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INFLUENCE OF VARIOUS LAND USE SYSTEMS ON SELECTED SOIL PRODUCTIVITY PARAMETERS OF WETLAND SOILS.

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ABSTRACT

A scientific investigation was undertaken to compare productivity parameters of wetland soils as influenced by different land use systems. The study was conducted in Hadejia-Nguru wetlands, Nigeria. A total of 54 each of composite and core samples were collected across irrigated rice field, rainfed millet and natural fallow-land in three replicates, at 0-30 cm depth using stratified random sampling. Result showed that soil of fallow-land was statistically higher than soils of rice and millet land use systems in dry mean weight diameter (MWDd) (1.31) by 3.5 % and 4.4 %, wet mean weight diameter (MWDw) (0.349) by 5.4 % and 10.3 %, organic carbon (OC) (8.11 g/kg) by 5.9 % and 25.2 % and total nitrogen (TN) (1.28 g/kg) by 15.9 % and 40.81 % respectively. For saturated hydraulic conductivity, fallow-land recorded highest compared to millet and rice by 6.73 % and 20.18 % respectively. Rice land use had greater cation exchange capacity (CEC) than fallow-land and millet land use by 9.3 % and 11.8 % and sodium (Na^+) by 62.3 % and 62.5 % respectively. Soil pH values obtained showed that rice land use had the least (pH 5.25), which could be due to leaching process. Fallow-land was inferred to be best in nutrient reserve and physical attributes. It's therefore recommended that conservation agriculture be adopted in rice and millet land uses to replenish depleted nutrients and improve physical attribute of the soils. Use of heavy machineries in the two cultivated land uses should be minimized.

Keywords: Wetlands, productivity, land use, Jigawa State, climate

INTRODUCTION

Land use is one of the main drivers of many processes of environmental change. It influences soil resources within the landscape (Antonio *et al*., 2014). Food and Agricultural Organization (FAO), Water Development Division (2011) explains that land use concerns the products and benefits obtained from use of the land as well as the management activities carried out by humans to produce those benefits. Land use and land cover are sometime mistaken as one. On clarity note however, land cover describes the physical land type such as forest, surface water or hills, whereas land use relates to how people put land to specific uses such as cropping, grazing, conservation, recreation or mining. Soil physical, chemical, biological and geological properties become altered over time by land use system. Crop species vary in anatomy, physiology and environmental requirements (water, air, nutrients). As such, different crop based land use systems may influence soil properties differently. Tukahirwa (2003) had reported 38 to 110 % reduction in exchangeable calcium (Ca), magnesium (Mg), and organic carbon (OC) in cultivated soils in relation to undisturbed woodlands in wetland soils. In the same study, extractable phosphorus (P) accumulated in cultivated and fallow-land relative to undisturbed woodlands, due to repeated P applications and immobility of P. Soils of the uplands had shown reductions in total C (-56 %) and TN (-51 %) in cultivated fields compared to native woodland of flooded luvisols (Solomon *et al*., 2000). In an uncultivated land use, the type of vegetation cover is a factor influencing the soil organic carbon content, which was observed to be highest in the poorly drained wetland (Jun *et. al.*, 2001) as cited by (Abubakar *et al.*, 2016). Devan *et al*. (2014) had reported that deep-rooted grasses in lowland areas can increase carbon sequestration by increasing organic matter deposition in the soil profile. Conversely, shallow-rooted crops can deplete carbon storage. Farmland soil had more sand content (90.5 %) and more variable (SE±3.5) than soils of uncultivated land use (Brady and Weil, 2002). Contribution from Abubakar *et al.,* (2016) revealed that porosity of wetland soil in Yobe State, were generally low with values less than 50 % in rice/wheat, maize and virgin land uses. Virgin land recorded 45 % porosity which was the highest. . However, Brady and Weil (2002) who worked in wetland areas in Maryland, USA, reported similar OM in soils of different land use. Solomon *et al*. (2000) also obtained similar pH result in paddy, vegetables and rangeland land uses.

Some low-lying areas of Jigawa State are prone to seasonal flooding and are appropriately called wetlands. A wetland can be described as any part of landscape where water accumulates for long to influence plants, animals and soils occurring in that area (Lain and Theo, 2012). Globally, wetlands are found in all climates; except Antarctica, and covers approximately 6 % of earth's land surface (Mitsch and Gosselink, 2007). Wetlands resources occupy 10-15 % of the Nigerian land area (Ojanuga, 2006). Jigawa State has about 8,500 hectares of wetland (Jigawa State Agricultural and Rural Development Authority (JARDA) and Institute for Agricultural Research (IAR, 1997)). Despite its significance, wetlands in Nigeria are rapidly being degraded as a result of natural and human interference (Vincent *et al*., 2014). Land use practices are part of anthropogenic interference. Wetlands are generally fertile and potentially productive compared to adjoining uplands (Abdullahi *et al*., 2011; Thenkabail and Nolte, 1995). Notwithstanding, for optimum productivity and sustainability, wetland should be regularly investigated. This is a necessity, because the tendency of wetlands to produce more food and fibre heavily depends on the manner in which they are managed (Thenkabail and Nolte, 1995). Antonio *et al*. (2014) stated that poor management of wetland soils can rapidly deteriorate its productivity, which becomes a major threat to rural subsistence in many developing countries. More so, impact of land use changes on soil can occur so unnoticed that farmers and land managers hardly initiate ameliorative measures. This was the motivator of this study.

MATERIALS AND METHODS

Area of the Study

The study was conducted in Hadejia-Nguru wetland area of the eastern part of Jigawa state, Nigeria (Fig. I). The area cuts across Hadejia (12°.45 N, 10°.04E), Guri (12°.63 N, 10°.48 E), Kirikasamma (12°.69 N, 10°.21 E), Auyo (12°.21 N, 9°.59 E), Kaugama (12°.47 N, 9°.73 E) and Kafin Hausa (12° 14' N, 9° 54' E) (Fig. II). This area is usually flooded during the rainy season. The most affected parts are farmlands and outskirt developments. There are different land use and land covers in both the Seasonally Flooded Field (SFF) and Non Flooded Fields (NFF) (visual observation and verbal interviews with farmers, 2016). Soil types of the area have been classified as Entisols, Inceptisols and Vertisols (Jigawa State Agricultural and Rural Development Authority (JARDA) 2002; Institute for Agricultural Research (IAR) and JARDA, 1997).

Geology, Slope, Climate and Vegetation of the study area

Permeable sedimentary rocks of the Chad formation underlie this natural wetland (Ogunkoya, 2014). An extensive low-lying plain that gently slopes northeastwards characterizes the relief around the site. River flow is highly seasonal (Haladu and Bello, 2014; Muhammed and Gert, 2003).The climate is of two seasons: the wet and dry. The wet season starts in May and ends in September (Roger, 2013). Annual rainfall is 500mm - 700 mm (Ogunkoya, 2014; Roger, 2013). Dry, dusty, Harmattan winds are prevalent between November and March. Mean minimum temperature (12°C) is in January while the hottest period is in April with a mean temperature of 40°C (Wikipedia, 2016; Ogunkoya, 2014). Potential evaporation in the area ranges from 2600 mm to 4000 mm annually (Ogunkoya, 2014; Chad Basin National Park, 2010). The general vegetation is characteristic of Sudan savanna – sparse shrubs and isolated tall trees (Wikipedia, 2016; Roger, 2013; Food and Agriculture Organisation (FAO, 2009)).

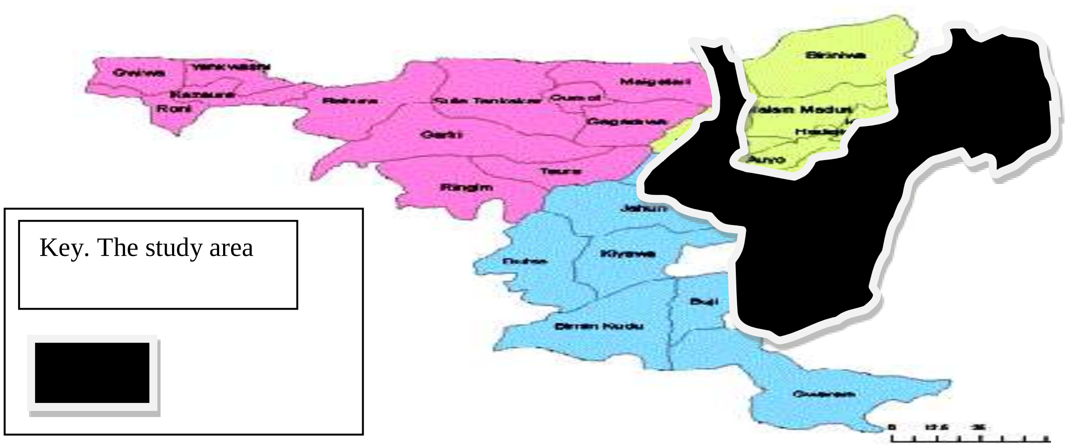

Fig. I: Location of the Study area in Jigawa state

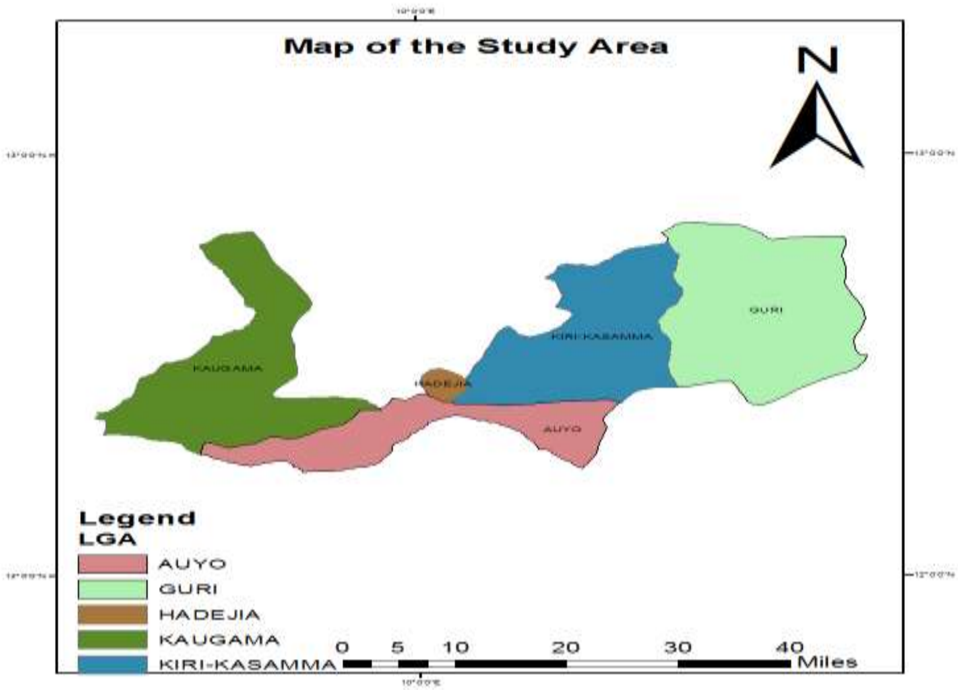

Fig. II: Map of the Study Area

Sample Collection

The area was divided into partitions based on land uses identified into:

1. Continuous irrigated rice,
2. Rainfed millet, and
3. Natural fallow-land

Each treatment was replicated three times (Same land use kind situated at different locations within the area were considered replicate) and sampled at 0– 30 cm soil depth. A total of 54 each of composite and undisturbed core samples were collected from the study sites by stratified random sampling technique; 3 landuse types, 6 local government areas and 3 replications.

Laboratory Analysis

The auger (disturbed) samples, were air dried and passed through 2 mm sieve, for determination of particle size distribution by Bouyoucos hydrometer (Gee and Bauder, 1986), wet and dry mean weight diameters (Van Bavel, 1950) as modified by Kemper and Rosenau, (1986), soil acidity (pH) in water and $CaCl_2$ as described by (Thomas, 1996), organic carbon by the dichromate wet oxidation method, (Nelson and Sommers, 1982), total nitrogen by the Kjeldahl digestion method (Bremner, 1982) available P by Bray No. 1 method (Bray and Kurtz, 1945), exchangeable bases (Black, (ed) 1965), exchangeable acidity by titration method (McLean, 1965), cation exchange capacity neutral K – acetate saturation and neutral NH_4- acetate Displacement method (Black, 1975) as described by International Institute of Tropical Agriculture (IITA)(1979).

Undisturbed soil samples were collected by the use of core (height = 5 cm, diameter = 4 cm and volume = 62.86 cm^3) and were used to determine dry bulk density (BD) (Anderson and Ingram, 1993), saturated hydraulic conductivity (Ksat) by constant head permeameter. Macro, micro and total porosities were determined as described by Jarvis *et al.* (2002); Dexter and Czyz, (2007); Reynolds *et al.*, (2008); Dexter *et al*., (2008) as follows:

Total porosity = the volume of water at saturation (0.0 bar), Thus

$$Pt = \frac{Ws}{Wd} \times \frac{BD}{\rho W}$$

Equation (1)

Where:

Pt = Total porosity

Ws = Weight of saturated soil

Wd = Weight of oven dry soil

BD = Bulk density

ρW = Density of water at 20˚C

Macro-porosity was computed using the formula:

$$Pmac = \theta s\ (\psi=0.0\ \text{bar}) - \theta m\ (\psi=0.33\text{bar})$$

Equation (2)

Where;

Pmac = Macro porosity

θs = Moisture content at saturation,
θm = Moisture content at field capacity,
ψ = Suction/ Pressure
Whereas microporosity was determined as;
Pmic =. Pt − Pmac Equation (3)
Where;
Pt = Total porosity
Pmac = Macro porosity

Mean weight diameters (MWD) were determined after obtaining aggregate size proportion of various mesh size by the formula
$MWD = \sum_{i=1}^{n} x_i \omega_i$ Equation (4)

Where MWD is the Mean Weight Diameter (mm),
n = the number of aggregate fractions,
X = the arithmetic mean diameter of the size fraction and
ω_i = the proportion of the total water stable aggregates in the corresponding size fraction after deducting the weight of sand and/gravels particles as described by Van Bavel, (1950) and modified by Kemper and Rosenau, (1986).
The sand correction was done through converting percent sand fraction determined in the particle size distribution analysis of each sample to gram. Proportional macro aggregate and micro aggregate fraction were computed as;

$\frac{Weight\ of\ stable\ macro\ aggregate}{Total\ weight\ of\ all\ the\ aggregate\ (200g)}$ and $\frac{Weight\ of\ micro\ aggregate\ fraction}{Total\ weight\ of\ all\ the\ aggregates\ (200g)}$ respectivelyEquation (5 and 6)
(Ontel *et al*., 2015)

Statistical Analysis

A general linear model, multivariate ANOVA principle was used by GenStat (Edition 4) application to determined/test whether there was significant difference in the result obtained for the various land use systems. Where there was significant difference among the means, least means square difference (LSD) was used to compare the means.

RESULTS AND DISCUSSION

Physical Properties

Result of particle size distribution (Table 1) showed that rice field had the lowest sand content but highest silt and clay fractions. This may be as a result of physical disintegration and chemical weathering occurring in the rice field from puddling operation and solubilisation (due to water ponding) respectively. This is in conformity with Azadeh *et al.* (2014); Hyohyemi, (2014) who found higher clay content in soils under rice cultivation compared to soils under fallow.
Fallow-land was found to have highest wet mean weight diameter (MWDw) and dry mean weight diameter (MWDd) (Table 1). The MWDw in fallow-land was greater than rice and millet fields by 5.4 % and 10.27 % respectively. This could be attributed to the fact that the land has not been under cultivation. Soils under minimum disturbance, further accompanied by higher plant residues are likely to be more strongly aggregated than cropped soils. Lawal and Lawal (2017) had reported that conventional tillage effected soil aggregate stability negatively. Hydraulic conductivity index was also found to vary significantly among the means of the land use treatments. Soils under fallow land use system recorded highest compared to millet and rice by 6.73 % and 20.18 % respectively. This is probably as a result of good aggregation of soil particles in fallow-land which ease permeability.

Millet field had highest value of soil bulk density (1.37 mg/m^3), which will however, not restrict plant root penetration and seedling emergence. This may be due to its limited total porosity owing to higher sand percentage and low organic matter (OM) content. With respect to macro aggregate, fallow-land recorded highest mean and was greater than rice and millet fields by 6.55 % and 12.4 % respectively. Farming operations particularly ploughing operation may have exerted disintegrative effect on the macro aggregate portion in the two cultivated lands.

No statistical variation was observed among the three land use systems regarding microporosity. Further, millet and fallow-land were observed to be statistically similar in proportional macroporosity. Grazing may be responsible for lowering the total porosity in fallow-land as observed by (Devan *et al*., 2014).

Soil Chemical Properties

The pH value obtained showed that rice field had the least value (pH 5.25). This probably resulted from excessive irrigation done on the field, which could facilitate leaching of basic cations. The highest pH value in the fallow-land (6.11) may be attributed to its high buffering capacity due to high humus substance owing to more OM; thus, tilting the pH toward neutrality. Oguike *et. al.* (2016), Ekunalalo and Olayinka (2016); Kekong *et al*. (2016); Okon *et al*. (2016) also observed increase in pH upon organic matter addition.
The study revealed a significant difference among the three land use with respect to OM, OC and TN in the order of fallow > rice by 6.28 %, 5.98 % and 15.9 % respectively and > millet by 24.9 %, 25.18 % and 40.81 % respectively. The highest values obtained in the fallow-land (Table 2) may be on account of lower nutrient consumptive/exploitative power of shrubs and ephemeral grasses growing in the fallow-land, compared to food crops particularly rice as reported by Iren *et al.* (2014). More so, decomposition of added organic materials through frequent litter fall, perished grasses and droppings from grazing animals may increase the content of the parameters, (OM, OC and TN) in the fallow-land. Rice land use was observed to have higher OC and TN over millet land use. This may be connected to heavy fertilization made onto the rice field by farmers because of its higher nutrient demand and economic value. Unlike millet which is believed to thrive satisfactorily on marginal soils and has lower economic value in the study location. George, (2005)

stated that millet both finger and Parle could do well on a low nutrient status soil.

Result of the exchangeable bases determined showed irregular pattern among the three land use systems. Millet and fallow land uses were statistically similar and higher compared to rice. Higher Na^+ value obtained in the rice field was greater than fallow and millet fields by 62.7 % and 62.9 % respectively. This may be in response to its cumulative deposition overtime through capillary rise of groundwater. As the water molecules evaporate, they leave behind salt deposit especially due to shallow water-table which support frequent rise of groundwater by capillarity. Mati, (2018) stated that sodium salt may be deposited on soil surface through capillary rise of groundwater. Fallow and rice land uses recorded higher cation exchange capacity (CEC) compared to millet. This could be due to higher negative charge surfaces owing to higher clay and organic matter content of the fallow-land. A contrast result was obtained in available P. This may be linked to its possible fixation by clay colloidal surfaces in the fallow and rice fields. Although rice field has the highest mean of EC but no statistical difference was observed at 95% confidence level among the treatment in EC (Table 2).

CONCLUSION AND RECOMMENDATION

This research was conducted to determine the effect of land use on selected soil properties of wetlands. From the results, fallow-land was concluded to be best for crop production due to appreciable nutrient content and good physical attributes comparative to millet and rice land use systems. It's therefore recommended that conservation agriculture and minimum tillage practices be adopted in rice and millet land use systems in order to enhance agricultural sustainability and productivity of the soils.

Table 1: Effect of Land use on Soil Physical Properties

Treatment	MILT	RICE	FLW	SE
Depth	⟶	30 cm ⟶	⟵	
Parameter				
Sand (%)	76.16a	59.11c	71.56 b	2.39
Silt (%)	12.72b	18.94a	15.20 ab	2.45
Clay (%)	11.22 c	22.06a	13.44b	1.03
Pmac (%)	32.89 a	22.83b	30.72a	0.86
Pmic (%)	28.11	28.17	26.78 Ns	0.71
PT (%)	61.00a	51.00c	57.50b	0.82
Mac.Ag (g/200g)	30.00c	36.56b	43.78a	0.60
Mic.Ag (g/200g)	167.22a	160.44b	153.7c	0.63
BD (mg/m^3)	1.37a	1.06c	1.33b	0.06
Ksat (mm/s)	3.67b	2.33c	4.44a	0.11
MWDw	0.256c	0.30b	0.349a	0.002
MWDd	1.15b	1.18b	1.31a	0.04

Pmac = Macro-porosity, Pmic = Micro-porosity, PT = Total porosity, Mac. Ag. = Macro-aggregate, Mic.Ag.= Micro-aggregate, BD= Bulk density, MWDw = Wet mean weight diameter, MWDd = Dry mean weight diameter, Ksat = Saturated hydraulic conductivity, MILT = Millet, FLW = Fallow. SE= Standard error

Table 1: Effect of Land use on Soil Chemical Properties

Treatment	MILT	RICE	FLW	SE
Depth	⟶	30 cm ⟶	⟵	
Parameter				
pH (water)	5.94 b	5.28 c	6.11 a	0.13
pH ($CaCl_2$)	5.44 a	4.30 ab	5.39 a	014
OC (g/kg)	3.44 c	7.00 b	8.11 a	0.17
OM (g/kg)	6.00 c	11.94 b	13.94 a	0.28
TN (g/kg)	0.28 c	0.89 b	1.28 a	0.009
Av.P (mg/kg)	3.61 a	2.56 c	3.33 b	0.13

EA (Cmol/kg)	0.44 b	0.54 ab	0.59 a	0.05
CEC(Cmol/kg)	3.94 b	5.56 a	4.28 b	0.13
Exch. Bases (Cmol/kg)				
Ca	2.09 a	1.69 b	1.85 ab	0.11
Mg	1.11 c	1.93 a	1.57 b	0.44
K	0.23 b	0.36 a	0.20 c	0.09
Na	0.088 b	0.54 a	0.09 b	0.03

OC = organic carbon, OM= Organic matter, TN = Total Nitrogen, EA = Exchangeable acidity, CEC = Cation Exchange Capacity, Ec = Electrical conductivity, Av.P = Available phosphorus, MLT = Millet, FLW = Fallow. SE = Standard error.

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