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AGROECOLOGY AND SOIL SECURITY FOR SUSTAINABLE CROP PRODUCTION IN THE KANO REGION

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Abstract

Agroecology, with its focus on restoring ecosystem services and promoting sustainable agricultural practices, is crucial for achieving soil security and ultimate food security. Thus, soil fertility decline and climatic uncertainties are becoming serious hindrances to achieve soil and food security goals. This paper aimed to assess the spatial distribution and concentration of some soil chemical properties in the various agroecological zones of Kano region with a view to understanding how it influences soil security in the respective zones of the region. Cluster sampling method was adopted and 109 samples were collected using composite techniques. Inverse distance weighted (IDW) overlay technique was also employed in the GIS environment to display the spatial distribution of the properties considered. The findings revealed that, nitrogen, phosphorous, potassium, ECEC, organic carbon/matter and soil reactions in the studied agroecologies were generally low. These low concentrations might be the reason for low crops yield and subsequent food security in the region. However, the degree of the concentrations was observed to be more severe in the Sahelian (Babura) and Sudano-Sahelian (Dambatta) agroecological zone of the region making it more fragile and vulnerable to soils security challenges than the Sudan (Wudil), Northern Guinea (Tudun Wada) and Southern Guinea (Maraku-Doguwa) zones. These have been attributed to soil moisture availability, sandy or clay distribution, inherent geological condition and poor farming practices adopted by smallholder farmers in the respective zones. Soil organic amendment applications as well as adoption of smart management practices compatible to the prevailing conditions are desirable for improve soil health, soil security and sustainable agricultural production in the different agroecologies in the Kano region.

Keywords: *Agroecology, Soil security, Kano region, Management practice, Sustainable production.*

Introduction

Agroecological zones (AEZ) in Nigeria like in other parts of the world, portray the varying biophysical characteristics and the management systems under which crops are grown. It is important to note that, information on biophysical variables of a particular agroecology and soil fertility levels are essential for understanding best management practices and consequent farming intensification scenario.

Soil security is concerned with the ability of the soil to retain and supply nutrients and water in order to enable crops to maximally utilize the climatic resources of a given location. It is also the ability of soils to function effectively in the supply of nutrients for optimum food and fibre production under diverse agroecologies (Food and Agricultural Organization of the United Nation - FAO, 2015).

The fertility of a soil is determined by both its physical and chemical properties. Adequate agricultural exploitation of the climatic potentials and maintenance of land productivity largely

depend on soil fertility and the management of soils on an ecologically sustained basis. An understanding of these factors and insight in their interrelations is essential to the effective utilization of climate, terrain and crop resources for optimum use and production.

By the year 2050, global food demand is expected to increase by more than half, above 2006 levels, driven by urbanisation and population increase (FAO, 2016). This is fuelled by fears of the impact of soil fertility decline, inappropriate management practices and the impacts of climate variability and change on agriculture and its effect on crop yield.

Agricultural potential in the Kano Region is unlimited with opportunities for agricultural development spanning the various agroecological zones (AEZs), each with its unique characteristics. The region is the most populous in Africa with projected figures of about 20,880,717 people (NPC projection, 2018). However, the major challenges have been on how to feed the ever increasing population in a sustainable way. This is in consideration of the fragile nature of soils and climatic resources of the region and with corresponding pressure on land. Thus, these problems are becoming serious hindrances to achieving soil and food security goals. This paper aimed to assess the basic biophysical (soil properties) characteristics of the agroecological zones in order to clearly understand the level of soil security under the varying agroecological zones in the Kano region.

Material and Methods

Location and Extent

The study area covers the Kano region which combined Kano and Jigawa States of Nigeria. It is located at the eastern margin of the Northwest Geo- Political Zone of Nigeria consisting of 71 Local Government Areas (44 in Kano State and 27 in Jigawa State). This area is located between latitudes $10^{\circ} 30'N$ and $13^{\circ}02'N$ of the equator and longitudes $7^{\circ}45'E$ and $10^{\circ}35'E$ of Greenwich meridian. The area falls within the dryland (Semi-arid) Savannas of northern Nigeria (Liman, 2014; Olofin, 2008). The region covers approximately 45,792.5 km² (Ibrahim, 2014) Figure 1.

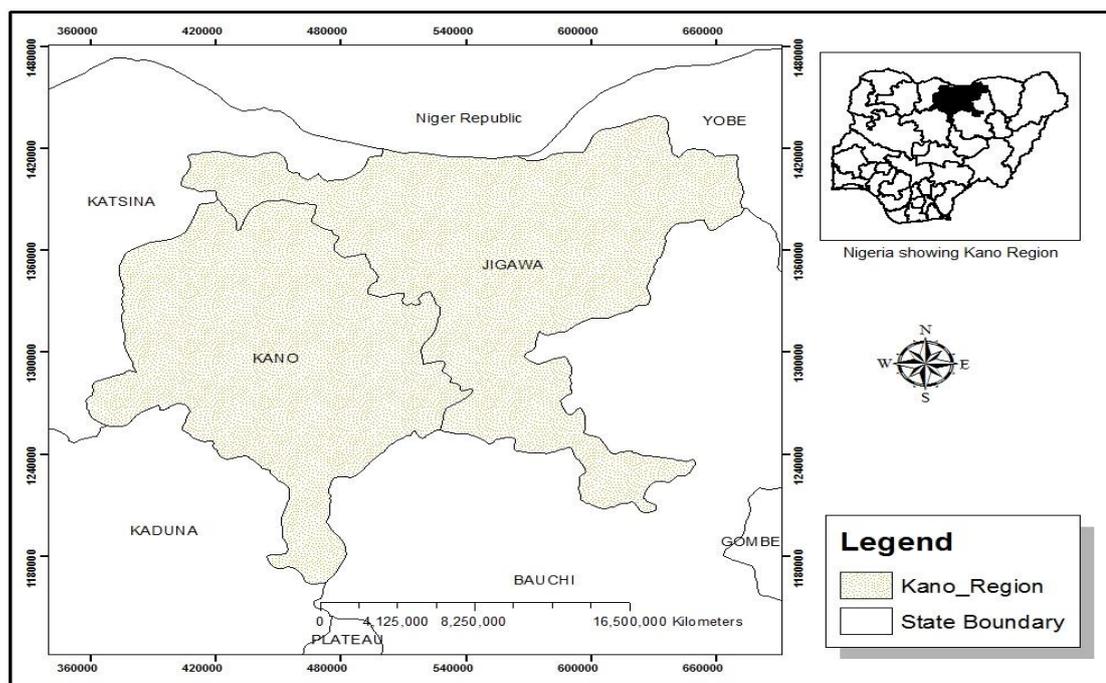


Figure 1: Map of the Kano Region

The climate of the Kano region is the Tropical wet and dry type, coded as Aw according to Koppen's classification, although climatic variability and change is believed to have occurred in the region. The wet season lasts from June to September although May is most often humid. The dry season extends from mid- October to mid- May (Olofin, 2008).

The mean annual rainfall in the region ranged between 500mm and 900mm with variations of up to plus or minus 30% (Olofin, 2008). The spatial distribution of rainfall over the region shows some decreasing trends from the southern parts towards extreme north-eastern parts. The annual average rainfall received in the southern parts most often rose to more than 1000mm and decreases to around 800mm to 500mm in the central and northern parts respectively (Olofin, Nabegu and Dambazau; 2008). On the average, the wettest month is August where the highest number of rainstorms and sediment transport are recorded (Maryam, Halima and Umami, 2014).

Soil Sampling and Samples Collection Procedures

Cluster sampling method was adopted such that, a typical soil type identified within a particular agroecology was considered as the sampling cluster. Soil sampling points were located randomly within each cluster identified and 109-points composite samples were collected. The size/area of the identified clusters determined the number of sampling points (proportionate sampling).

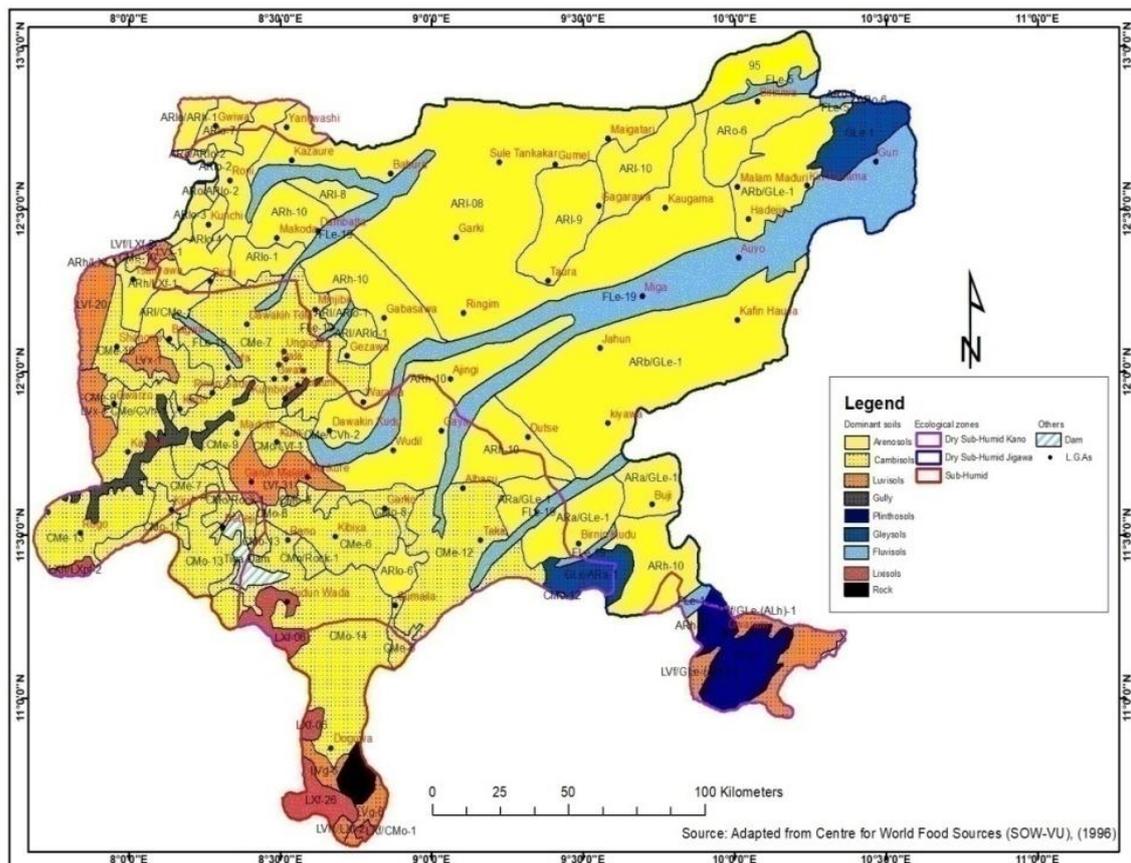


Figure 2: Sampling Point Distribution in the Study Area

The samples were collected at 0 - 15cm (top soil) depth using soil auger, composited and put the required sample (1/2 kg) into indexed sample bag for onward submission to the Centre for Drylands Agriculture (CDA)' laboratory, Bayero University, Kano for soils chemical analysis. The coordinates of the sampling points were taken and recorded using Global Positioning System (GPS) for subsequent mapping.

Laboratory-based Data Analysis

The soil samples were taken to the CDA's laboratory, Bayero University, Kano air dried and gently crushed with pestle and mortar and passed through 2mm sieve to remove coarse fragments. The fine earth samples (2mm soil portion) were analysed for chemical parameters;

Soil reaction (pH); the soil pH was determined both in water and 0.01M CaCl₂ solution, using a soil to water solution ratio of 1:2.5 (IITA, 1979).

Organic Carbon/Matter; The Walkley–Black wet digestion method was used to determine the organic carbon content of the soil samples. The values of the organic carbon percent in each sample tested were multiplied by the constant value of 1.724 to generate percent organic matter content of the soil samples.

Total Nitrogen (N); Total nitrogen was determined using the Macro–Kjedhal method.

Available Phosphorous (P); Soil available phosphorus was determined using the Bray I method calorimetrically.

Exchangeable Bases; Exchangeable Ca, Mg, Na and K were extracted with 1m ammonium acetate saturation method (1M NH₄OAc). The cation in the leachate was determined using Atomic Absorption Spectrophotometer (AAS) at appropriate wavelength (Soil Survey Staff, 2010).

Effective Cation Exchange Capacity (ECEC); Cation Exchange Capacity (CEC) of the soil was determined using ammonium acetate saturation method, buffered at pH 7.0.

Mapping the Spatial Distribution of some Soil Chemical Parameters in the Kano Region

Soils parameter maps were produced in GIS environment using inverse distance weighted overlay interpolation technique (IDW) which presented the spatial concentration of each parameter in the region and then administrative division maps were overlaid for location efficiency and clarity. The distributions were presented indicating the variation over the different AEZs and the region. Major soil properties considered were nitrogen, phosphorous, potassium, soil reactions (pH), organic carbon/matter, exchangeable bases and cation exchange capacity. This attempts to identify areas of availability and or deficiencies of these properties as per the different agroecological zones of the Kano region and thus were considered the major indicators to soil security in each of the agroecologies.

Results and Discussion

Spatial Concentration of some Soil Chemical Properties in the Kano region

The study presents the major soil chemical properties showing their spatial concentration in the various agroecological zones of the region.

Soil Nitrogen

Figure 3 presents the distribution of soil nitrogen over the study region.

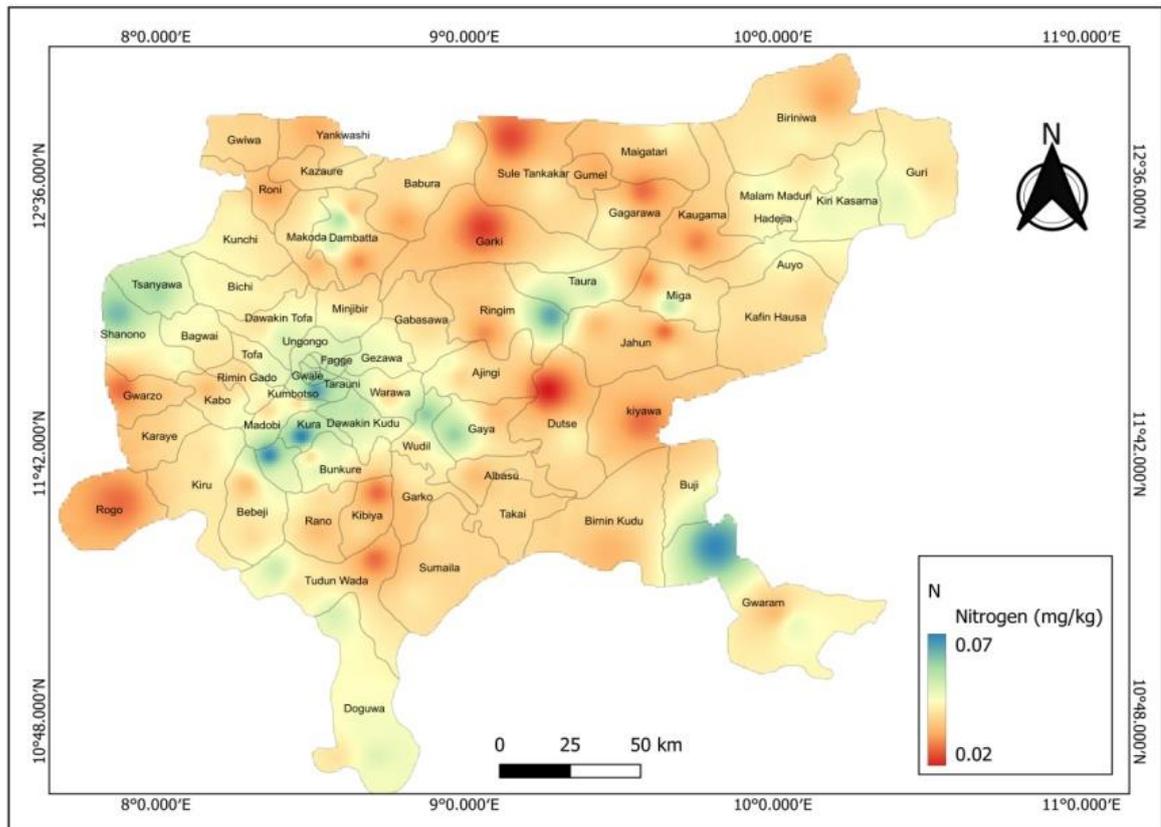


Figure 3: Distribution of Soil Nitrogen in Kano Region

Total nitrogen (Figure 3) was generally very low with values ranges from 0.02 mg/kg to 0.07 mg/kg. The highest value was recorded at Sudan AEZ particularly around Kano Closed Settled Zone, Shanono, Bagwai, Gaya and Gwaram area. Nitrogen is critically low in the north eastern parts of the region, and the low values were attributed to sandy nature of the soil encouraging higher rates of leaching of the nutrients in the area.

This finding corroborates Abdulkadir (2013) where nitrogen was found to be low in the peri urban Kano state (0.5 g/kg to 1.0 g/kg). This low nitrogen content in the region is generally attributed to low nitrogen contents of the parent materials, intensive arable crop cultivation, soil texture and the poor soil management and conservation practices due largely to poor economic capacity of the low-income smallholder farmers in the region. This range of nitrogen could be a major limiting factor for sustainable arable crops production and therefore detrimental to soil security in the region.

Soil Available Phosphorous

The spatial distribution of soil phosphorous in the study region was presented in figure 4. Adequate P helps plants particularly for root growth and seed production. The concentration of Phosphorous in the region is shown in Figure 4 with the highest value was 12.79 mg/kg while the lowest was 0.33 mg/kg. The highest values were recorded in Wudil, Birnin Kudu and Gwaram and were at marginal level while Makoda, Bagwai and significant parts of southern and northern guinea Savanna recorded the lowest value. Abdulkadir (2013) found out that areas around Kano Closed Settled Zone recorded high to medium phosphorous contents. Similarly, all sites studied in southern guinea agroecology had low available P below the critical limit value of 15 mg/kg.

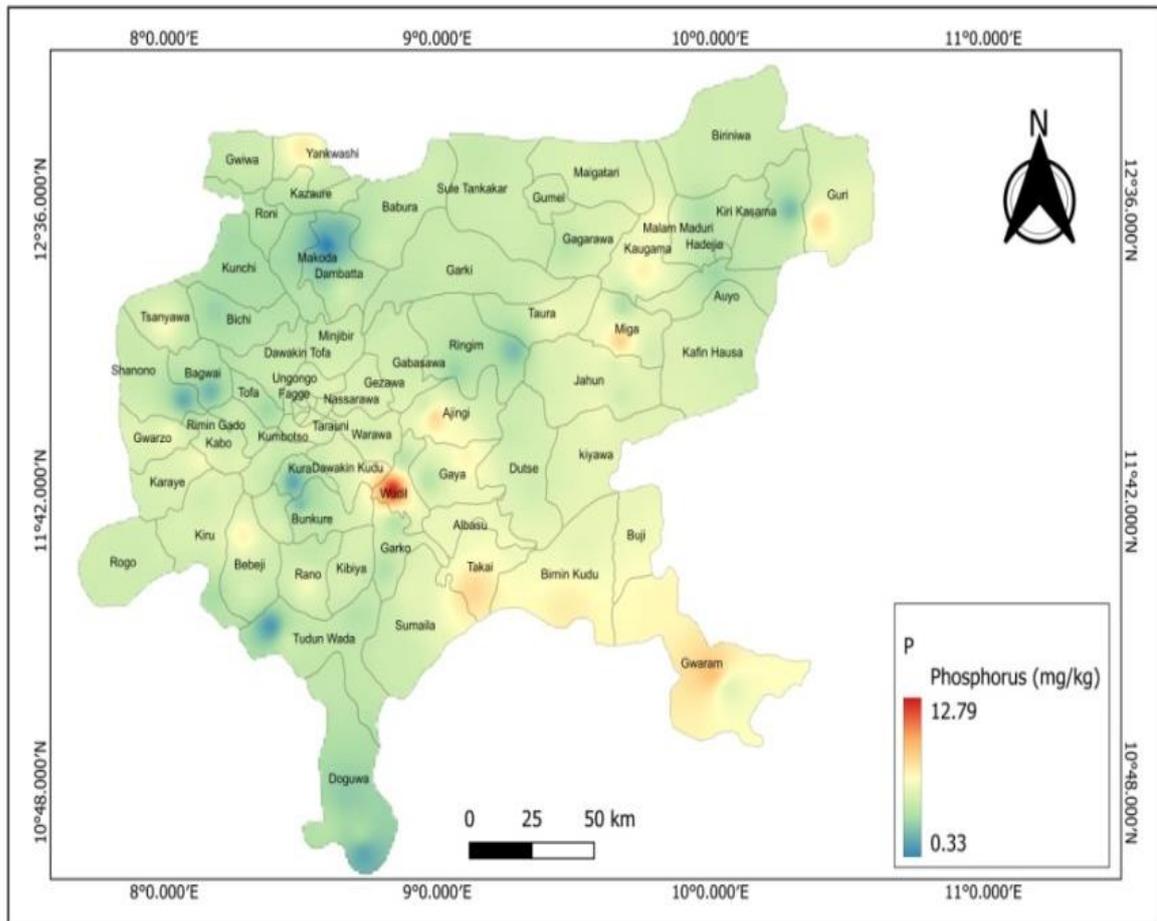


Figure 4: Distribution of Soil Phosphorous in Kano Region

These low levels of available P in southern and north western parts of the region may be attributed to the textural class (sandy clay) of the soil. As a result, the P can leach, especially in lower topography and thus P is not sufficient for most crops production; however, Ahmed and Jeb (2014) observed low P content in parts of Kano region (Bunkure). This is probably due to moderate soil pH which normally favours P immobilization (Umar, 2016). Soil pH influences availability of soil phosphorous as emphasized in Umar (2017) that soils with higher pH values tend to have more readily available phosphorous. The production of arable crops particularly maize will therefore be affected as P is among the important nutrient elements for its production. The soil P value across the agroecologies in Kano region was therefore becoming serious hindrance to general soils security and health requiring urgent attention for improvement.

Soil Potassium

The spatial distribution and concentration of soil potassium over the Kano region is presented in Figure 5. From the figure, Potassium concentration ranges between 0.09 % and 0.35 %. The Sahelian and Sudano-Sahelian parts of the region were observed to have higher concentration of potassium whereas the Sudan, Southern Guinea and Northern Guinea agroecologies were affected by low concentration of the nutrient.

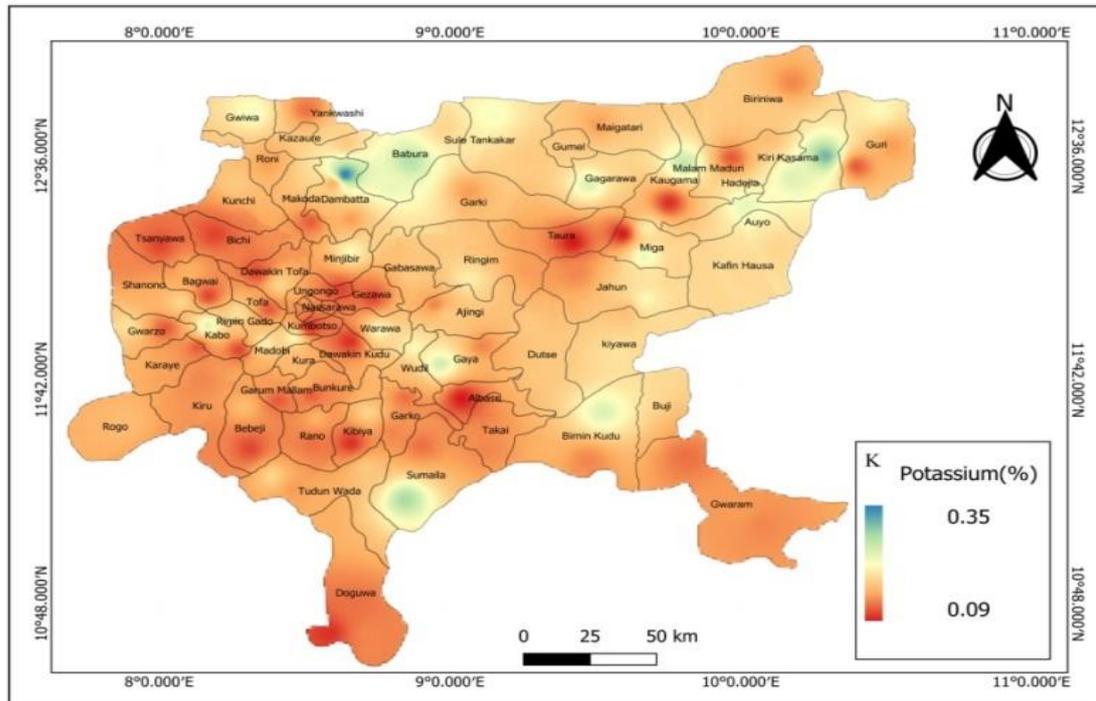


Figure 5: Distribution of Soil Potassium in Kano Region

This result indicates that the concentration of Potassium in the region was predominantly low. These variations were observed to be aligned to differences in geological formations of the region. The figure shows that; geology influences the concentration of Potassium in the region with higher values mostly found in the Chad formation and the lower values mostly from the basement complex. The low K value that characterised the area was attributed to low ECEC, low clay contents and low organic materials recorded in the soils of the region. Studies carried out in the area and similar environment reported low to medium potassium content in the soils (Ahmed, 2014; Salisu, 2020; Adamu, 2016) with positive relationship corresponding to increase or decrease in the organic matter contents and percentage clay in the respective study areas.

Soil Organic Carbon

The distribution and concentration of organic carbon in the soil of Kano region is presented in Figure 6. The values ranged from 0.31 (%) to 1.19 (%). The general pattern of the distribution was observed to be uniformly very low with some patches showing low to moderate concentration (Figure 6). The organic carbon concentration varied with geological formations with lowest concentration observed in the Chad formation (northern and north-eastern) and is increasing with progression to the basement complex formations. The Sahelian and Sudano-Sahelian zones had the most critically low concentration than the Sudan, Northern Guinea and Southern Guinea zones (wetter areas) with exception of Maigatari, Kaugama and Garki LGAs. Areas that recorded higher percentage were in Tudun-Wada, Sumaila LGAs (Northern Guinea), Maigatari, Garki, and Kaugama LGAs (Sahelian and Sudano-Sahelian) which could probably be as the result of higher ability of the soil to carbon sequestrations in the area and availability of organic residue in the locations.

The low-level organic carbon (below 1%) could be attributed to high rates of organic matter decomposition and burning of organic residues by farmers and poor use of organic materials to compliment the fertility status. This indicates serious threat to soil security and by implication non possibility of obtaining potential crop yield in the area.

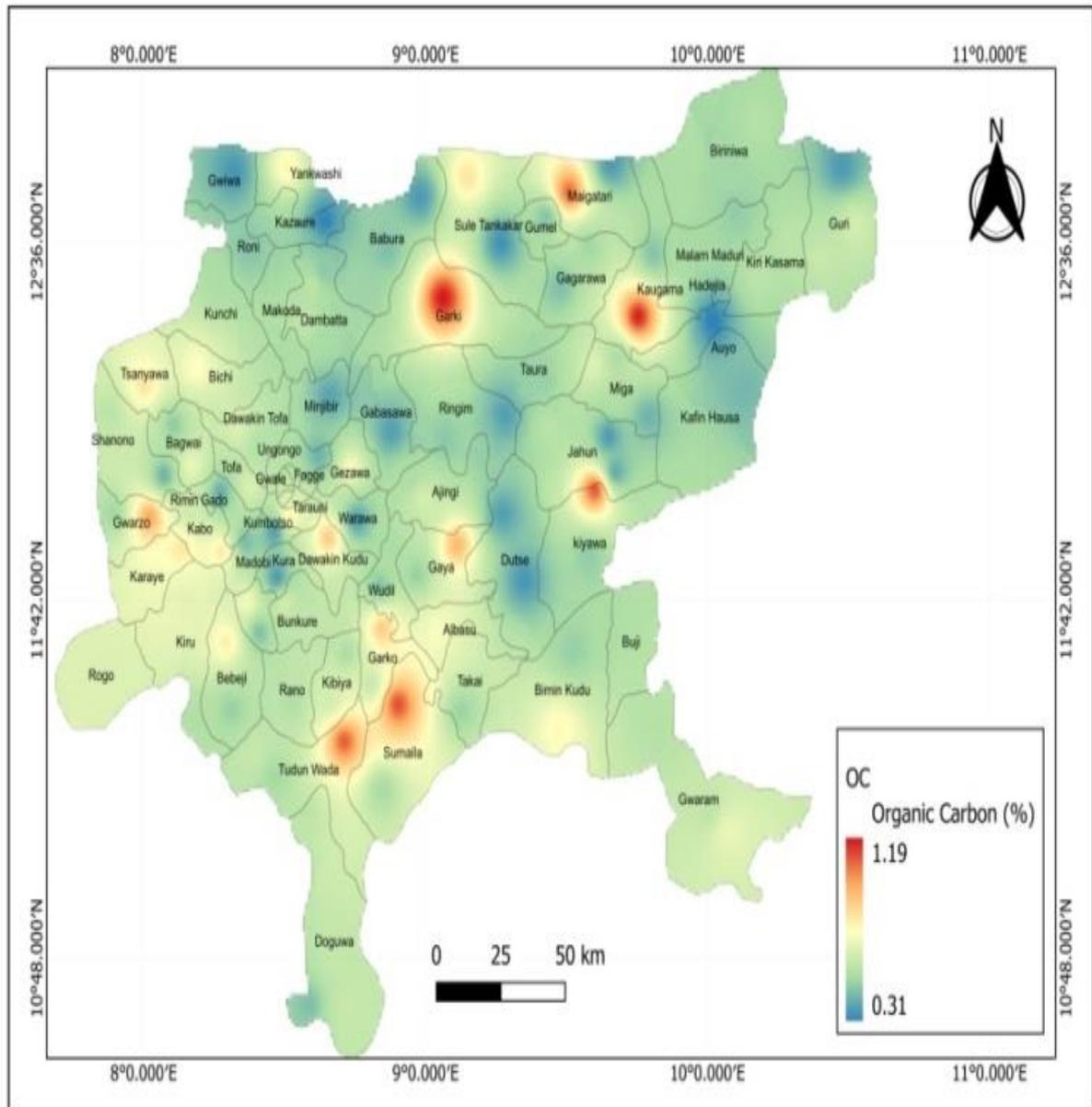


Figure 6: Distribution of Soil Organic Carbon in Kano Region

According to Jairos (2016), soils organic carbon was relatively high (>1%) in Doguwa and Soba and low in Bankura (<0.5%) and medium values for soil organic carbon ranged from 0.4% to 1.2% across studied sites. This is due to the low root growth of crops and natural vegetation and also the rapid turnover rates of organic materials with high soil temperature and micro-fauna, particularly termites. Other researchers such as Malgwi *et al.*, 2000 and Shehu, 2015 had equally reported low content of organic carbon in the Nigerian Savanna.

Soil Organic Matter

Soil organic matter primarily concentrated near the surface with highest level typically found in the top soil layer, gradually decreasing with depth. The study presented the concentration of soil organic matter in the top soil of the Kano region, indicating the variability over different location (Figure 7).

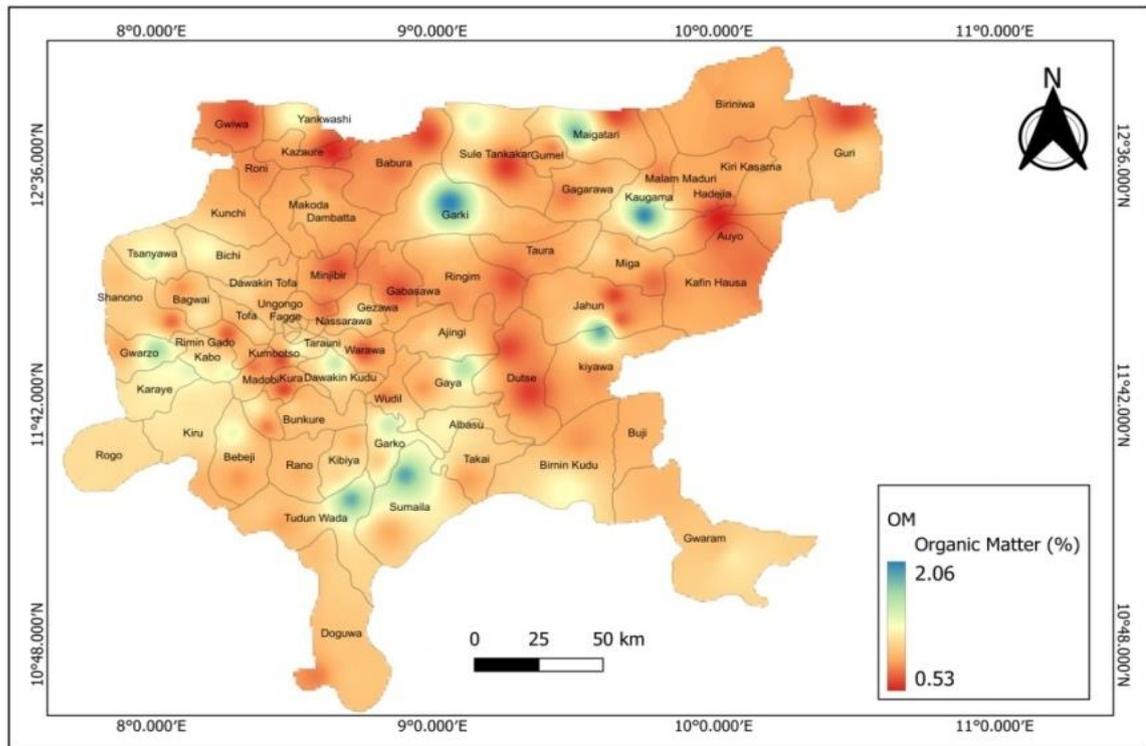


Figure 7: Distribution of Soil Organic Matter in Kano Region

Figure 7 presents the distribution of soil organic matter in the top soil of Kano region. The result indicates that, the percent organic matter in the soil is generally within the range of 0.53 (%) to 2.06 (%) with lower values dominating the Sahelian and Sudano-Sahelian parts of the region and high percentage was obtained in the parts of Sudan, Southern Guinea and Northern Guinea zones of the region. This percentage reflect the assertion that organic matter contents of a typically well- drained mineral soil is generally small, varying from 1% to 5% by weight in the top soil with greater influence on soil properties and plant growth (Adamu, 2016). The only area where the concentration was found at highest values was in parts of Tudun Wada, Sumaila LGAs (Northern Guinea), Maigatari, Garko, Kaugama LGAs (Sahelian, Sudano-Sahelian) and Kiyawa LGAs (Sudan).

The distribution of organic matter in the area is mostly within the low class. Soil organic matter is considered central and major soil fertility parameter indicator (Shehu, 2015) and thus, higher amounts of soil organic matter relate to soil security, soil health and increased productivity because of its contribution to water holding capacity, improved soil structure, and supply of nutrients.

Soil Reaction (pH)

Soil reaction indicates the ability of soils to provide necessary nutrients needed by crops for proper growth and developments. It also indicates the microbial activities in particular soils which is key to soil security, soil health and crop performance. Figure 8 presents the distribution of soil reaction (pH). The values ranged from 5.55 to 6.92. The lower values were obtained generally at the Sahelian, Sudano-Sahelian and Sudan agroecological parts of the region. The highest values were found to have concentrated in the central Sudan ecological zone with some patches found in Gwiwa, Yankwashi and Maigatari LGAs in the Sahelian and Sudano-Sahelian ecologies.

zones particularly in the Southern and Northern Guinea agroecological zone and along Hadejia-Nguru wetland showed higher concentration of ECEC. The lower values in the northern parts of the region could be influenced by low clay content, low organic matter and low water holding capacity characterizing the area and where improvements in the contents of ECEC was recorded in the region could well be as the result of improved clay and organic matter contents.

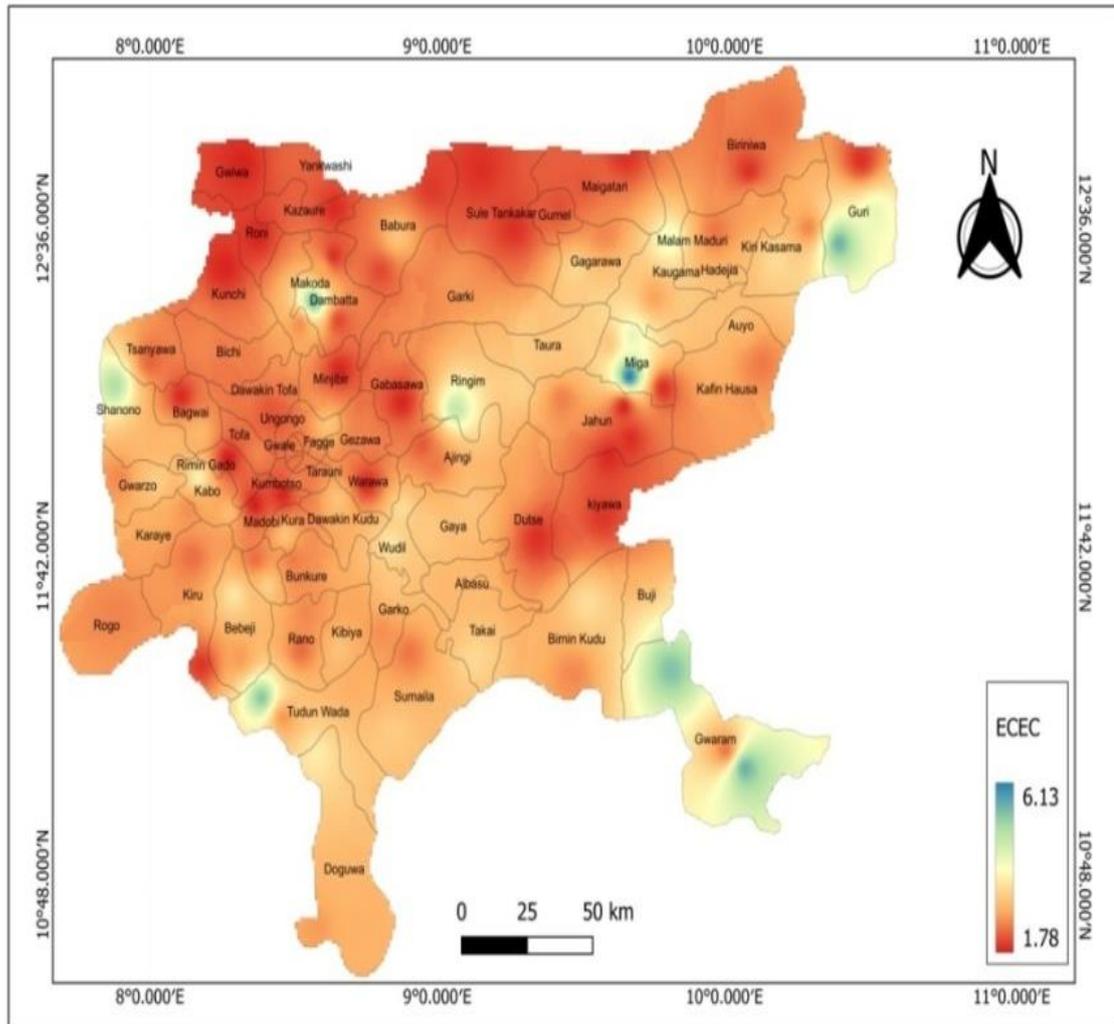


Figure 9: Distribution of Soil Effective Cation Exch. Capacity in Kano Region

Abdulkadir (2013), Shehu (2015) and Ahmed (2014) reported similar findings in their respective studies in Kano region and similar environment. The low values of ECEC may be attributed to low clay and organic matter contents of these soils; something which invariably leads to low nutrients retention capacity of these soils thus expressing the vulnerability and fragile soil security across the various agroecologies in the region. ECEC relates positively with organic matter content of every soils as was revealed in Adamu (2016), Shehu (2015). The ideal ECEC for arable crops is moderate and ranged from 18-27 meq/100g as this range provides a balanced between nutrients retention and availability. This indicates low soil fertility with possible low responses to nutrients addition exposing the security status of the soil to be at stake in the region for satisfactory production of arable crops.

Soil Security and Limiting Factors for Sustainable Crops Cultivation in Kano Region

The major soil nutrients obtained in the study location were observed to be below the optimum requirements for cultivation of various arable crops (maize, sorghum, rice, soybean and hibiscus sabdariffa among others). The nitrogen was determined to be at the range lower than most arable crops requirements. The Sudan agroecological zone recorded the highest values of nitrogen largely due to organic manure application. The lowest value was so critical in the Sahelian and Sudano-Sahelian zones of the region because of the sandy nature of the soil, promoting high rate of nutrients leaching leading to pronounced soil insecurity. Phosphorous was found to be low in some locations and medium values were recorded in southern and northern guinea agroecologies. The acidic nature of the soil, texture and climatic conditions might be the major factors that influenced the status of most nutrients in the region.

The trends of soil cation distributions in the Kano region have been generally low however; the drier zones (Sahelian and Sudano-Sahelian) recorded the lowest values while the wetter zones (Southern and Northern Guinea) recorded the highest values of the nutrients. The low status was attributed to soil textural class and moisture conditions. The northern parts of the region (drier zones) been the areas with the lowest values as a result of sandy texture, low soil moisture, low ECEC, and poor organic matter contents whereas the moderate concentration of these nutrients in the southern and northern guinea zones is attributed to improved moisture conditions and significant values of clay particles prevalent in the area.

Conclusion and Recommendations

The fertility status of Kano region according to the outcome of the soil nutrients determination revealed that, the nutrients varied with changes in biophysical conditions prevailed in the region. The general concentrations of the soil nutrients were low in the region however; some locations were observed to have moderate phosphorus. Organic matter, pH and potassium. These low concentrations were attributed to prevailing moisture condition across different agroecologies. The more the drier the zone the lower the soils nutrients determined thus more vulnerable of the zone to soil security threat. Therefore, understanding the spatial variability of some chemical properties could serve as important tools for the adoption of sustainable management practices, as per the different agroecological zones in the Kano region.

Based on the major findings, the following recommendations were forwarded to includes; application of soil nutrients based on soil test results in the respective agroecologies, incorporating organic amendment to aligned with the agroecological zones needs and adoption of crops and crop cultivars/varieties that are friendly to the prevailing conditions in order to avoid further nutrient mining of the already fragile nutrient reserve in the region.

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