Effect of Land Utilization Types on Some Physical and Hydraulic Properties of Soils in Gidan Sule, Wamakko, Sokoto State, Nigeria

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Abstract:-**A reconnaissance soil survey was conducted using free survey method on a 20 hectares site on the part of Wamako Local Government between latitude 13° 11' N and longitude 5° 20' E to study the effect of land utilization types on some physical and hydraulic properties of soils in Gidan Sule. Three land utilization types were identified and mapped which include rainfed, irrigation and orchard farming. A total number of three pedons (one for each land utilization types) were dug, described, sampled, and analyzed to collect data on some physical and hydraulic properties of the soils. The data generated were subjected to descriptive statistics such as mean, ranges, percentages, standard error etc. The soils of all LUTs were rated low in bulk density values (<= 1.3 gcm^{-3}) at the surface horizons, due to high organic matter content therefore, it is recommended that farmers should practice reduce tillage in order to maintain low bulk density values.**

Key words: land utilization type, Ksat, bulk density, porosity, orchard, rainfed, irrigation.

I. INTRODUCTION

Soil can be defined as the natural body in which plant grow, it provide the starting point for successful agriculture [1]. Different soil types exhibit diverse behavior due to differences in soil properties such as physical and hydraulic properties etc. These variations are due to influence of the soil forming factors and processes operating on different parent materials, under different climatic, topographic, and biological conditions over varying of time [2]. The intensity of land utilization varies widely throughout the world. In large regions of Africa and Latin America, and in some parts of Asia, the system of land use is very extensive. The situation in the Sudan savanna during the early 1980s and up to 2002, despite the fact that rainfall has decreased, the vegetation cover is in the process of recovering. However, there is tremendous pressure from grazing, especially by goats. In other areas, on the clay plain, there is a continuing land degradation process, estimated that overgrazing accounts for 47% of the clearance of natural vegetation, whereas mechanized cropping and woodcutting, and urban demand for charcoal account for 22% and 19% respectively. The increasing need of wood for construction and fuel in the Sudan savannah may accelerate the trend of woodland destruction [3].

Many studies [4] indicated strong and statistically significant relationships between soil quality and land use type. Effects of land use changes on soil physical and hydraulic properties are inherently regional and highly dependent on the soil type [5], climate [6] and topography [7]. However, there is need to assess the effects of land use types have on soil physical and hydraulic properties in different agro-ecological regions. The different land utilization types in and around Gidan Sule village affect both physical and hydraulic properties of soil. One of the clear effect include conversion of the finer particle to coarse ones translated in to low moisture retention capacity of the soils. This research provided scientific information as regards to the causes of the above problems, and make recommendation on how to manage the situation.

II. MATERIALS AND METHODS

A. Description of the Study Area

The study was conducted at Gidan Sule village located between latitude 13^0 11' N and longitude 5^0 20' E Wamako Local Government, Sokoto State with an average elevation of 246 m and total area of 20 hectares. The annual rainfall average ranges between 600-700 mm [8] and occurs between May and September with a peak in August. The dry season usually spans from November to March during which there is Harmattan period that is characterized by the cold dusty wind between the months of November to February. The hot periods starts from March and ends around May during which the recorded environmental temperatures are in the range of 38–42 °C with an average humidity of less than 20% [9]. The administrative map showing Wamako local government and surrounding local government was presented in figure 1 below.

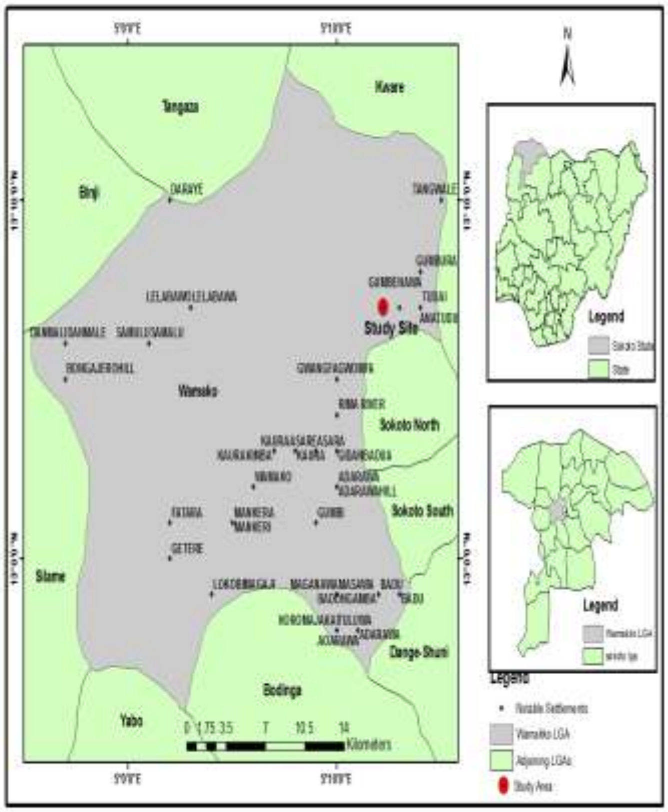

Fig. 1: Administrative Map showing Wamako LGA and surrounding LGAs.

Source: Arc GIS Generated by GIS Lab. Department of Geography UDUS 2018.

B. Field Work Procedure

Contact was made with community leader(s) and their people whose lands were used in the research to create awareness about the research conducted and also prior permission were sought to use their farmlands. During this, enlightenment was made as regard to the significance of the research in their area. A reconnaissance soil survey was conducted using free survey method to identify and document different land use types. Prior to the commencement of the study, a reconnoiter was made around Gidan Sule and its surrounding environ to collect information on landform, vegetation, cropping history, topography and slope of the area. This enabled the identification of area that represented the soils of the study area. SPOT-5 images of the study area were used as base map (Figure 2). Mapping of the land use types was made by the satellite imagery interpreted. The different land use types were documented. Three land utilization types were selected for soil examination at soil series level. Three (3) Pedons were dug one for each of the land utilization types and described according to [10] procedure and Samples were collected from each genetic horizon for physical and hydraulic properties determination in the laboratory.

Fig. 2: SPOT-Image of study site showing Orchard, irrigated and rainfed Land

Source: Arc GIS Generated by GIS Lab. Department of Geography UDUS 2018.

C. Sample Preparation and Laboratory Analysis

The soil samples collected were taken to the laboratory, air-dried, crushed gently, and sieved using 2 mm sieve. Separates with particle sizes < 2 mm (fine earth fractions) were used for the particle size distribution. Undisturbed soil sample for bulk density and hydraulic conductivity determination were taken using core samplers of known volumes. Samples for bulk density determination were oven dried at 105 ^{0}C for 24 hours.

1. Particle Size Distribution: Particle size distribution was determined using Bouyoucos hydrometer method [11].

2. Bulk Density: Bulk density was determined using core sampler method as described by [12].

3. Particle Density: Particle density was determined by the use of Pycnometer bottle method [13].

4. Total Porosity: Total porosity was calculated using the following relationship: p = 100 (1-Bd/Pd).

Where, *p* =porosity, Bd = bulk density, pd= particle density, 100 and 1 are constants.

5. Saturated hydraulic conductivity (Ksat): Saturated hydraulic conductivity (Ksat) of the soil was determined using the falling head permeameter method similar to that described by [14].

D. Data Analysis

The data generated were subjected to descriptive statistics (such as means, percentage etc) using SPSS statistical package version 20.

III. RESULTS AND DISCUSSIONS

A. Extent and Distribution of Utilization Types

The result on the extent and distribution of land utilization types (LUTs) was presented in Table 1 and Figure 3. Orchard farming appeared to be the most expansive (9.8 ha ≈ 49%) in coverage followed by irrigated farming covering 6.8 ha

(34%). Rainfed farming had the lowest coverage of 3.4 ha (17%) (Table 1) and (Figure 3). The analysis and interpretation of Figure 4 revealed that the people in study site were predominantly orchard (49%) and irrigated (34%) farmers, but they also practice rainfed farming to a lesser extent. This result contradicted the findings of the [15] who observed that in developing countries, rainfed agriculture account for 60% of agricultural production.

Table 1: Extent and Percentage Coverage of LUTs

LUTs	Soil Series	Hectares	% Area
Rainfed Farming	Gidan Sule Series P1	3.4	17
Irrigated Farming	Gidan Sule Series P2	6.8	34
Orchard Farming	Gidan Sule Series P3	9.8	49
Total		20.0	100

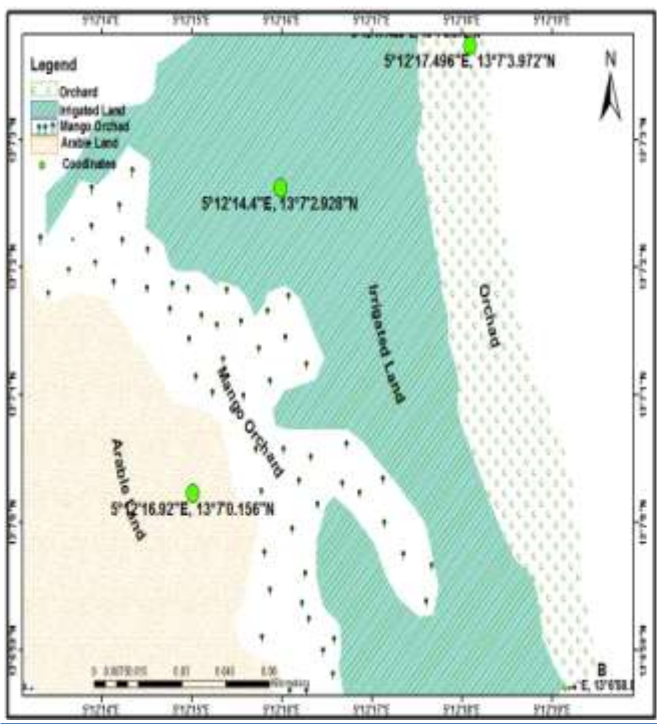

Fig. 3: A map showing the extent and distribution of LUTs as well as location of profile pits

Source: Arc GIS Generated by GIS Lab. Department of Geography UDUS 2018

B. Site Characteristics and Land Use of the Pedons

The general information on parent material, location, slope, surface drainage and erosion characteristics regarding each pedon were presented in Table 2. The site characteristics of the LUTs have shown discernible differences in slope, surface drainage and parent material (Table 2). The rainfed, irrigated and orchard farming were on landscapes with slope of 2-3, 1-3 and 1-3% respectively. The LUTs rainfed and orchard farming were well drained, whereas irrigated farming was poorly drained. This could be due to varied textures and drainage of the soils. According to [16], the soils with varied textures and drainage may range from well drained to poorly drained. Rainfed soils developed from Aeolian and Alluvial deposits, while both irrigated and orchard soils developed from alluvial deposits. According to [17], soil properties vary in vertical and lateral directions and such variation follow systematic changes as a function of the landscape position (slope), soil forming factors (e.g. parent material) and/or soil management practices (land use or LUTs).

C. Particle Size Distribution as Affected by LUTs

The effect of land utilization types on particle size distribution of soils of the soils were presented in Table 3. The percentage sand at surface horizons of the Pedons under the different LUTs ranges from 24-65% (45% mean) which was rated high (Table 3). In the subsurface horizons of the Pedons, the Sand content varied between 7-60% (34% mean) which was rated moderate (Table 3). In the surface horizons of the Pedons, the highest sand content (65%) was recorded in the Ap horizon of the rainfed soil. This could be attributed to the effect of continuous cultivation. The highest Sand content (60%) observed in the Btg horizon of the Irrigated farming could be due to illuviation Process.

The percentage Silt at the Surface horizons of the Pedons, under different LUTs ranged from 32-62% (47% mean) which was rated high (Table 3). In the subsurface horizons, of the Pedons the silt contents ranges from 19-89% (54% mean) which was rated very high (Table 3). The highest silt content observed in the surface and subsurface horizons of orchard and irrigated lands could be attributed to the nature of parent materials (Table 2) of the soils.

The percentage clay at the Surface horizons of the Pedons, under different LUTs varied from 12-21% (17% mean) which was rated low (Table 3). At the subsurface horizons of the Pedons, the clay content ranges from 4-21% (13% mean) which was rated also low (Table 3). The low clay contents observed both at surface and subsurface horizons could be attributed to the effect of long term cultivation.

D. Effect of LUTs on Bulk Density

The bulk density at the surface horizons of the Pedons under different Land Utilization Types ranges from 1.2-1.3 g/cm^3 (1.3 g/cm^3) which was rated low (Table 3). In the subsurface horizon of the pedons, the bulk density content assorted from 1.0-1.4 g/cm^3 (1.2 g/cm^3 mean) which was also rated low (Table 3). This could be as a result of high organic matter content and finer texture of the layers. This result is in line with the finding of the [18] who reported low bulk density values for soils with high organic matter content and ascribed decrease in bulk density to conversion of coarse textured mineral soils to finer textured soils. The bulk density generally increases with soil depth due to lower organic matter content and overburden of the upper soil layers (Table 3).

E. Effect of LUTs on Particle Density

The particle density at surface horizons of the Pedons varied between 2.1-2.5 g/cm^3 (2.3 g/cm^3 mean) (Table 3). In the Subsurface horizons of the Pedons, it ranged from 2.3-2.4 g/cm^3 (2.4 g/cm^3 mean) (Table 3).

F. Effect of LUTs on Total Porosity

The total porosity at surface horizon of the Pedons under different LUTs ranges from 45-50% (48% mean) (Table 3). In the subsurface horizon of the Pedons the Porosity assorted from 43-61% (52% mean) (Table 3). The result (Table 3) shows that, the soils are good for root development. This result is in line with finding by [19] who observed that soil total porosity ranged from 30 to 60 % is considered good for root development.

G. Effect of LUTs on Ksat

The saturated hydraulic conductivity (Ksat) at surface horizons of the Pedons under different land utilization types ranges from 1.61-2.38 cm/hr (2.00 cm/hr mean) (Table 3). In the Subsurface horizons of the Pedons, the Ksat ranged from 1.10-2.23 cm/hr (1.67 cm/hr mean) (Table 3). The Ksat was higher at the surface as compared to subsurface horizons. This could be attributed to porosity, bulk density, tillage practices, compaction, differences in land cover and management, loss of topsoil and the thinning of the layer above the clay pan.

IV. CONCLUSIONS

In terms of coverage, the orchard soils were more expansive (9.8 $ha \approx 49\%$) in coverage of all the LUTs studied followed by irrigated farming covering 6.8 ha (34%). Rainfed farming had the lowest coverage of 3.4 ha (17%). Rainfed soils developed from Aeolian and Alluvial deposits while both irrigated and orchard soils developed from alluvial deposits. All the land utilization types fall within the slope class of 1-3%. The soils of LUTs rainfed and orchard were well drained whereas irrigated soils were poorly drained.

The Percentage sand at surface horizons of the Pedons under the different LUTs was rated high. The Bulk density at the surface horizons of the Pedons under different Land Utilization Types was rated low.

V. RECOMMENDATION

According to the findings of the research, the following recommendation was made: The farmers were encouraged to adopt reduce tillage practices in order to maintain low bulk density and high porosity status of their soils.

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Table 2: Some Physical and Hydraulic Properties of the Soils of Gidan Sule Series

Horizon	Depth (cm)	PSD (%)			Textural Class	BD	PD	Porosity (%)	Ksat cm/hr
		Sand	Silt	Clay		g/cm^3			
Rainfed Farming – Gidan Sule Series P1 (Typic Kanhaplustalfs/Sodic Cambisols (Oxyaquic)									
Ap	0-57	65	23	12	SL	1.2	2.5	50	1.62
Bt	57-144	57	35	8	SL	1.4	2.4	43	1.12
BC	144-200	49	43	8	L	1.4	2.5	41	1.10
Irrigated Farming – Gidan Sule Series P2 (Aeric Endoaquerts/Haplic Vertisols)									
Ap	0-60	41	38	21	L	1.2	2.1	45	2.38
Btg	60-129	60	19	21	SCL	1.0	2.3	61	2.23
BCg	129-170	14	82	4	SiL	1.7	2.5	31	2.05
Orchard Farming – Gidan Sule Series P3 (Leptic Endoaquerts/Haplic Vertisols)									
Ap	0-104	24	62	14	SiL	1.3	2.5	47	1.61
Bt	104-149	7	89	4	SiL	1.0	2.3	57	1.60

PSD= particle size distribution, SL= sandy loam, SCL=sandy clay loam, L=loam, SiL=silt loam. BD=bulk density, PD= particle density

Table 3: Parent Material, Location, Slope, Drainage and Erosion characteristics of LUTs

LUTs	Geographic Position		Slope (%)	Surface Drainage	Erosion Hazard	Parent Material
	Latitude	Longitude				
Rainfed Farming	13^{0}11’72.8¨N 13^{0}11’61.7¨N	5^{0}20’37.0”E 5^{0}20’45.5”E	2-3	WD	--	Aeolian and alluvial deposits
Irrigated Farming	13^{0}11’77.3¨N 13^{0}11’63’1¨N	5^{0}20’48.5¨E 5^{0}20’53.2¨E	1-3	PD	--	Alluvial deposits
Orchard Farming	13^{0}11’74.4¨N 13^{0}11’61.6¨N	5^{0}20’41.7”E 5^{0}20’49.8”E	1-3	WD	--	Alluvial deposits