UNIVERSITI PUTRA MALAYSIA

ASSESSMENT OF LAND CAPABILITY AND SUITABILITY CLASSIFICATION FOR CROP PRODUCTION IN KATSINA, NIGERIA

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By

ABDULLAHI SANI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

April 2022

DEDICATION

To Almighty Allah and my Parents, Abdullahi and Ramatu for whom owe everything I have in this life. Also to my lovely wives Maryam Bello and Asma u Rabilu for their kindness and support especially during undertaking this work. Deepest thanks also goes to my supervisors, Dr. Roslan bin Ismail, Dr. Syharudin bin Zaibon and Prof. Samaila Sani Noma for all the valuable guidance and support.

Abstract of thesis presented to the senate of University Putra Malaysia in fulfilment of the requirement for the degree of doctor of philosophy

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Chairman : Roslan bin Ismail, PhD
Faculty : Agriculture

ArcGIS and remote sensing play a vital role in generation of spatial information, mapping of natural resources and inventory such as mapping for optimal land use for sustainable agriculture. Lack of sufficient and adequate information on climate and soils characteristics are among the major limiting factors affecting agricultural development in Nigeria. Thus, the study was conducted to determine the physiochemical properties of soil, land characteristics, land capability and suitability for selected crops in Katsina State, Nigeria. The agriculture area was divided into land units and a total of 5 soil profile pits were excavated corresponding to each unit. The different soil horizon in soil profile were described using United State Department of Agriculture soil taxonomy, with 500g of sample were collected from each soil horizon. A total of fifteen (15) samples were collected from the profile pits (three in each pit from three different horizons) for land capability analysis. For suitability analysis fifty-five (55) sub surface samples were collected. Soil survey was conducted on each land unit to record the physical and chemical properties of the soil. Soil samples coordinates were marked with GPS Garmin 60csx and subjected to geospatial distribution analysis. Data collected for climatic (rainfall and temperature) and soil physio-chemical characteristics were analyzed using descriptive statistics (SAS v9.4). The soil properties analyses results indicate that the area is highly susceptible to erosion and low in soil fertility that limit the land capability for agricultural production. Soil properties distribution map were generated with ArcGIS v10.3 using Inverse Distance Weighted (IDW) techniques. The spatial distribution of soil properties of the land units was showed in variation map of each soil properties. The land capability assessment was undertaken based on United State Department of Agriculture (USDA) criteria. The results showed that three land unit maps were rated capable for rain fed farming of major crops under different management practices which included in the category of classes II, III, and IV, whereas the V and VI land unit was not capable due to permanent limitations associated with slope, stoniness and soil depth. In order to have more detail and direct information on land suitability for use by specific crops, land evaluation for selected crops was carried out using Food and Agricultural Organization (FAO) framework of land suitability. The generation of crops suitability map was prepared using two modelling techniques of GIS. Analytical hierarchical processes

(AHP). and Food Agricultural Organization (FAO) Frame work of land evaluation. The weightage and score of each parameter and their classes are based on administered questionnaire to Nigeria millet expert opinion. The suitability for millet in Katsina from the climate and physical-chemical parameters indicates that annual rainfall (604-702mm), elevation (434.75-558.5°), temperature (26.50-26.99°C), drainage, erosion, soil depth (0-30cm), soil pH (6.4-6.7), organic carbon (OC, 1.67-2.22) and organic matter and (OM, 02.96-3.0) are noted within the acceptable suitability index values (for Class S1 to Class S3), that represent sustainable crop production. While, cation exchange capacity (CEC, 5-15 $cmol_{(+)}/kg$), total nitrogen (TN, 0.5-5.0%), exchangeable acidity (EC,0.03-0.65dS/m), phosphorus (P, 4.40-10.23%) and effective sodium percentage (ESP, 1.06-1.53%) were noted below average value for crop production. Land Suitability Class S1 (highly suitable) covers 1328.40ha which is about 21.19% of the study area. While land suitability Class S2 (moderately suitable) covers 1098ha (17.53% area). The land suitability Class S3 cover 1767ha (28.19% area). Besides that, Class N1 (potentially not suitable) covers about 851.33ha (13.58% area) and, finally Class N2 (potentially and actually not suitable) covers about 1223.08ha (19.51% area) with scores below average selected crops. Further, the Class N2 areas marked with rock outcrop and inherent low fertility. Studied area (Katsina) suitability class for crop production as follow: S3>S1>N2>S2>N1. This indicates that, land area under Class S3 (28.19%) requires moderate level of soil amendment to improve millet, sorghum, beans and groundnut production. Whereas, Class S2 (17.53%), requires minimal level of soil amendment, whereas Class N1 and N2 with total land area of percentage of 30.09%, requires high input of soil amendment. The result indicates that there are general limitation factors in each land unit such as slope, soil depth, CEC, erosion, and rainfall for groundnut production. Meanwhile, OC, OM, CEC, soil depth, for millet, CEC, EC, ESP and stoniness for sorghum cultivation, and for beans, soil depth, pH, texture, rainfall, temperature. From the study data, climatic condition (rainfall and temperature) and soil properties are the first step (primary factor) in site specific crop production. Therefore, different land unit requires different level of input and land management to facilitate (improve) crops production in Katsina state for sustainable agriculture. Government and other non-governmental organization should encourage mix-cropping and mixed farming in the area to enhance soil fertility, there is also emphasize of avoiding using non-agricultural land for agricultural use, long term soil monitoring sites should be established using a localize soil map by the government using regular soil samples and management aspect should be taken and stored in database. The study also recommends for further studies in combining Fuzzy-AHP for fertility variability in the area and advance statistical analysis such as non-descriptive analysis and nuclear magnetic resources (NMR) study should be use on physiochemical properties of soil.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

KEUPAYAAN TANAH DAN KLASIFIKASI KESESUAIAN BERDASARKAN KEPADA DATA TANAH, PENDERIAAN JAUH DAN GIS BAGI PENGELUARAN TANAMAN MAMPAN DI DAERAH KATSINA, NIGERIA

Oleh

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ArcGIS dan alat penderiaan jauh memainkan peranan penting dalam menghasilkan maklumat ruangan, pemetaan sumber semula jadi dan inventori seperti pemetaan penggunaan tanah bagi kelestarian tanah. Kekurangan maklumat yang mencukupi dan memandai mengenai ciri iklim dan tanah merupakan faktor utama yang mempengaruhi pembangunan pertanian di Nigeria. Oleh itu, kajian ini dilaksanakan untuk mengenal pasti sifat fisiokimia tanah, ciri tanah, keupayaan tanah, dan kesesuaian tanah bagi tanaman terpilih di daerah Katsina, Nigeria. Kawasan pertanian tersebut dibahagikan kepada unit tanah dan sebanyak 5 lubang profil tanah digali berdasarkan setiap unit. Perbezaan horizon tanah dalam profil tanah dijelas berdasarkan taksonomi tanah Jabatan Pertanian Amerika Syarikat di mana 500g sampel dikumpulkan dari setiap horizon tanah. Sebanyak lima belas (15) sampel dikumpulkan dari lubang profil (tiga bagi setiap lubang dari horizon berbeza) untuk menganalisis keupayaan tanah. Bagi analisis kesesuaian pula, lima puluh lima (55) sampel permukaan tanah dikumpulkan. Tinjauan tanah dilakukan bagi setiap unit tanah untuk mencatat sifat fizikal dan kimia tanah. Koordinat sampel tanah ditandakan dengan GPS Garmin 60csx dan analisis taburan geospatial dilaksanakan. Data dikumpulkan bagi iklim (curahan hujan dan suhu) dan ciri fiziokimia tanah dianalsis menggunakan statistik perihalan (SAS v9.4). Dapatan analisis sifat tanah menunjukkan kawasan tersebut terdedah terhadap hakisan dan mempunyai kesuburan tanah yang rendah, yang membatasi keupayaan tanah dalam pengeluaran pertanian. Peta taburan bagi setiap sifat tanah dihasilkan dalam persekitaran ArcGIS v10.3 dengan menggunakan teknik Wajaran Jarak Terbalik (IDW). Taburan ruangan sifat tanah bagi unit tanah ditunjukkan di dalam peta variasi bagi setiap sifat tanah. Penilaian terhadap keupayaan tanah dilaksana berdasarkan kepada kriteria Jabatan Pertanian Amerika Syarikat (USDA). Dapatan kajian menunjukkan tiga unit peta didapati berupaya untuk pertanian tanaman hujan bagi tanaman utama di bawah amalan pengurusan berbeza yang termasuk di dalam kategori kelas II, III, dan IV. Manakala, unit tanah V dan VI didapati tidak berupaya disebabkan oleh batasan kekal yang berkaitan dengan cerun, batu dan kedalaman tanah. Untuk mendapatkan lebih banyak perincian dan maklumat terus mengenai kesesuaian tanah untuk kegunaan tanaman tertentu, penilaian tanah bagi

tanaman tertentu dilaksana menggunakan rangka kerja kesesuaian tanah oleh Organisasi Makanan dan Pertanian (FAO). Dari segi iklim dan parameter fiziokimia, kesesuaian bagi sekoi, betari, kekacang, dan kacang tanah di Katsina menunjukkan curahan hujan tahunan (604-702mm), ketinggian (434.75-558.5°), suhu (26.50-26.99°C), saliran, hakisan, kedalaman tanah (0-30cm), pH tanah (6.4-6.7), karbon organik (OC, 1.67-2.22) dan bahan organik dan (OM, 0.2-3.0) didapati dalam nilai indeks kesesuaian (bagi kelas S1 hingga kelas S3), yang mewakili pengeluaran tanaman lestari. Manakala, kapasiti pertukaran kation (CEC, 5-15 $cmol_{(+)}/kg$), jumlah nitrogen (TN, 0.5-5.0%), keasidan boleh tukar (EC,0.03-0.65dS/m), fosforus (P, 4.40-10.23%) and peratus keberkesanan natrium (ESP, 1.06-1.53%) didapati di bawah nilai purata bagi pengeluaran tanaman. Kelas kesesuaian tanah S1 (sangat sesuai) meliputi kawasan seluas 1328.40ha iaitu sekitar 21.9% dari keluasan kajian. Manakala, kesesuaian tanah kelas S2 (sederhana sesuai) pula meliputi 1098ha (17.53% keluasan). Kesesuaian tanah kelas S3 meliputi 1767ha iaitu sekitar (28.19% keluasan). Selain itu, kelas N1 (berpotensi tidak sesuai) meliputi sekitar 851.33ha (13.58% keluasan) dan, akhir sekali kelas N2 (berpotensi dan tidak sesuai) meliputi 1223.08ha (19.51% keluasan) dengan skor di bawah purata tanaman terpilih. Tambahan lagi, kelas N2 ini terkesan oleh singkapan batuan dan kesuburan tanah yang rendah. Kesesuaian kelas kawasan kajian (Katsina) bagi pengeluaran tanaman adalah seperti berikut: S3>S1>N2>S2>N1. Ini menunjukkan, kawasan tanah di bawah kelas 3 (28.19%) memerlukan tahap perubahan tanah sederhana untuk meningkatkan pengeluaran sekoi, betari, kekacang, dan kacang tanah. Manakala, kelas S2 (17.53%) memerlukan tahap perubahan tanah minimum, kelas N1 dan N2 dengan jumlah peratusan 30.09% keluasan tanah memerlukan tahap perubahan tanah yang tinggi. Dapatan menunjukkan bahawa terdapat faktor pembatasan umum di setiap unit tanah seperti cerun, kedalaman tanah, CEC, hakisan, dan curahan hujan bagi pengeluran kacang tanah. Manakala, OC, OM, CEC dan kedalaman tanah bagi sekoi, CEC, EC, ESP dan batuan bagi penanaman betari, dan bagi kekacang pula adalah kedalaman tanah, pH, tekstur curahan hujan, dan suhu. Dari data kajian, keadaan iklim (curahan hujan dan suhu) dan sifat tanah adalah langkah pertama (faktor utama) dalam pengeluaran tanaman di kawasan tertentu. Oleh itu, berlainan unit tanah memerlukan tahap input dan pengurus tanah yang berbeza untuk membantu (meningkatkan) pengeluaran tanaman di daerah Katsina bagi pertanian mampan. Kerajaan dan organisasi bukan kerajaan perlu menggalakkan tanaman dan perladangan campur di kawasan tersebut untuk meningkatkan kesuburan tanah. Terdapat juga penekanan terhadap hindaran penggunaan tanah bukan pertanian bagi tujuan pertanian, pelaksanaan pemantauan tapak tanah bagi tempoh jangka panjang menggunakan peta tanah setempat oleh kerajaan menggunakan sampel tanah dan aspek pengurusan perlu diambil dan disimpan dalam pengkalan data. Kajian ini turut mencadangkan kajian lanjutan dalam gabungan Fuzzy-AHP bagi kebolehubahan kesuburan di kawasan tersebut dan analisis statistik lanjutan seperti analisis bukan perihalan dan kajian sumber magnetik nuklear (NMR) perlu digunakan terhadap sifat fiziokimia tanah.

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During the time of this research, I have received a number of support assistance and encouragement from a number of people, Government and non-Governmental organization. First and foremost, I deeply thank to Almighty Allah for His blessing that gave me the opportunity to explore and acquired knowledge. I also deeply extend my thank to my supervisor Dr. Roslan bin Ismail for the guidance, support, checking and editing the thesis draft.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

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LIST OF ABBREVIATIONS

AD	After death
AEZ	Agro ecological zone
AHP	Analytical hieratical process
ANOVA	Analysis of variance
ArcGIS	Geographic information system software
AWC	Available water capacity
BD	Bulk density
C	Climate limitation
CEC	Cation exchange capacity
CLI	Canada land inventory
CV	Coefficient of variance
DEM	Digital elevation model
E	Erosion limitation
Ec	Electric conductivity
ESP	Exchangeable sodium percentage
FAO	Food and agricultural organization
Fe	ion
FMWH	Federal ministry of work and housing
GIS	Geographic information system
GPS	Geographic positioning system
H	Hydrogen
IDW	Inverse distance weight
IITA	International institute of tropical agriculture

ITCZ	Intertropical convergent zone
LC	Land capability
LCC	Land capability classification
LCCS	Land capability classification system
LSD	Least significant differences
LSTAT	Excel statistic software
LU	Land unit
LU	Land use
MCDM	Multi criteria decision making
MCE	Multi criteria evaluation
N	Nitrogen
NIMET	Nigerian metrological agency
NMR	Nuclear magnetic resources
OC	Organic carbon
OM	Organic matter
P	Phosphorus
pH	Measure of soil acidic or basic
S	Slope
SAS	Statistical analysis system
SD	Soil depth
SDGs	Suitability development goals
SI	Suitability index
SMR	Soil moisture region
SNR	Soil nitrogen region
SOM	Soil organic carbon

SOM	Soil organic matter
UNESCO	United nation educational scientific and cultural organization
US	United state
USDA	United state department of agriculture
W	Excess wate
WHC	Water holding capacity
WIOA	Weigth index overlay analysis
WLC	Weight linear criterion

CHAPTER 1

INTRODUCTION

1.1 Background of the study

Many life support systems are built on the foundation of land. Biomass (producing function) that directly or indirectly provides humans with food, feed, fiber, fuel, wood, and other biological resources, such as aquaculture and inland and coastal fisheries. The land is the foundation of terrestrial biodiversity, providing biological habitats and gene pools (biological environmental functions) for plants, animals, and microbes above and below ground. Land evaluation is the process of assessing the performance of land utilized for specified purposes by conducting and interpreting surveys and research on topography, soil, vegetation, climate, and other features of the land in order to find and compare the application of prospective land use types. The following terms are used in the assessment aim. The overall amount of agricultural land is gradually constrained and reduced as a result of land degradation and competition from other land use regimes. Land assessment is the basis for the sustainable programming and management of land resources, because it helps us understand whether resources are degrading or increasing in quality and quantity (Verheye, 2008). Nigeria's agricultural land accounts for 78%, of which arable land represents 37.3%, permanent arable land 7.4%, permanent rangeland 33.3%, forests 9.5 % and others represent 12.5% (World Bank, 2017). The expansion of agricultural land has been observed in all ecological regions from forested areas in southern Nigeria (where root crops and trees dominate) to the transition between forests and savannas in the central part of the country (mainly crops of roots), also as food crops. Semi-arid area in northern Nigeria. Urban areas are known as the main centers for all activities, including commercial, industrial and other institutional uses (Öztürk, 2017). The size of urban areas is expanding and outstrips land use for other land uses, especially agricultural land (Sinclair and Dobos, 1977). Urban sprawl is mainly due to the continuous migration of residents from the urban center to relatively cheap land around the urban periphery (Victoria, 2008). Katsina is one of the 36 states of Nigeria. The total land area is about 4,100 square kilometers, which has been used for various land uses. Generally speaking, the soil in this area is tropical rust-colored, red and brown soil from basements in the southern part of the state. Soil tends to accumulate water in heavy rains, and is dry and cracked in the dry season. This kind of soil is difficult to handle. In the northern part of the area, the soil is rough, the nature of this soil is sandy, light in color, and low to medium fertility.

The expansion of arable land to compensate for low yields and intensive farming to limit fallow periods are common features in northern Nigeria, which makes this land use system unsustainable. Land assessment is the foundation of sustainable land management because it helps to understand whether resources are degrading or improving (Mishra, 2007). Suitability is determined by soil parameters such as soil type, which are very important for any production, relief, drainage and slope. Agriculture is the backbone of Katsina's economy, because more than 75% of the population are farmers. Therefore, the study area can be described as an agricultural society. The main

crops grown are millet, sorghum, corn, cowpea, cotton, and peanuts, which are mainly consumed and loved by farmers.

1.2 Justification of the Study

Natural resources should be maintained sustainably so that planned adjustments to meet development demands can be implemented without jeopardizing their future utility (Kanwar, 1994). The increase in the human population comes with associated pressure on land resources which could invariably lead to land degradation and environmental pollution in the study area. The productivity of the soils in the study area is declining due to fertility depletion, imbalance in soil nutrients, and reduction in soil organic matter among other factors. However, agricultural intensification helps to guarantee national food security (Zhong*, et al,*2018), Agricultural intensification and abandonment can have a wide range of consequences for human society, including food supply, cultural identity, tourism, and ecosystems and biodiversity. To build the most effective soil management systems, information on soil resources and land features such as distribution, potentials, and restrictions of major soil is required. Agricultural intensification has been more common in many developing countries in recent decades (Bonny, 2011). The study area is blessed with a large proportion of idle land which is yet to be fully classified in terms of capability and suitability. Therefore, the research work intends to find out the land capability and suitability classification of the area to help farmers and other land users to identify areas that are best suited and capable of different land uses. Intensification of agriculture on land currently used for traditional farming in the study area which is due to the increasing demand for land concerning the incessant increase in the human population has made it necessary to determine the extent of land been used. As such knowledge on land capability and suitability classification are also essential n Katsina Senatorial Zone to identify areas best capable and suitable for different uses.

In recent years thematic mapping has undergone some changes due to advances in geographic information science and remote sensing, especially in the soil studies. This study also attempted to demonstrate the capabilities of Arc GIS and Remote Sensing in land capability and suitability classification at a larger scale (local level), which can be applied to medium and even smaller scales (state and country at large), as well as provide a guide for the quantitative assessment of land for agricultural and non-agricultural uses, and address the practical issues (Grose, 1999).

1.3 Problem Statement

Land resources are gradually deteriorating and becoming scarce as the world's population grows, putting strain on natural resources. As the world's population rises, an increase in food supply is urgently needed to meet the demands of an ever-increasing population. According to FAO (2011), agriculture efforts in the Sub-Saharan region have failed to grow food calories per capita above 2100/day during the last thirty years, despite losing export markets. All other major emerging world regions, on the other hand, improved dramatically (Alexandratos, 1995). Stoorvogel, Smaling, and Janssen (1993) made estimations in 38 sub-Saharan African nations. The findings suggest that the majority of

essential soil minerals were lost in the area, with the losses expected to worsen annual nutrient depletion. Also, the study of Henao and Banaante (1999) claimed that 86% of the sub-Saharan African countries are losing soil (through erosion) not less than 60-100 kg/ha/year (World Bank, 2003). Furthermore, a direct link between soil nutrient depletion and food insecurity has been suggested by noting improvements for some major food crops (Gruhn, Goletti and Yudelman 2000).

Agriculture is the mainstay of the Nigerian economy since over 70% of the Nigerian population directly or indirectly depends on agriculture for a living and equally, important the sector provides over 32% of Gross domestic products (NGD, 2017). Agriculture supplies food to the teaming population and provides raw materials for agro-based industries. Declined, in food production in the country could be as a result of declining soil fertility in the country which can lead to a shortage of food, rise in the price of food crops and may also lead to a lot of consequences on the people (Mueller, *et al.,* 2010).

Nigeria is one of the countries with high declining soil fertility, the major soil types are Alluvial, Aridisols, Inceptisols, and Alfisols, of the USDA Soil Taxonomy system. Most of these soils are highly susceptible to erosion and hence low productive capacity. As such the soil series of the region are highly dominated by aluminum, iron which makes the soil very susceptible to erosion and low fertility which limits its capability for various cultivated land (Girmay, Sebnie, & Reda, 2018). Katsina State soils are low in cation exchange capacity, low SOM, low nitrogen among others which affect the growth and production of food crops. However, Katsina is among the rapidly growing state in Nigeria. It has a population of over 4.7 million. To sustain such the largest, population, the government has to provide infrastructures and other physical developments that could better the current land use (NPC, 2017). The increase in the number of people makes pressure rate on land resources inevitable that causes an impact on the land degradation (NGD 2017). Therefore, the fragmentation of agricultural land which coupled with its low soil fertility affects agriculture production capacity and rural land quality (Atalay, 2016).

Furthermore, it should be noted that as agricultural productivity increase, land degradation could also increase if careful land management strategies are not put in place, hence large areas of cropland, grassland, woodland, and forest could seriously be degraded, intensive cultivation, and urban expansion removing large areas of agricultural land use from production (Abdelrahman, Natarajan, & Hegde, 2016). To increase the yield of productivity is requiring to conserve the soil for future use. Inadequate soil information affected most of the farming activities and management in the study area. Sorghum demands high nutrients compared to millet and other cereal crops like rice and wheat (Oparacke 2009). Agbede *et al* (2009) reveal that low soil organic matter, total nitrogen, and available phosphorus attributed to the yield of sorghum in some soils of Nigeria. Most of the factors limiting agricultural production in Nigeria is lacking adequate soil information and their characteristics (Adamu 2012). Most of the researches conducted in the North west zone concentrated on other crops for instance the study of Umar (2014) analysed the soil of Rugu rugu in Tudun wada of Kano State for suitability analysis for Arish Potato. Soil unit were used in the classification and the result shows that three areas were identified (soil units) and they are all moderately suitable with some

management practice such as erosion, and low fertility. MARDITECH, (2011) analyzed areas suitable for rice cultivation in some selected dam sites which includes Zobe, Jibia, Magaga, Watari and Tomas. The study showed potential areas are available for rice cultivation within. Baffa (2012) researched on the water requirement for irrigation on some crops such as Sugar cane, Garden egg, Rice, Onion, Tomato, and Hot pepper through irrigation method of farming in the region. The study also shows that yield (output) is low and the study concluded that salinity and other forms of land degradation are the major factors. Tanko (2001) conducted studied on the effect of salinity and Foli (2012) characterized the soils of region, all their finding shows poor drainage arising from the application of irrigated water in the area there by increasing the effect of salinity and low soil fertility status. But none of the works ever attempted to classify the agricultural land of the area for major agricultural uses and specifically for some selected crops in the area. For sustainable development, any region needs to make its land evaluation, adopt land-use planning, as well as to conduct land classification as it helps in easy communication to farmers and other land users (Raju, 2015). As such it is because of this that the current work intends to answer the following questions:

1.4 Research Questions

i. Is there any relationship between the physical properties of soil and land units as well as climatic characteristics of the area?

ii. Is there any correlation between the chemical properties of soil of the land units in the area?

iii. Which types of land class are best capable in the area?

iv. Which type of land (s) best suited for selected crops?

1.5 Significance of the Study

Natural resources should be maintained in a sustainable way, so that planned adjustments to fulfill development demands can be implemented without reducing the potential for future usage (Kanwar, 1994). As the population grows, there is an inevitable increase in the demand for land resources, which has an impact on land degradation and pollution in the studied region. Fertility depletion, soil nutrient imbalances, and organic matter loss are all contributing to a fall in soil productivity in the study area. Agricultural intensification, on the other hand, contributes to national food security (Zhong et al.,2018), Agricultural intensification and abandonment may lead to a lot of implications to human societies, for example, food production, cultural identity, and tourism, as well as ecosystems and biodiversity. Soil as resources and attributes of the land information on distribution, potentials, and constraints of major soil is needed so that the most appropriate soil management system can be designed. Agricultural intensification has become highly widespread in developing countries during the last few decades (Bonny, 2011).

A major sector or proportion of land in the study region has yet to be properly categorized in terms of capability and suitability. As a result, the focus of the research is on determining the area's land capability and suitability classification in order to assist farmers and other land users in identifying places that are most suited and capable of various land uses. Intensification of agriculture on land currently used for traditional farming in the study area which is due to the increasing demand for land with respect to the incessant increase in the human population has made it necessary to determine the land being used. As such knowledge on land capability and suitability classification are also essential to help farmers and other land users in Katsina senatorial zone to identify areas best capable and suitable for different uses.

1.6 Research Aim

The research's main aim is to employ a remote sensing and GIS technique to classify land use capability and suitability in Katsina State. This will be achieved through the following specific objectives:

1.7 Research Objectives

i. To determine soil and land characteristics of the selected area

ii. To produce a land capability map of the study area using USDA classification and ArcGIS techniques.

iii. To determine the land suitability for some selected crops based on FAO framework land evaluation.

1.8 Limitation of the Study

Given the large expanse of land in Katsina State, the study will be limited to selecting purposely some local governments due to high cost and time constraints. Man's usage and misuse of land may be traced all the way back to prehistory. Men's major occupations in ancient life were only harvesting wild fruits and hunting animals. The Old Stone Age's social life appears to have shifted from one raw material source to another. Man eventually found how to collect seeds, cultivate them, and harvest them. Long-term land use has been conflated with soil conservation, which is the flip side of preventing deterioration. More production is required as the population grows, necessitating the improvement of soil fertility and moisture. While soil can be improved to some extent, it has natural limits, and a reasonable approach would be to use the soil that is most suitable for the role, such as forestry, grasslands, agriculture, and so on, because we all live on the land in some way. We get practically all of our food and practically all of our needs from the earth, whether they are mineral or not. We're running out of land, and by misusing it, we're hastening the process. If we misuse land, we are just cutting down our main source of nutrition and hastening the date of world starvation.

1.9 Constitutive and operational terms

1.9.1 Land

All aspects of the physical environment that influence land use, whether directly or indirectly, make up the land (Colin, 1991). Land contains qualities such as geology, landforms, climate and hydrology, plant cover, and fauna, including disease-associated insects and microfauna (Cassidy et al., 2010). Land, as a source of food, identity, shelter, and riches, is considered by some as everything in the context of human existence and survival (Chukwu, 2007). Land is also a critical natural resource on which other resources are dependent (ztürk, 2017). The term "land" also refers to the portion of the earth's surface that is not covered by water, such as the continents and islands (Al-mashreki et al., 2011). To others, it views as a portion of the earth's solid surface characterized by boundaries and ownership (LIOH, 2015). In a nutshell, the land is much more than a resource. “land is like our vein since we can’t survive without it. If cut the root of the tree, it can’t grow up and sooner or later it will die. It’s similar to our lives without land” (LIOH, 2015).

Land as a resource includes both historical and contemporary human activity. Because such activities have a considerable impact on current and future land usage. As a result, land can be defined as the sum of natural and man-made resources (Barlowe, 1978). As a result, soil survey or the interpretation of a soil map are commonly used to classify land capabilities (Klingebiel and Montgomery, 1961).

1.9.2 Land capability

The extent to which a land facet can meet the needs of a specific land use under management practice without causing damage is referred to as land capability (Dent and Young, 1981). Land capability is a globally accepted method of assessing a land's potential to support a variety of land uses in the context of long-term development (Pareta & Jain, 1992). Land capability is simply a classification of soils based on their ability to support a broad range of land uses without degradation or negative consequences for farm planning (Rossiter, 1994).

1.9.3 Land suitability

The process, method, or manner of assessing the performance of land when it is used for specific purposes is known as land suitability classification. An important tenet of sustainable land management is crop growth adaptation to the potentialities and restrictions of local agroecologists. Land suitability classification's main objective is to understand the best land use for specific land units while also preserving environmental resources for future use. However, depending on the aim and size of land classification, precise objectives can differ significantly.

1.9.4 Land capability classification

Land in general varies in its capability to support specific land uses. It is required to undertake land capability categorization in order to determine an area's ability and capability (Abdullahi, 2013). Land capability classification is a way, method, or system of classifying soils based on their capability to produce frequently farmed crops and pasture plants over a long period of time without endangering the environment (Bhandari et al., 2013). Land capability classification depend on the physical characteristic of land (e.g. Geology, slope, soil) and other factors such as (climate, erosion hazard, management practice) which determine land use over the long term for sustainable agricultural development (U.S. Department of the Interior, 2005). Land capability classification should not be confused with land suitability. Land suitability classification grades land on specific and precisely defined land, whereas land capability classification grades land on a broader scale. Land capability classification can also be viewed as land valuation, with system components classified into several categories based on the nature of which is the potential and constraint in the use of sustainable resources (Arsyad, 2010).

1.9.5 Land capability categories

The land capability category is a process of classified land into different categories during classification. All in all, the capability category falls into four that is units, subclasses, classes, and orders.

1.9.6 Soil parameters

Soil parameters are popularly called soil attributes or characteristics and they are made up of three categories that are physical parameters which consist of attributes such as texture, structure, coarse fragments, permeability, water holding capacity, etc. Chemical parameters that consist of soil pH, salinity, cation exchange capacity, phosphorus, total nitrogen, and Biological parameters include organic matter, organic carbon, etc. The derived soil parameters are needed to underpin the broad-scale Agro-ecological zone (AEZ) for growth, simulation, and analysis of the global environment (ISRC, 2019).

1.9.7 Land limitation

Land limitation refers to soil characteristics that restrict crop yields. Example of land limitations is acidity, liming, poor aeration, nutrient deficiency, water stress, erosion, as well as salinity. Although management practice can overcome many soil limitations (Miller, 1983).

1.9.8 Arable land

The word arable land is derived from Latin words arabilis which laterally means able to be plowed, that is the ability of land in being capable of plowed and use to cultivate crops (Wikipedia). Arable land is also connoting as the land which is under temporary crops, temporary for hay, temporary for fallow of at least less than five years (Ahujja, 2013).

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