kg^{-}	<6	6-12	12-25	25-40	>40
PBS (%)	-	<20	20-60	>60	-

FAO, (2006)

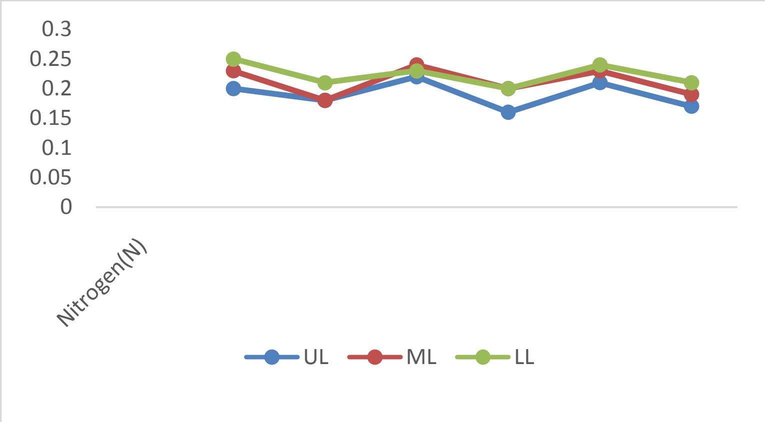

Fig. 5 Comparison of Nitrogen content in the three Study Sites

Potassium (K) assessment showed a an increased in values from upland (HL) with a range between 0.21 – 0.43 mg/l giving a weighted average of 0.29mg/l; Middle land (ML) recorded a range from 0.33 – 0.47mg/l and a weighted average of 0.40 mg/l, while lowland (LL) had a range between 0.42 - 0.56 mg/l with a weighted average of 0.51 mg/l (Table 2). The K results also showed (LL) had the highest increase in nutrient content, followed by (ML) and (HL) respectively (Figure 7).

Thus, among the three macronutrients (N, P, K) analyzed in this studied, K had the highest values and when compared with the standard rating categories, the (HL) site falls within a soil range as "low"; (ML) and (LL) falls within the "medium" category. However, the general high level of K might be due to application of fertilizer in addition to the added amount already in the soil itself as a natural K source, and those from leaving crop residue on the soil also returns significant portion of K to the soil [4]. On a general note, the organic content fluctuates among the sites but they all fall under "medium" category [26].

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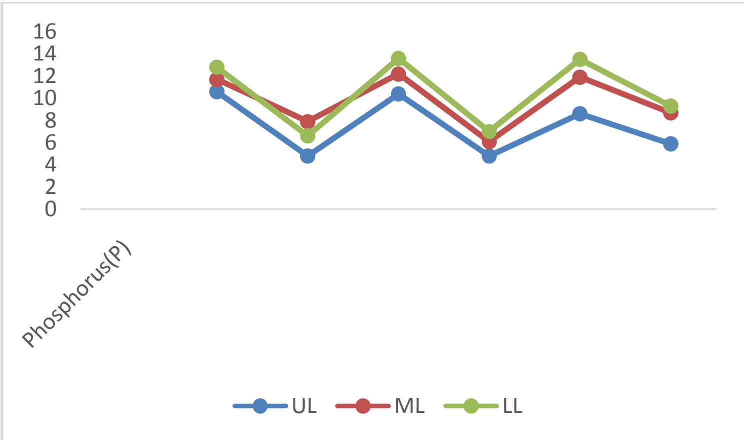

Fig. 6 Comparison of Phosphorus content in the three Study Sites

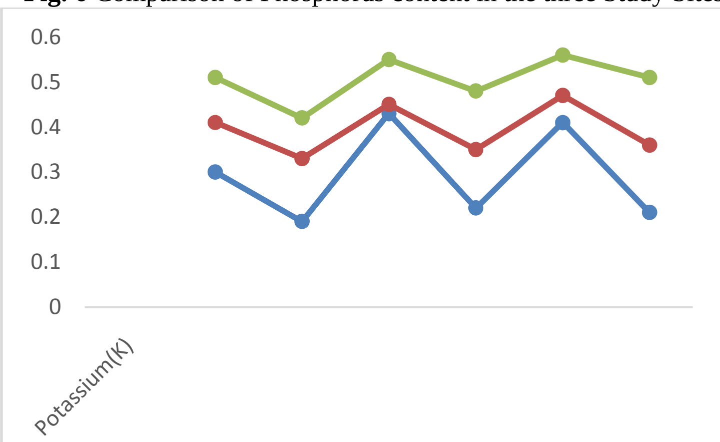

Fig. 7 Comparison of Potassium content in the three Study Sites

4. CONCLUSION

From this watershed soil studied, the physico-chemical parameters showed that; the soils of all the classes were light to medium in texture varying between sandy clay loam at the surface level and few classes of clay loam at the bottom depth with some variation in silt and clay content along the depth of the soil profile.

Sand percentage ranged higher at the highland surface and lower at the bottom; this means the percentage of sand kept decreasing along the slope of the watershed. Silt had a higher weighted average in highland site compared to Middle land site. In Lowland site, silt increased in composition as the highest deposits among the study sites. The clay content was found to increase down the depth of the profile with increase in slope from soil surface into the lower horizon.

The soil physico - chemical properties of pH, bulk density, organic carbon and those of Nitrogen (N), Phosphorus (P) and Potassium (K) were determined. Soil reactivity (pH) had higher pH across the soil profile for all classes. Among the three macronutrients (N, P, K), K had the highest values and when compared with the standard rating categories for soil fertility measurement, the organic content were found to have fallen under the category of "medium" statues. Generally, this result proved that not all watershed soils are exceptionally fertile; contrary to most of the rural farmers believe. It is recommended that:

i. Farmers should be managing watershed farm lands like any other farm so as to maintain the required soil fertility.
ii. Application of organic and inorganic fertilizers should regularly be applied in order to continuously replenish the used up soil organic matter after every cropping season.

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