Assessment of Physico – Chemical Properties of Soils and Fertilizer Requirements in Southern Senatorial District in Kaduna State, Nigeria

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Abstract: It is evident that the production of food, fodder, fuel and feed to meet the requirement of human beings and animals is primarily dependent upon agriculture and allied areas which are dependent on soil resources. The study set out to assess the physico – chemical properties of soils and fertilizer requirements in Southern Senatorial district in Kaduna State, Nigeria. The main aim of this study is to assess the physico – chemical properties of the soils and the best types of fertilizers most suitable for those soils in Southern Senatorial District in Kaduna state. This study adopt an analytical approach, in which primary data (soil samples) were collected for physical and chemical properties analysis in laboratory. Four local government areas were selected out of seven for soil samples collection. The General Linear Model (GLM) Univariate ANOVA was used for determination of physico – chemical properties variations. The results showed that all the soils in the study area are slightly acidic with PH ranging from 5.4 – 6.5. The soils in Malagum ward, Kaura Local Government area are considered to be most deficient. The ANOVA test for all soil physical and chemical properties indicates that $p<0.05$ significantly varies 'within' and 'between' the local government areas. The study recommends the use NPK 15.15.15 or NPK 20.10.10 as the most appropriate fertilizer type suitable for use in crop production. When Urea fertilizers are needed to enhanced faster leave growth, they should be used in combination of basic superphosphates or lime. The study therefore, recommends training of Smallholder farmers for efficient fertilizer use and sustainable agricultural practices such as integrated soil fertility management (ISFM) which combines mineral fertilizer, organic matter and improved seeds to sustainably replenish nutrients to the soil, and to better conserve soil water.
Keywords: Soil, Physico – chemical properties, fertilizers, farmers, crop yield

INTRODUCTION

The natural resources of any country are the national treasure and there is need for proper planning to make best use of them. The most important and basic natural resource is soil. It is evident that the production of food, fodder, fuel and feed to meet the requirement of human beings and animals is primarily dependent upon agriculture and allied areas which are dependent on soil resources. Soil resources of the world are finite, easily degraded by misuse and mismanagement, nonrenewable over the human time frame, and shrinking because of degradation and conversion to nonagricultural uses (Uttam, 2017). Every successive government in Nigeria have made deliberate effort to make sure this natural resource provide the much needed food for the fast growing population through the provision of fertilizers and other farm inputs for higher production. Fertilizers and fertilizer practices that meet the specific needs of the tropical soils must be tailored to the crop, soil, climate, and socioeconomic factors that prevail. Fertilizers add essential nutrients (such as nitrogen, potassium and phosphorous) back into the soil that are often depleted through regular use by plants. To sustain and improve food production to meet future demands we need to pay closer attention to the way in which soil resources are managed (Ognyan, 2019).

According to Ku and Sangita (2015), an understanding of physical and chemical condition of any soil is essential for proper implementation of the other management practices. Therefore the physico-chemical study of soil is very important because both physical and chemical properties affect the soil productivity. This physico-chemical study of soil is based on various parameters like pH, electrical conductivity, texture, moisture, temperature, soil organic matter, available nitrogen, phosphorus and potassium. This knowledge will create awareness among the farmers about economic productivity.
The United Nations Millennium Development Goal (1); 'eradicate extreme poverty and hunger' is only obtainable if proper management of soil resources is maintained. The role of soils in agricultural production, food security and sustainable intensification plays a vital role in the stability and wellbeing of our country (Uttam, 2017; Ognyan, 2019). Thus, it has become a yearly routing for successive government to distribute fertilizers to farmers to boost agricultural production which is the main stay of our rural economy.

Statement of the research Problem
That the farmers in southern senatorial district in Kaduna state lack the basic scientific knowledge of the characteristics of their farmlands in terms of physical and chemical properties of their soils is an understatement. There is also no established type of fertilizers most suitable and most of the farmers apply inorganic fertilizers on the basis of personal experience and discretion based on conceived mindset of what is suitable for their soils under cultivation. The gap in knowledge in terms of soils properties (physical and chemical properties) and the lack of knowledge on specific fertilizers types needed for their farmlands in order to achieve higher yields thereby fulfilling the Millennium Development Goal (MDG 1) of eradicating extreme poverty and hunger, forms the research gap this study intends to cover. Thus, information and findings that would be derived from this findings would provide recommendations for inorganic fertilizer type Federal, State and Local government councils including non – state actors would supply to farmers in the study area.

Justification of the Study
Distribution of fertilizers to famers from Federal, States and Local government authorities including individuals in Government, Non-Governmental Organizations and charity bodies are all aimed at achieving Millennium Development Goal (MDG 1) of *'Eradicating Poverty and Extreme Hunger*' in Nigeria and other countries of the world. On the other hand, the target population (farmers) lacks the ability and knowledge of the actual physico – chemical properties of their farmlands, and the best fertilizers types most suitable for their soils, which can enhanced high crop yield thereby improving the standard of living of the local population, hence the need for this study.

Secondly, information to be obtain from this study will guide farmers, federal, state, local government and other donors in the specific types of fertilizers most suitable for soils in each locality within the senatorial district. By this action, higher agricultural yields would be achievable if these fertilizers are made available and at affordable prices to the farmers.
Lastly, the results obtained from this study would provide a template that could be used or employed to guide fertilizers supply to farmers in different parts of Nigeria in order to boost agricultural production nationwide.

Objective of the Study
The main aim of this study is to assess the physico – chemical properties of the soils and the best types of fertilizers most suitable for those soils in Southern Senatorial District in Kaduna state.
The Specific objectives includes:

1. Assessment of the Physical and Chemical properties of the soils in the study area.
2. Identify the nutrients needs of the soils in the study area and
3. Recommend the most suitable fertilizers types to remedy the nutrients deficiency of the soils in the study area.

LITERATURE REVIEW

Growth, yield, and quality of a plant species differ with soil types, soil nutrient status, and fertilizer management; and a plant species requires suitable soil for higher yield and better quality (Haroon et al, 2021; Ku & Sangita 2015; Ibrahim et al., 2014). Soil fertility and crop productivity differ significantly with the amount and combination of Na, K, Ca, Mg, S. P, Fe, Al, pH, and N in soil (Faisal et al, 2017; Masanobu et al, 2015).

According to Ojuola (2016), Nigerian soils are generally light textured and low in cation exchange capacity (CEC); clay content range from 9 to 43% in more than 60% of the area, clay content is less than 15%. The CEC range from 2.40 to 5.95 me/100g of the soils, the value being less than 5 in the majority of the area. Soil PH ranges from 4.2 to 8.1; combined Calcium (Ca) and magnesium (Mg) content varies from 0.5 to 5.55 me/100g; potassium (K) is generally low (0.07 to 0.45) tending to be lowest in soil sandstones . Organic matter content varies from 1 to 2.55%. Nigeria population from 1986 to 2024 has increased from about 78 million to a projected population of 230 million which implies intense use of soil and decline in soil fertility.

Soil types and fertilizer regimes were evaluated on growth, yield, and quality of Amaranthus tricolor lines, IB (India Bengal), TW (Taiwan), BB (Bangladesh B), and BC (Bangladesh C) in developing management practices in Okinawa (Masanobu et al, 2016). The observed that growth and yield of all amaranth lines were higher in gray soil (P^H 8.4) than in dark red soil (P^H 6.6) and red soil (P^H 5.4). The results of their experiment showed that the combined NPK fertilizer resulted in highest growth parameters and yield of amaranths in all soils. Nitrogen fertilizer alone did not affect growth parameters and yield of amaranths in dark red and red soils. Growth parameters and yield increased similarly with the 30, 40, and 50 gm^{-2} of NPK fertilizer in BB line, and with the 20, 30, 40, and 50 gm^{-2} in BC line. Agronomic efficiency of NPK fertilizer at 50 gm^{-2} was not prominent on the amaranths, compared to the fertilizer at 40 gm^{-2}. Amaranth lines had higher Na in dark red and red soils, while K and Mg in gray soil, Ca in gray and red soils, and Fe in dark red soil. The NPK fertilizer resulted in higher Na, Ca, Mg, and P in BB line in glasshouse. These minerals in BB line were not clearly affected, but in BC line were lower with NPK fertilizer at 20–50 gm$-^{2}$ in field. These studies indicate that gray soil is best for amaranth cultivation and combined NPK fertilizer at 20–40 gm$-^{2}$ is effective in gray soil in Okinawa for higher yield and minerals of amaranth.

In the same vein, a research conducted by Ibrahim, Tasi'u, Umma and Dangora (2014), to evaluate the effects of inorganic fertilizer (NPK) on soil characteristics and productivity of Solanum melongena in Warawa local government area of Kano State, for physico-chemical properties (pH, organic matter, total nitrogen, phosphorous, exchangeable bases, exchangeable acid, micronutrients and cation exchange capacity). The findings of their results shows that, at 0.15kg level of inorganic fertilizer, highest number of fruits, diameter of fruit (cm) and weight of fruits observed at farmers' site while at experimental site 0.05kg and 0.10kg had the highest. They therefore, recommended that farmers of Warawa town should maintain 0.15kg level of inorganic fertilizer in order to counteract the problems associated with the cultivation of pepper in their area.

Inorganic fertilizers are used to provide immediate nutrients to the plant when they need it unlike organic fertilizers that only have a slow release capability. Inorganic fertilizer works more rapidly and it may be utilized in balance of the farms need. They are less expensive than commercial organic fertilizers as well as may be used in large amounts (Haroon et al, 2021; Ibrahim et al., 2014). The inorganic fertilizers are required for promoting plant growth and production. They enhance the chemical soil properties, such as increasing the supply of macro and micro essential nutrients to meet the crop needs (Ilahi et al., 2020; Prasetyo et al., 2013).

Knowing the fact that soil is the natural source for plant growth (Haroon et al, 2021). The soil is habitat of soil organisms and is a nutrient recycling system (Ilahi et al., 2020). It provides many of the other ecosystem services. The excessive use of chemical fertilizer can cause many soil problems including soil acidification and soil crust disturbance if the right type suitable for such soil is used. This can thereby lowered the organic matter content in the soil, humus content, stunting plant production and growth, disturbing beneficial organisms in soil, changes the pH of the soil, increases pests and also contributes in the releasing of greenhouse gases. The acidity in soil diminishes phosphate intake from soil by crops, increases the toxic ions concentration in the soil (Haroon et al, 2021). Similarly, the reduction of humus content in the soil reduces its ability to store and use nutrients. The increased application of Nitrogen to fields destroys the balance between the three nutrients such as N, P and K with the passage of time which would cause lack in micronutrients and can also damage the topsoil.
It is a common practice in the study area that farmers apply the types of fertilizers they dim fit and suitable to their crops without the knowledge of their farmlands soil chemistry. Further to this, the services of agricultural extension officers that used to guide local farmers on best agricultural practices has since ceased to exist in the part of the country. Hence, subsistence farmers that form the majority of the population are forced to rely on their intellect. Thus food production still remain at the subsistent level and poverty is still ravaging the communities in the study area.

METHODOLOGY

The Study Area

Southern senatorial district in Kaduna State is located at the southern parts of Kaduna state (figure 1) covering a total of seven Local Government Areas (LGAs) namely: Jema'a, Jaba, Kachia, Kagarko,

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Kaura, Kajuru, Sanga and Zangon Kataf. The district had an estimated population of 5.1 million (2021) with farmers dominating the population by 70 – 80%. The district lies within Latitude 09°38′N and 10°05′N and Longitude 7°22′E and 8°35′E. This area is home to Ginger production that is an international export commodity with other major crops such as maize, rice, beans, sweet potato, yams, cassava etc. The Climate of the study area is a tropical continental climate characterized by two distinct seasons in a year each lasting for six months. The rainy season starts from April and ends in October while the dry season begins in November and ends in March. Temperatures are generally high with an annual average of 30ºC, (Ayoade, 1988). The study area is located within the areas of Tropical Ferruginous soils characterized by duricrust hard pans in some areas called duricrust/ laterite Udo, (1981). Due to variations in micro – topography and drainage, some areas have alluvial deposits of silt – clay soil (Dogo, 2018a). Such soils are found in areas liable to flood along the stream valley or fadamas. About 45% of the area is richly endowed with deeply weathered silty – loams soils, with high moisture retention capacity. The soils when properly managed, that is, the application of organic manures and/or chemical fertilizers, makes it good for the cultivation of food crops such as legumes and cereals. The vegetation of the study area is influenced by the micro – climate, topography and human activities but generally the vegetation is Southern Guinea Savanna type. The vegetation is characterized by riparian forest along streams and river valleys, thick woodland with thick undergrowth of shrubs, grasses and herbs (Dogo, 2018b).

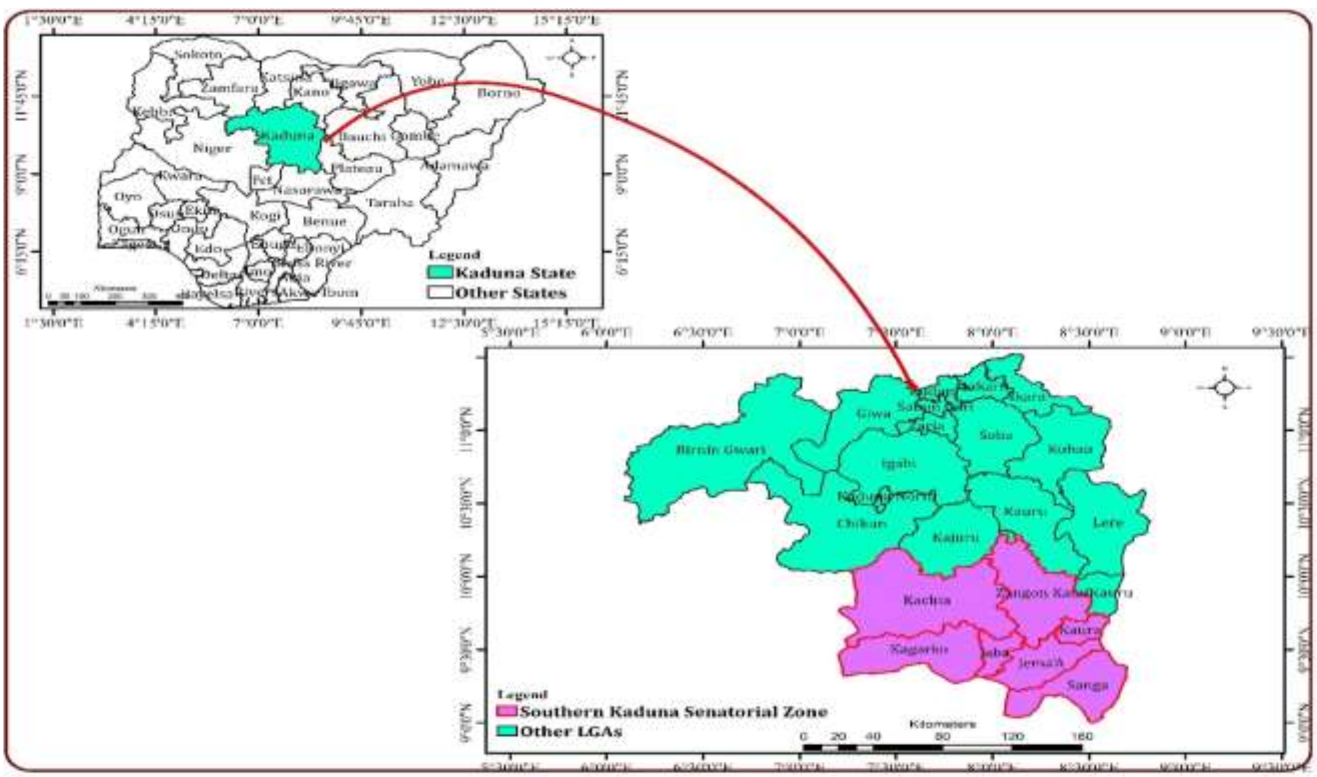

Figure 1: Map of Kaduna State showing the study area.
Source: G.I.S. Laboratory, Department of Geography, Federal University of Lafia.

Research Design & Sampling Techniques

This study adopts an analytical approach, in which primary data (soil samples) were collected for physical and chemical properties analysis in laboratory. Secondary data were obtained from focus group discussion from farmers on common types of fertilizers used for their cultivations and lastly, information from dailies, e – library/other secondary sources.

Sampling Frame

A multi – stage purposive and random sampling techniques was employed to collect soil samples from the top 50cm for each selected local government area. In the first stage, sampling of soils from four (4) out of the eight (8) local government was carried– out. Secondly, within each of the local government area, soil samples was collected from six (6) randomly selected number of wards based on nature of topography putting into consideration other local variations as the case may be. Lastly, the soil samples collected from each of the randomly selected wards was properly packaged in new polyethylene sheets labeled and taken to Soil Chemistry and Plant Analysis/ Biochemistry Laboratory, Faculty of Agriculture, Nasarawa State University, Keffi, Shabu – Lafia Campus for analysis. Thus, the total number of soil samples analyzes were 96 soil samples (see table 1).

Table 1: Soil Samples collected for Physico – Chemical Analysis.

s/no.	L.G.A.	Total Wards	Wards selected	Samples collection in each ward	Total sample for each L.G.A.
1	Jaba	10	6	6	24
5	Kaura	10	6	6	24
7	Sanga	11	6	6	24
8	Zango Kataf	11	6	6	24
Total	4	42	24	24	**96**

Method of Soil Samples Collection.

Collection of soil samples was carried – out using the following equipment/tools:

1. Shovel – for clearing and collecting soil samples.
2. Measuring cylinders/ beakers – for measuring equal quantity of soil to be analyzed.
3. Black Polyethylene sheets for storage and transporting collected soil samples to Laboratory.
4. Masking Tapes/permanent markers for sample labelling.
5. Cartons for packaging collected soil samples – for conveying them to laboratory.
6. GPS Garmin 101 Gecko Hand – held instrument for sites identification.
7. Bulk Density cups – for measuring bulk density
8. Soil thermometer – for measuring soil temperature

Soil samples were purposively collected from wards selected from the selected local governments in the study area. For each site, soils were dogged to 10cm and collected in black polyethylene bags and labeled. The coordinates of sample sites were also recorded using the hand held GPS Garmin 101 Gecko instrument. The samples collected were carefully packaged and transported to the Laboratory for physic – chemical analysis.

Data Analysis

Soil samples collected were sent to Soil Chemistry and Plant Analysis/Biochemistry Laboratory, Faculty of Agriculture, Shabu – Lafia Campus Nasarawa State University, Keffi for physico – chemical analysis of these soil samples.

Results obtained from both field and laboratory analysis was subjected to further statistical analysis using the SPSS Version 27 interface. Both descriptive and inferential statistics was employed for cross tabulation, data grouping, frequencies, analysis of variance using the General Linear Model (GLM) Univariate ANOVA for determination of physico – chemical properties variations and discussion of results for inferences on best types of fertilizers recommendation for each LG.A./Wards respectively.

RESULT PRESENTATION

The result of physico – chemical analysis of soil samples collected from selected sites are presented in Tables 2 to Table 9. Parameters of prime importance to this study that were analyzed includes; P^H, Exchangeable Cations (EC), % Organic Carbon (O.C.), % Organic Matter (O.M.), % Nitrogen (N), Available Phosphorous (P), Potassium (K), Sodium (Na), Magnesium (Mg), Calcium (Ca), Aluminium (Al), Iron (Fe) and Cation Exchange Capacity (CEC). Other physico – chemical properties analyzed includes; % M. C., BD and Porosity.

Table 2: Physico - chemical and Heavy Metals Properties of Soil. Kaura L.G.A. Kaduna State.

S/no	Soil Sample Code	Location	P^H	EC (us/cm)	%O.C	%O.M.	% N	Avail P (ppm)	K (mg/l)	Na (mg/l)	Mg (mg/l)	Ca (mg/l)	Al (meq/100g)	Fe (mg/l)	CEC (mg/kg)
1.	Manchok	8°3019E, 9°4048N	5.5	086	2.31	3.97	0.28	3.67	0.210	2.401	4.534	1.775	0.35	0.046	9.274
2.	Malagum	8°2324E, 9°4152N	5.7	034	2.43	4.18	3.57	7.82	0.209	2.304	0.000	0.000	0.49	0.017	3.003
3.	Atakar	8°2843E, 9°3937N	5.8	043	2.33	4.01	0.63	4.26	0.002	3.661	2.387	1.514	0.18	0.111	7.744
4.	Fadan Daji	8°2318E, 9°3721N	5.6	050	2.35	4.04	0.70	4.10	0.000	3.538	4.348	2.747	0.49	0.070	11.123
5.	Sabon Gari	8°3140E, 9°3939N	5.7	228	2.25	3.87	0.28	3.84	0.008	2.613	1.849	2.163	0.17	0.080	6.803
6.	Kaura	8°2821E, 9°4044N	5.5	080	2.28	3.92	0.49	4.24	0.007	8.782	8.386	10.039	0.15	0.118	27.364

Source: researcher Soil analysis, August 2025.

Table 3: Physical, Chemical and Heavy Metals Properties of Soil. Kaura L.G.A. Kaduna State.

S/no	Soil Sample Code	Location	M.C. %	BD (g/cm)	Porosity (%)
1.	Manchok	8°3019E, 9°4048N	11.50	0.79	7.9
2.	Malagum	8°2324E, 9°4152N	12.17	0.82	6.8
3.	Atakar	8°2843E, 9°3937N	8.35	1.01	61.9
4.	Fadan Daji	8°2318E, 9°3721N	8.13	1.09	58.9
5.	Sabon Gari	8°3140E, 9°3939N	4.92	1.11	58.1
6.	Kaura	8°2821E, 9°4044N	8.46	0.90	0.66

Source: researcher Soil analysis, August 2025.

The results in Tables 2 and 3 (Kaura L.G.A.) shows that the soils are slightly acidic (P^H<6.0), the values ranges from 5.5 – 5.8, but very low in Nitrogen (N) values ranges from 0.28 – 3.57 and Potassium (K) with values ranging from 0.000 – 0.210 mg/l. The available Phosphorous is rich including Sodium (Na), Magnesium (Mg). However, the soils in Malagum area are poor and highly deficient for most of the soil minerals Mg, and Ca (0.00 values) due to prolong farming and leaching. Other parameters such as percentage Porosity, shows that soils in Manchok and Malagum are very low in porosity due to their high clay content. Soils generally in these locations are red, with very fine clay particles, heavily weathered and very sticky during the wet season but powdery when dry.

Table 4: Physico - chemical and Heavy Metals Properties of Soil. Sanga L.G.A. Kaduna State.

S/no	Soil Sample Code	Location	P^H	EC (us/cm)	%O.C.	%O.M.	% N	Avail P (ppm)	K (mg/l)	Na (mg/l)	Mg (mg/l)	Ca (mg/l)	Al (meq/100g)	Fe (mg/l)	CEC (mg/kg)
1.	Gwantu	8°2702E, 9°2704N	6.4	075	2.63	4.21	0.35	3.67	0.23	3.41	4.63	1.65	0.34	0.13	7.34
2.	Kurmi Goro	8°3252E, 9°2844N	6.5	083	2.28	3.86	1.57	7.81	0.26	2.41	3.48	0.84	0.50	0.06	7.23
3.	Sabon Gida	8°3223E, 9°2502N	6.3	220	2.71	4.48	0.65	4.26	0.21	3.62	2.67	1.61	0.22	0.07	6.84
4.	Randa	8°2934E, 9°0357N	5.9	183	2.38	4.21	0.82	4.10	0.34	3.01	6.48	2.48	0.43	0.18	11.02
5.	Ungwan Nungu	8°3159E, 9°1359N	6.1	116	2.64	4.43	0.69	3.83	0.08	2.86	2.37	3.91	0.26	0.74	6.48
6.	Aboro	8°3411E, 9°2600N	6.4	094	2.61	3.74	0.49	4.25	0.09	3.05	4.82	6.01	0.22	0.09	11.51

Source: researcher Soil analysis, August 2025.

Table 5: Physical, Chemical and Heavy Metals Properties of Soil. Sanga L.G.A. Kaduna State.

S/no	Soil Sample Code	Location	M.C. %	BD (g/cm)	Porosity (%)
1.	Gwantu	8°2702E, 9°2704N	5.50	1.09	6.9
2.	Kurmi Goro	8°3252E, 9°2844N	10.18	1.05	26.8
3.	Sabon Gida	8°3223E, 9°2502N	13.25	1.01	51.9
4.	Randa	8°2934E, 9°0357N	6.12	1.06	68.9
5.	Ungwan Nungu	8°3159E, 9°1359N	7.98	0.09	48.2
6.	Aboro	8°3411E, 9°2600N	10.64	1.07	47.6

Source: researcher Soil analysis, August 2025.

The results in Table 4 and 5 (Sanga L.G.A.) shows that the soil P^H (<6.6) the values ranges from 5.9 – 6.5 thus, are slightly acidic. The soils in this areas have averagely good E.C. (075 – 220 us/cm), %O.C. 2.28 – 2.71, %O.M. and available P (3.67 – 7.81 ppm). The Al, Fe, and C.E.C. are within the acceptable range of good soils. Soils within these areas are rich in crop production with minimum application of Fertilizers. Other parameters of interest such as N, P, K, are relatively low in these areas including BD and % M.C.

Table 6: Physico - chemical and Heavy Metals Properties of Soil. Zangon Kataf L.G.A. Kaduna State.

S/no	Soil Sample Code	Location	P^H	EC (us/cm)	%O.C	%O.M	% N	Avail P (ppm)	K (mg/l)	Na (mg/l)	Mg (mg/l)	Ca (mg/l)	Al (meq/100g)	Fe (mg/l)	CEC (mg/kg)
1.	Zaman Dabo	8°2746E, 9°5043N	6.4	089	2.48	3.46	2.68	4.32	0.30	2.41	3.86	1.24	0.42	0.06	6.47
2.	Gora	8°1959E, 9°5046N	6.2	067	2.26	2.78	2.15	6.83	0.16	2.25	1.48	1.69	0.56	0.02	5.22
3.	Madakiya	8°1922E, 9°3931N	6.3	074	2.76	3.81	0.96	5.67	0.03	3.71	2.25	2.21	0.29	0.13	11.78
4.	Ungwa Rimi	8°1332E, 9°5841N	5.9	180	2.85	3.91	0.78	3.49	0.04	2.44	3.72	2.88	0.16	0.06	4.73
5.	Farman	8°1110E, 9°4202N	5.8	092	2.16	2.86	0.51	3.76	0.01	2.63	4.68	1.04	0.49	0.10	3.48
6.	Kamuru	8°1106E, 9°5302N	6.5	125	2.67	3.56	2.01	6.31	0.12	5.68	3.36	0.15	0.16	0.08	12.04

Source: researcher Soil analysis, August 2025.

Table 7: Physical, Chemical and Heavy Metals Properties of Soil. Zangon Kataf L.G.A. Kaduna State.

S/no	Soil Sample Code	Location	M.C. %	BD (g/cm)	Porosity (%)
1.	Zaman Dabo	8°2746E, 9°5043N	10.43	1.21	41.7
2.	Gora	8°1959E, 9°5046N	13.19	1.01	48.8
3.	Madakiya	8°1922E, 9°3931N	5.61	0.09	51.9
4.	Ungwa Rimi	8°1332E, 9°5841N	11.13	1.06	48.1
5.	Farman	8°1110E, 9°4202N	8.26	0.07	38.6
6.	Kamuru	8°1106E, 9°5302N	12.46	1.11	34.7

Source: researcher Soil analysis, August 2025.

The results in Tables 6 and 7 shows the physico – chemical properties of soils in Zango Kataf L.G.A. The results indicates that the soils are also slightly acidic with P^H ranging from 5.8 – 6.5. %K (0.01 – 0.30), Al (0.16 – 0.56), and %Fe (0.02 – 0.12) are slightly deficient in most areas. Available P, Ca, and C.E.C. are high compared to soils in Kaura L.G.A. The soils are well drained in most areas (porosity slightly high) but low in BD.

Table 8: Physico - chemical and Heavy Metals Properties of Soil. Jaba L.G.A. Kaduna State.

S/no	Soil Sample Code	Location	P^H	EC (us/cm)	%O. C.	%O. M.	% N	Avail P (ppm)	K (mg/l)	Na (mg/l)	Mg (mg/l)	Ca (mg/l)	Al (meq/100g)	Fe (mg/l)	CEC (mg/kg)
1.	Kwoi	8°0100E, 9°2703N	5.7	067	2.41	4.15	0.32	4.25	0.004	2.38	3.86	2.34	0.28	0.13	6.88
2.	Daddu	8°0449E, 9°3337N	5.8	048	2.38	3.92	0.68	3.92	0.031	2.40	0.02	0.08	0.36	0.14	4.26
3.	Kurmi Jatau	7°9538E, 9°5854N	6.2	053	2.40	4.21	0.57	5.68	0.170	3.21	4.23	2.79	0.47	0.06	10.54
4.	Fai	7°9503E, 9°5806N	5.9	036	2.39	3.86	0.25	3.64	0.008	3.47	2.16	1.83	0.21	0.17	9.01
5.	Kurmi Musa	8°0200E, 9°3600N	5.8	046	2.22	3.87	0.56	5.72	0.005	2.85	1.64	1.48	0.16	0.11	7.48
6.	Sanbam Gida	8°0308E, 9°2716N	6.4	208	2.41	3.92	0.48	4.81	0.460	2.04	0.86	6.42	0.35	0.08	14.36

Source: researcher Soil analysis, August 2025.

Table 9: Physical, Chemical and Heavy Metals Properties of Soil. Jaba L.G.A. Kaduna State.

S/no	Soil Sample Code	Location	M.C. %	BD (g/cm)	Porosity (%)
1.	Kwoi	8°0100E, 9°2703N	5.58	0.90	23.2
2.	Daddu	8°0449E, 9°3337N	7.13	1.03	28.9
3.	Kurmi Jatau	7°9538E, 9°5854N	10.36	0.82	53.4
4.	Fai	7°9503E, 9°5806N	4.87	1.21	48.2
5.	Kurmi Musa	8°0200E, 9°3600N	7.94	1.01	47.1
6.	Sanbam Gida	8°0308E, 9°2716N	8.46	0.90	36.6

Source: researcher Soil analysis, August 2025.

The results of soil analysis for Jaba L.G.A. in Tables 8 and 9, shows that the soils are mostly acidic in nature (P^H ranges from 5.8 – 6.4) on the average. The soils have relatively low Exchangeable Cations E.C. (us/cm), K (mg/l), and Al (mg/l). Available Phosphorous is relatively high in the soils including Na, and Ca. The Cation Exchange Capacity (C.E.C.) is slightly low in these areas but with adequate application of fertilizers, the soils produces high yields of crops. Soils in these axis covering Jaba, Kachia and Kagarko L.G.A.s are rich in Fe and suitable for Ginger, Upland rice and other cereals.

Data Analysis for Soil Physico – chemical Parameters

The statistical analysis using the General Linear Model (GLM) for Univariate ANOVA was used to test the variation in Physico – chemical properties for each soil parameter analyzed for each Local Governments Area. The results are presented in Table 10 to Table 15. The analysis tested each parameter for significant variation in each Local Government 'within Variation' and between the four local governments 'Between Variation', the overall results is henceforth inferred on the entire senatorial zone under study.

Table 10: Univariate ANOVA for Exchangeable Cations (E.C.) Tests of Between-Subjects Effects.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	9373.792[a]	3	3124.597	.846	.485
Intercept	235422.042	1	235422.042	63.768	.000
Iga	9373.792	3	3124.597	.846	.485
Error	73837.167	20	3691.858		
Total	318633.000	24			
Corrected Total	83210.958	23			

a. R Squared = .113 (Adjusted R Squared = -.020)

Results of data analysis in Table 10 test of significance for Exchangeable Cations (E.C.) shows that F = .864 (i.e. 84.6%) of the soil share similar E.C. characteristics in the study are. The results also shows that p-value (.485 – not significant difference within the L.G.A.; .000 – significant between the L.G.A.s) in Exchangeable Cations (E.C.) in the study area. This ‘within’ similarity could be as a result of similar Underlying parent materials that weathered to produce the soils found in that area.

Table 11: Univariate ANOVA for percentage Nitrogen (%N) Tests of Between-Subjects Effects.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3.478[a]	3	1.159	1.778	.184
Intercept	21.038	1	21.038	32.260	.000
Iga	3.478	3	1.159	1.778	.184
Error	13.043	20	.652		
Total	37.559	24			
Corrected Total	16.521	23			

a. R Squared = .211 (Adjusted R Squared = .092)

Results of data analysis in Table 11 test of significance for %N in the soil shows that F = 1.778 (i.e. 17.78%) of the soil share similar %N characteristics in the study area. The results also shows that p-value (.184 – not significant difference ‘within’ the L.G.A.s; .000 – significant ‘between’ the L.G.A.s) in %N characteristics for the soil in the study area. This percentage similarity is very low and could be as a result of differences in underlying parent rocks. The types of crops cultivated in those areas especially legumes encourages higher concentration of soil Nitrogen.

Table 12: Univariate ANOVA for Available Phosphorous (P) Tests of Between-Subjects Effects.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.735[a]	3	.245	.128	.942
Intercept	543.878	1	543.878	284.508	.000
Iga	.735	3	.245	.128	.942
Error	38.233	20	1.912		
Total	582.845	24			
Corrected Total	38.968	23			

a. R Squared = .019 (Adjusted R Squared = -.128)

Results of data analysis in Table 12 test of significance for available Phosphorous shows that F = .128 (i.e. 12.8%) of the soil share similar available Phosphorous characteristics in the study area. The results also shows that p-value (.942– not significant difference; .000 – significant between the L.G.A.s) in available Phosphorous characteristics in the soils of the study area. This similarity could be as a result of similar Underlying parent materials that weathered to produce the soils found in the study area.

Table 13: Univariate ANOVA for Potassium (K) Tests of Between-Subjects Effects.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.054[a]	3	.018	1.083	.379
Intercept	.371	1	.371	22.360	.000
lga	.054	3	.018	1.083	.379
Error	.332	20	.017		
Total	.757	24			
Corrected Total	.386	23			

a. R Squared = .140 (Adjusted R Squared = .011)

Results of data analysis in Table 13 test of significance for available Phosphorous shows that F = .018 (i.e. 1.8%) of the soil share similar available Phosphorous characteristics in the study area. The results also shows that p-value (.379– not significant difference; .000 – significant between the L.G.A.s) in available Phosphorous characteristics in the soils of the study area. This similarity could be as a result of similar Underlying parent materials that weathered to produce the soils found in the study area.

Table 14: Univariate ANOVA for Calcium (Ca) Tests of Between-Subjects Effects.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	7.659[a]	3	2.553	.470	.706
Intercept	144.492	1	144.492	26.616	.000
lga	7.659	3	2.553	.470	.706
Error	108.575	20	5.429		
Total	260.726	24			
Corrected Total	116.234	23			

a. R Squared = .066 (Adjusted R Squared = -.074)

Results of data analysis in Table 14 test of significance for available Phosphorous shows that F = .470 (i.e. 47%) of the soil share similar available Phosphorous characteristics in the study area. The results also shows that p-value (.706– not significant difference; .000 – significant between the L.G.A.s) in available Phosphorous characteristics in the soils of the study area. This similarity could be as a result of similar Underlying parent materials that weathered to produce the soils found in the study area.

Table 15: Univariate ANOVA for Cation Exchange Capacity (CEC) Tests of Between-Subjects Effects.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	40.759[a]	3	13.586	.526	.670
Intercept	1872.331	1	1872.331	72.462	.000
lga	40.759	3	13.586	.526	.670
Error	516.776	20	25.839		
Total	2429.866	24			
Corrected Total	557.535	23			

a. R Squared = .073 (Adjusted R Squared = -.066)

Results of data analysis in Table 15 test of significance for available Phosphorous shows that F = .526 (i.e. 52.6%) of the soil share similar available Phosphorous characteristics in the study area. The results also shows that p-value (.670– not significant difference; .000 – significant between the L.G.A.s) in available Phosphorous characteristics in the soils of the study area. This similarity could be as a result of similar Underlying parent materials that weathered to produce the soils found in the study area.

DISCUSSION OF RESULTS AND FERTILIZERS REQUIREMENTS

Inorganic fertilizers are used to provide immediate nutrients to the plant when they need it unlike organic fertilizers that only have a slow release capability. Inorganic fertilizer works more rapidly and it may be utilized in balance of the farms need. They are less expensive than commercial organic fertilizers as well as may be used in large amounts (Ilahi, et al., 2020). The inorganic fertilizers are required for promoting plant growth and production. They enhance the chemical soil properties, such as increasing the supply of macro and micro essential nutrients to meet the crop needs (Negasa,et al., 2017).

Several scholars have observed that fertilizer nutrient uptake by plants is likely to be highest when fertilizers of the right composition and the right amount are applied at the right time and the right place (Ilahi, et al., 2020; Obiechefu & Emerson, 2021; Haroon et al, 2021). The infinite combinations and interactions between crops, soil and environmental conditions call for fertilizer recommendations to be extremely precise and location-specific (Obiechefu & Emerson, 2021; Masanobu et al, 2016).

The physico – chemical properties of soils in the study area shows that they are slightly acidic (P^H ranges from 5.3 – 6.5) indicating soil nutrients deficiencies due to leaching and illuviation of soil basic components of N, P. K, Al and Fe. Degraded soils of this nature requires a balanced NPK fertilizer (like 15:15:15) or one with higher nitrogen (like 20:10:10) is suitable, with nitrogen often split into a pre-plant application and a later top-dressing to ensure high yield and balancing of soils. This agreed with the study made by Obiechefu & Emerson, (2021) on C. crepidiodies and turmeric plants.

Soil nitrogen in the study area is observed to be deficient and varies in concentration from place to place, however it is a common practice in the study area to see farmers applying only Urea Fertilizers which is 46% w/w Urea rich in Nitrogen to enhance plant growth. In most instances due to deficiency in other soil nutrients, the result often encourage only leafy growth and not crop yields at the end. This observation share similarities with findings of (Masanobu et al, 2016; Han et al., 2016). The soil physico – chemical properties in this zone required either NPK fertilizers (15:15:15 or 20:10:10) or

Urea (46%w/w) in combination of superphosphate and Lime to balance the nutrients requirement of soil in the study area.

Application of organic manures and fertilizers are increasingly becoming popular in the study area. This practice is common in the study area with the high cost of inorganic fertilizers. Farmers mostly use chemical fertilizers in combination with manures (from domestic animals) and refined organic fertilizers for crop production. The location of southern Kaduna senatorial zone located in Koppen's AW Climate with averagely high rainfall require that farmers consider the use of more organic manures/fertilizers that are less harmful to the soil rather than heavily depending on inorganic chemical fertilizers.

CONCLUSION

Results of this study showed that the physico – chemical properties of soil in the study area varies significantly from 'within' and 'between' the local government areas ($p<0.05$) for all the soil physical and chemical properties. The P^H of all the soils tested are within the range of (5.3 – 6.5), indicating they are acidic, thus requiring the application basic inorganic fertilizers to balance the soil P^H. The results in Table 2 indicates that the soil nutrients (Mg, Ca and Fe) are so far the poorest in the region thus, requiring active application of NPK Fertilizers (15:15:15) to achieved good crop yields. Increase in the use of organic manures and liquid organic fertilizers are increasingly becoming popular, thus farmers can embrace the combination of these fertilizers to maximized crop yields. The best fertilizers types suitable for the study area includes; NPK (15.15.15), NPK (20.10.10). It is strongly advised that farmers use Urea (46% w/w Urea) in combination with other basic fertilizers such as superphosphate or lime to achieve high quality yields of crops.

Recommendations

The following recommendations are made, given the results of findings made above that;

1. Since the soils in the study area are slightly acidic, smallholder farmers should concentrate in using compound inorganic fertilizers NPK (15.15.15) or NPK (20.10.10) for their crop production.
2. It has been observed that organic fertilizers and manures application over the years have little or no adverse effects on soil chemistry compared to inorganic fertilizers, thus this study strongly advocates the use of organic fertilizers and local affordable manures in their farmlands if inorganic fertilizers becomes unaffordable.
3. Smallholder farmers must have training in efficient fertilizer use and sustainable agricultural practices which is currently lacking in the study area. One example is integrated soil fertility management (ISFM). ISFM combines mineral fertilizer, organic matter and improved seeds to sustainably replenish nutrients to the soil, and to better conserve soil water.

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