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Land Capability Classification of Katsina Central, Nigeria Using Remote Sensing and GIS Techniques

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Abstract

The main objective of this research was to make the land capability classification of rained farming for major crops. The study was conducted in Katsina Central, Nigeria. In this study five land units were identified based on topography. Soil survey was conducted to each land units for exploration of physical and chemical characteristics of the soil. The results of soil analysis reveals that the study area is characterized by susceptibility to erosion and low in soil fertility which limit the land capability for multiple uses. The land capability classification was employed based on USDA classification system. The results depict that four land units were rated capable for rain fed farming of major crops under different management practices which account 75.26% of the total land covered of the study area While 24.74% is not capable no matter whatever management practice applied as such it is recommended for forestry. The land capability of the area can be improved through adapting appropriate measures.

Keywords: Land unit, land capability, Rain fed farming, major crops.

I. INTRODUCTION

Land is made up of all elements of physical environment that influence land use directly or indirectly (Colin 1991). Land does not only refer to soil but also encompasses attributes such as geology, land forms, climate and hydrology, the plant cover and fauna, including insect and micro fauna associated with diseases (Cassidy, 2010). Some seen land as everything in the context of human existence and survival as it is the source of food, identity, shelter, and wealth (Oguike, 2018). Land is also serve as a fundamental natural resources upon which other resources depend on (Öztürk, 2017). Land also refers to part of the earth surface that is not covered by a body of water, that means part of the earth surface occupied by continent and island (Al-mashreki et al., 2011). To others it views as portion of the earth solid surface that characterized by boundaries and ownership (LIOH 2015). In a nutshell land is much more than a resources.

The increase in the number of people accompanied by the increase in the economic needs, especially for the benefit of agriculture, makes a pressure rate on land resources inevitable that causes an impact on the land degradation and the environmental pollution (Lu et al., 2008). To be able to utilize the land resources in a focused and efficient, are require appropriate technology to optimize land (Satriawan, 2014). Agricultural productivity is rising, cost in land degradation are high, large areas of crop land, grass land, wood land and forest are seriously degraded, intensive cultivation, and urban expansion removing large areas of agricultural land use from production (Abdelrahman, 2016). In order to use the land resources in a focused and efficient it require an appropriate technology. Information on Climatic conditions, physical and chemical properties of land are highly needed for sustainable land use (Satriawan et al., 2014).

The capability potential of a land is determined mainly by the collective effects of soil, terrain and climatic factors, which are the permanent physical

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limitations of soil, land features and climate (Abdelrahman et al., 2016). These permanent limitations are referred to as the parameters or criteria that determine land capability categories (Abdelrahman et al., 2016). Land capability categories are determined after the assessment of the adverse effects of these permanent limitations for the potential use of the land. These categories are referred to as the land capability units, subclasses, classes and orders. Therefore, the method is based on the concept of limitations to land use imposed by land characteristics (Abdelrahman et al., 2016).

Land capability classification enables the land on a farm to be allocated rationally to the different kind of land use required, i.e. rotational arable, permanent grazing, wood land, recreation, wild life e .t c. Whilst leaving as much choice as possible open to the farmers, there is a strong element of guidance on soil conservation needs, Young cited in (Maduakor, 1991) It is through land capability classification one can know how the type of land use the area can be put to. It also helps in assessing the limitation to use due to some attributes of the land. The attributes limit the types of use (Elsheikh et al., 2013). Katsina is one of the 36 states of Nigeria. It has a total land area of about 4,100sq km and consist of many land uses. Generally, the soil of the area is tropical ferruginous, red and brown of the basement complex in southern part of the state. The soil forming factors are rocks and sand materials. The soil tends to be water logged with heavy rain fall and dry out and crack during dryseason this soil is difficult to work. In the northern part of the area the soil is coarse, this soil is sandy in nature, light in color and low to medium fertility. Expansion of cultivated area to compensate for low output and intensive cultivation without allow the farms to lie fallow are common features of Northern Nigerian which is not a sustainable.

II. MATERIALS AND METHODS

Katsina central, is found along the A9 highways in the Northern part of Nigeria, located on latitude 12° 27′ 16.00″ N to 12°59′ 26.95″N and longitude on 7″12′6.20″ E to 7°12′6.37″E. It falls in the Sudan Savannah zone, a region characterized by long dry seasons and short rainy season. Katsina central zone as the name implied, is a political entity located in the central part of Katsina state and the extremely north - western part of the state. It comprises of eleven local Government areas of Katsina, Kaita, Kurfi, Jibia, Batagarawa, Rimi, Batsari, Dutsin-ma, Safana, Danmusa, and Charanchi with land coverage of about 6,269 ha. It is relatively bounded by Funtua senatorial zone of the state to the South, Zamfara state to the west, Niger republic to the North, Kano and Jigawa states to the East. The zone has a total population of about 2, 667,000 in 2018 as projected from 2006 census figure based on growth rate of 3 %.

This study was conducted by the used of materials such as GIS, Prismatic compass, Abney level, ranging pole, soil auger, tape, chain etc. As field survey is very imperative for generating soil information's of a given region to verify the existing land use pattern in different soil series. In delineating land units. The physical attributes of the land of study area such as elevation, topography, soil depth, digital elevation model (DEM) were integrated with Remote sensing and arc GIS of 10.3 version to delineate the land units. The zooming in and zooming out image of study area shows detail information about the photo patterns of land surface i.e. slopes, stoniness, texture, soil depth, as well as soil type.

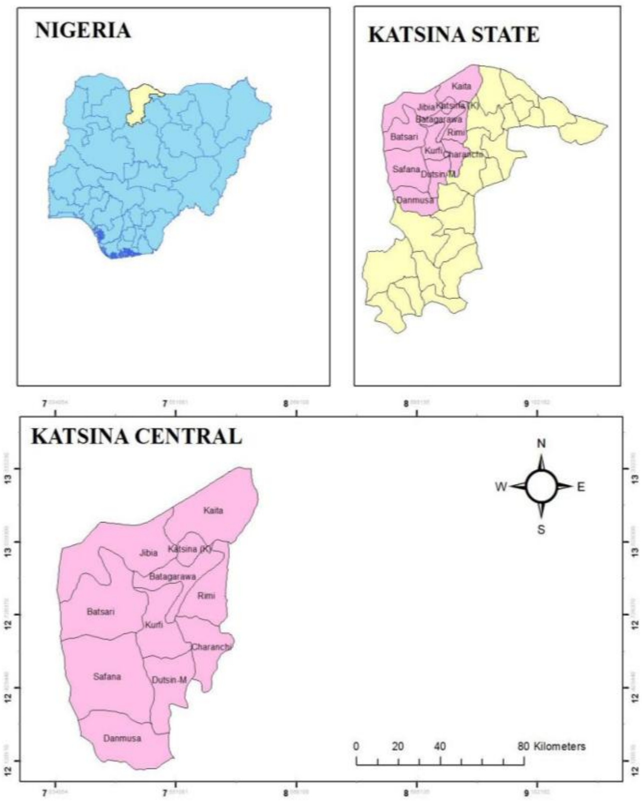

Figure 1 Map of study area

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III. DETERMINATION OF PHYSICAL AND CHEMICAL CHARACTERISTICS OF SOIL

The soil depth was assessed within the field by tape marked in meters. The surface stoniness was determined by the number of stones per square meter. The drainage condition of the area was determined through field observation. The erosion activities of the study area were also determined through field observation. Five profiles were opened, one from each land unit, after opened the profile and identification of the horizons a triplicate sample of half kilogram ($^1/_2$kg) was collected from each of the soil horizons identified, from five land units which gave a total of fifteen samples that air dried and faintly crushed with porcelain pestle and mortar after which it sieved through 2mm sieve in order to remove rough constituent part. to standard laboratory for physio – chemical analysis (CEC, EC, pH, TN, P, ESP) and particle size distribution (Yusuf, 2011). The soil samples collected from each land units, soil profiles were opened to measure soil depth and drainage conditions. Meanwhile, representative soil samples were collected to analyzed soil physical and chemical characteristics. For the determinations of total N and organic carbon (OC), a 0.5 mm sieve was used. Particle size distribution was analyzed by used of ratio method. Soil pH was determined in H2O using 1:2.5 soils to solution ratio using a combined glass electrode pH meter (Carter and Gregorich, 2006). Total N was determined by the Kjeldahl digestion and distillation procedure (Bremner and Malvanny, 1982). The CEC was determined from the summation of the exchangeable bases by 1M NH_4OAC extraction while the exchangeable acidity by IM KCI extract as ECEC (cmol/kg^{-1}) = $\sum (K^{+}+Ca^{++}+Mg^{++}+Na^{+}+\text{Acidity})$ (Aune, Bryn, &Hovstad, 2018).

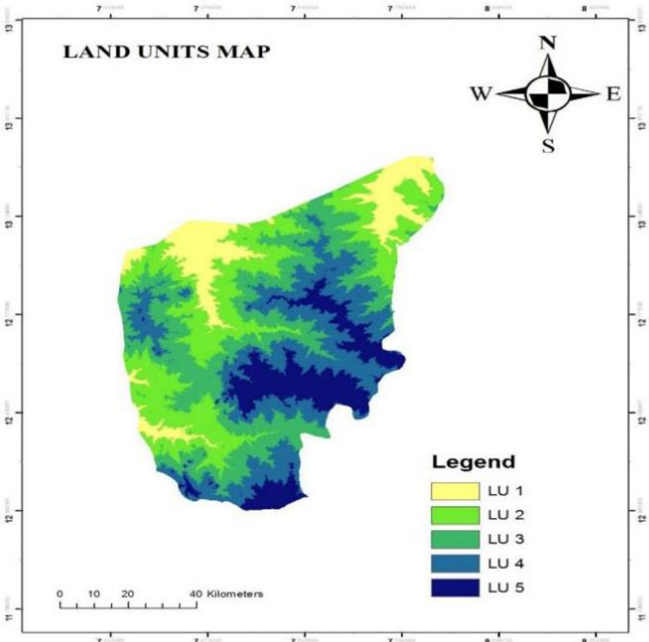

Figure 2 Land unit map of study area

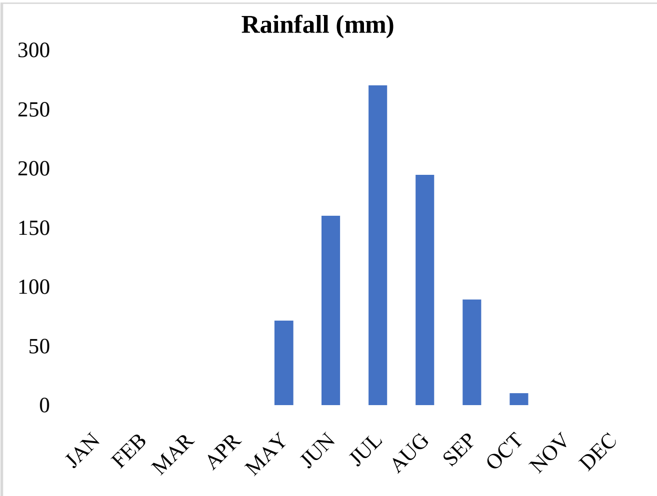

Figure 3 Mean monthly rainfall

A land unit (LU) may be a parcel of the landscape that has comparative characteristics and qualities distinguished on the basis of the image design. The translated nature of each design determined the characteristics of the mapping unit. The land units (LU) give the foremost point by point soil data on land characteristics. The study region is separated in to five major land units; Flood plain, Valley land, undulating lowland, Plain land and Hilly arrive. Soil profile were opened from each land unit to study and measured the soil depth, bulk thickness, consistency and drainage condition. Tests of soil are also collected from diverse horizons for routine investigation. The land units of the region extracted from digital elevation model (DEM) using arc GIS 10.3 version. Geographical sheets maps were serve as guide within the field study.

IV. CLIMATIC CHARACTERISTICS OF STUDY AREA

As it has been found the rainfall and temperature distribution are not normally distributed as some part of the data skew to different direction defending on trend of the variables. According to literature, CV is used to classify the degree of variability as less CV < 20% moderate, 20 < CV < 30% high, CV > 30% very high, CV > 40% and CV > 70% indicate extremely high inter-annual variability of rainfall (Panda 2019). With reference to this classification rainfall variability falls in to three classes that is months with moderate < 20% CV (September and October) and months with high variability that is > 30% and equally important the area characterized with the months of extremely high CV that is > 70%. Therefore, in a nutshell the rainfall distribution of the area reflects the movements of two major air masses that is wet and dry air masses. The first quarter of the year in study the period is dried, while the second and third quarter of the year the periods is wet seasons and the last quarter of the year is also dried.

The temperature of any region play a great role in climate variability (Panda, 2019). The temperature of the study area increases at a decreasing rate. As depict in (table 4.6) April, May and June temperature is very high while August and September the temperature decrease due to high rainfall during the period and intensive cloud cover which all served as factors that lowered the temperature.

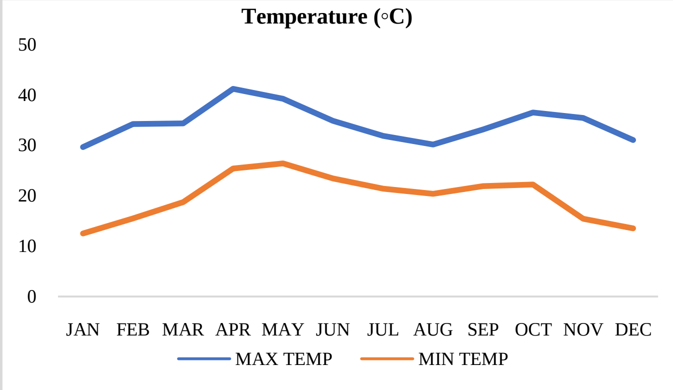

Figure 4 Mean monthly of maximum and minimum temperature

The climate and temperature facts show that climate change has an effect on the local climate of the study area for the last decade. The minimum and maximum monthly temperature of the study area (13.50-39.01) and CV (2.46-11.76) varies respectively. The rainfall trend of the area increases at decreasing with the highest peak at 2017. The coefficient of Kurtosis and skewness in both maximum and, minimum temperature has low variation and the data are negatively skewed (Sharififar, 2012).

Table 1 Characteristics of land units

LAND UNIT	SLOPE	EROSION	STONINESS	SOIL DEPTH	DRAINAGE	TEXTURE	CEC	OC	SOIL pH	AWC
1	0-4	severe erosion	0-18%	>120cm	poorly drained	l, sl, sil	5.55	2.1	6.2	85%
2	4-8	Moderate	18-21%	105cm	mod. Drained	s,sc,l,sil	7.03	2.3	6.3	63.18%
3	8-12	very slight	21-34%	90cm	well drained	s,cl	4.57	2.05	6.1	60.15%
4	12-16	Moderate	34-48%	75cm	mod. Drained	s,cl	4.44	0.19	7.1	56.76%
5	>16	severe erosion	>54%	60cm	well drained	Hc	4.04	1.8	6.9	56%

V. LAND CAPABILITY CLASSIFICATION

Land Capability Classification in Katsina central Based on the physical and chemical characteristics of the land presented in Table 4.20 below, and the matrix of the criteria from the USDA land capability classification modified (Gizachew and Ndao, 2008) in table 4.19, the land in Katsinacentral are included in the category of classes II, III, IV, and VI, with the limiting factor such as drainage (w) the slope (l), the threat of the occurrence of erosion (e), climate limitation (c), and the surface stoniness (s). Land capability classification for each land unit are presented in Table 4. 20 and Figure 4.21.

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Table 2 USDA Conversion table

Soil characteristics	Land capability classes							
	I	II	III	IV	V	VI	VII	VIII
Slope (%)	0 - 8	8 - 16		16 - 30		30 - 50	> 50	
Erosion	Nill or slight	Moderate	High			Very high	Extremely high	
Stoniness (%)	0 - 40	>60				> 40		
Soil depth (cm)	>60	45 - 60	15 - 45	< 15		> 15		
Soil drainage	Never saturated	Rarely saturated	Saturated for short period			Saturated for long period		
Soil texture	L, LS, SL	Si, SCL, CL, SiL, CL	S, C,SC	S,C		ANY		
CEC (cmol/kg)	20	15	10	5		5	2	0
Organic carbon (%)	> 1	0.8 - 1	0.6 -0.8	0.4 - 0.6		0.2 - 0.4		
Soil pH	5.5 - 7.9	4.5 - 5.5 , & 7.9 - 8.4	< 4.5 &> 8.4			< 4.5 &> 8.4		
AWC (cm)	25	20	15	10		5	2	0

Land capability class II

Land capability class II is suitable for a wide range of uses, including use for seasonal crops, annual crops, and pasture. This class is found in flood plain (land unit 1). However, this class of land in Katsina when use for intensive crop production it required certain management practices such as cover crops (Groundnut and beans) to minimized erosion activities, applied of fertilizer or manure to supplement the low organic matter. Land area for class II in Katsina central is about 1.03% (64.57ha) of the total land mass of the area.

Land capability class III

Land capability class III is capable for crop production both annually and seasonally. However, choice of crops or cropping system remain restricted because of inherent limiting factors, among the limitations of soil in this class are low fertility, high temperature and sloping. Land area for this class is about 4298.65ha which is about 68.57% of the study area.

The capability class IV

coarse texture, low available water capacity, low organic matter, low CEC, with shallow soil. This capability class can be used for both seasonal and annual cropping. This class covered about 30.30% of the study area (1899.03ha). When use for sustainable crop productions conservation practice such as vegetative ground for cover cropping, addition of organic matter and manure are highly needed.

The capability class VI

Land capability classes VI is very unsuitable for seasonal crops, but can be used for annual crop with good management practice such as ground cover plants, intensive grasslands, forest production, or protected forests. Land area for class VI it covered 6.27ha which is only 0.10% of the study area.

Table 3 Land classes with % covered

Capability classes	Dominant land unit	Area in (ha)	% of area covered
II	Flood plain	64.57	1.03
III	Valley land	4298.65	68.57
IV	Plain land	1899.03	30.30
VI	Hilly land	6.27	0.10

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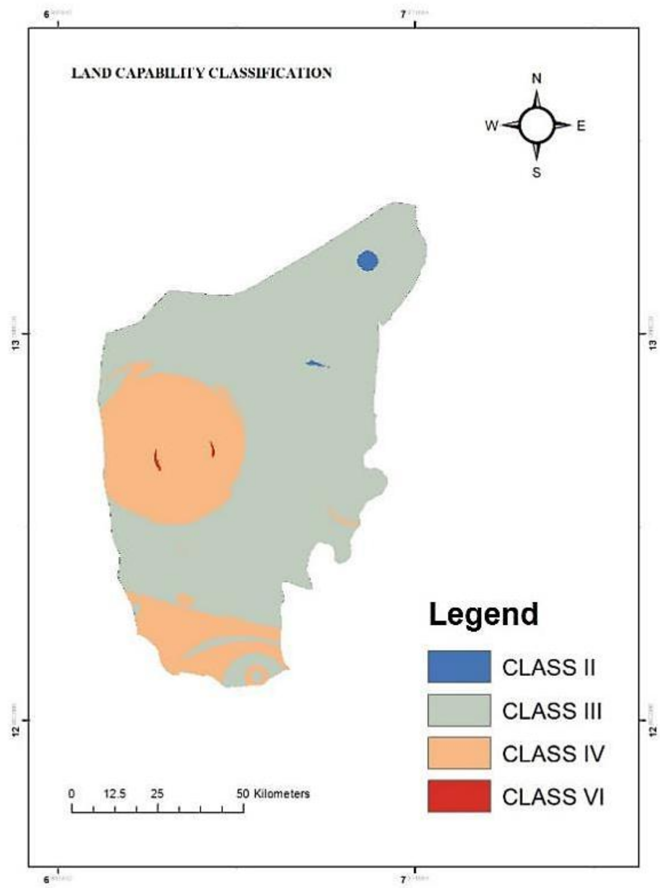

Figure 5 Land Capability Classification

VI. RESULT AND DISCUSSION

The soil depth of all capability classes of the study area ranges from 60-120cm. In terms of stoniness the area coverage ranges from nill to extremely high stoniness (<18% to >55%). Erosion activities characterized by three classes that is from slight, moderate to severely eroded areas. Equally important the classes are differed in terms of drainage, which ranged from well drained, moderately drained and poorly drained. Texturally the classes fall within five classes of USDA textural classes, that is very low, low, moderate, high and very high textural classes. To the chemical characteristics the capability classes are all depicted with very amount of OC (<1%), CEC (4.03-9.02), while the ph levels of all the classes are fall within the moderate range which is neither too alkaline not too acidic (Seyedmohammadi, Esmaeelnejad, &Ramezanpour, 2016). The study area is divided in to four capable classes for major crop production with some management practice. The classes are II, III, IV and VI. Class II, is characterized by severe erosion and low CEC, Class III is characterized by low fertility, sloping and high temperature, Class IV land has limitation of low AWC, low fertility. While class VI is steeper sloping, coarse texture as well as shallow soil. The three classes i.e II, III, and IV are capable for crop production with management practice and proper conservation(Mary Silpa&Nowshaja, 2016). While the class VI land is not capable for crop production due to it nature of steep slope, shallow soil, low WHC, coarse texture as well as low fertility. In a nut shell about 75.26% of the total land covered of the study area is capable for production while 24.74% is not capable no matter whatever management practice applied as such it is recommended for forestry, Tungay system of farming, game reserve or protection (Ziadat, 2007).

VII.CONCLUSION

No doubt measuring and monitoring the spatial variability of climate, and physio – chemical characteristics of soil is very important for agricultural land use, checking soil degradation and other related land use activities. The production of soil thematic maps in modern agriculture become very important as it helps in determining the spatial distribution of soil limitations and the ways of controlling it. It would also help in reducing the amount of farm inputs been added to the soil as way of supplements in order not to over exhaust the soil which can lead to pollution thereby degrading the land. andphysio – chemical characteristics of soil but also for nonagricultural development. There is also emphasize of avoiding using nonagricultural land for agricultural use. The erosion activities of the land units fall in to slight erosion, moderate erosion and severe erosion hazard with percentage covered of 22.72%, 72.56% and 4.75 respectively. Spatially the well-drained area covered 14.81%, moderately drained with 77.94% and poorly drained with 7.25% of the land units. CEC falls in to five classes in the study area. Very high covered 9.23%, high 46.80%, moderate 17.73%, low 23.87% and very low with 2.37% respectively (figure 4.12). Spatially the study area is divided in to five classes in term of soil ph. That is moderately alkaline which covered 25.78%, mildly alkaline 22.90%, neutral 20.365, slightly acidic 13.00% and moderately acidic with 17.96% respectively (figure 4.13). The area has five proportions of OC, as very high 17.45%, high

23.75%, moderate 34.75%, low 13.78% and very low 10.53% respectively.

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