Comparative Assessment of Physicochemical Properties under Continuous and Minimally Disturbed Cultivation in Jigawa State, Nigeria.

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Abstract
The objectives of this study were to compare the physicochemical properties of soils in relation to their fertility status under continuous and minimally disturbed cultivation plots, with the aim of promoting sustainable land management. A reconnaissance survey was conducted using a handheld GPS to delineate the study area and identify representative sampling locations across different topographic positions in the study area. Sixty (60) composite soil samples were randomly collected from each plot at depths of 0–30 cm and 30–60 cm using a soil auger for laboratory analysis. Results revealed that the soils are mainly sandy clay loam and loamy to sandy loam, bulk density values ranged from 1.58 - 1.66 Mg/cm-^{3} at the topsoil and from 1.69 - 1.87 Mg/cm-^{3} at the subsoil. The soils' reaction was slightly acidic, with mean pH values of 6.40–6.45 and no significant difference ($p > 0.05$). Organic matter and total nitrogen were significantly higher in minimally disturbed soils (1.78% and 0.19 g kg^{-1}) than in disturbed soils (0.52% and 0.07 g kg^{-1}) ($p < 0.05$). Cations Exchange Capacity was higher in minimally disturbed soils (10.89 cmol (+) kg^{-1}) compared with disturbed soils (7.69 cmol (+) kg^{-1}). Available phosphorus was slightly greater in disturbed soils (1.98 g kg^{-1}) than in minimally disturbed soils (1.49 g kg^{-1}).

Keywords: Chemical properties, cultivation duration, Land use types, Physical properties, soil fertility

Introduction
Land is one of the most vital natural resources that produce food for human consumption through sustainable agricultural production. Pedogenesis has influence on soil process and formation which also affect the growth of crops based on soil properties. Soil serves as medium for plant growth and contains primary and secondary minerals which are formed from weathering process, and may have characteristic that strongly influence the physical and chemical properties (Ousuocha *et al.*, 2016). Soil as a constituent of the earth ecosystem performed many tasks comprising those that are important for crop growth. Soil is an important factor to the economic status to any nation, and contributes to the food production and wellbeing of the people. Soil quality has become a subject of considerable scientific interest in recent years (Sinha *et al.*, 2014). According to Hewelke *et al.* (2022), soil quality influences the physical, chemical and biological properties and its serves as an indicator for evaluating the capacity of soil to performed essential functions. In evaluating soil quality, it is not merely the presence of essential nutrients that determines fertility, but their availability in balanced proportions to satisfy plant nutritional demands (Ayeni and Adeleye, 2011). Good quality soils not only provide better food and fibre, but also support natural ecosystems and improve the quality of air and water (Abdul Rashid *et al*., 2024). The ability of soil to supply nutrients for sustaining and supporting plant growth generally depends on its parent material. Researchers have reported that the nature of the parent material significantly influences soil development and characteristics (Umeri *et al.,* 2017).
The soil properties of the Faculty of Agriculture Research Farm support the cultivation of cereals and legumes such as millet, sorghum, groundnut, rice, and cowpea. These crops enhance the livelihood of farmers and promote sustainability within the Dutse communities.
In Jigawa State, most farmers practice continuous cultivation, where land is tilled and cropped year after year without enough time for soil recovery. This practice often leads to the loss of organic matter, reduction in essential nutrients, and weakening of soil structure. As a result, the soil becomes less productive, and crop yields continue to decline. Some farmers have started using cultivation methods that cause minimal soil disturbance, such as reduced tillage and the retention of crop residues, there is still limited scientific information on how these practices influence soil physical and chemical properties in the study area. Without such knowledge, it is difficult to design effective soil management practices that can maintain and improve agricultural productivity.
In view of the above, evaluating the variations in soil physicochemical properties under continuous and minimally disturbed cultivation systems will produce important data for understanding soil degradation levels and the possibilities for recovery through better management practices.

Materials and Methods
Description of the study area
The farm lies between latitudes 11°46′N and 11°47′N, and longitudes 11°42′E and 11°43′E and falls within the Sudan savanna agro ecological zone. The type of land use is usually arable and leguminous crops. The study area is portion into two parts: continuous and minimally disturb. The climate is characterized by two seasons: wet (May-October) and dry (November-April). Mean annual rainfall of 650-750 mm and mean annual temperature of 26°C-35°C. The vegetation consists of short grasses and shrubs.

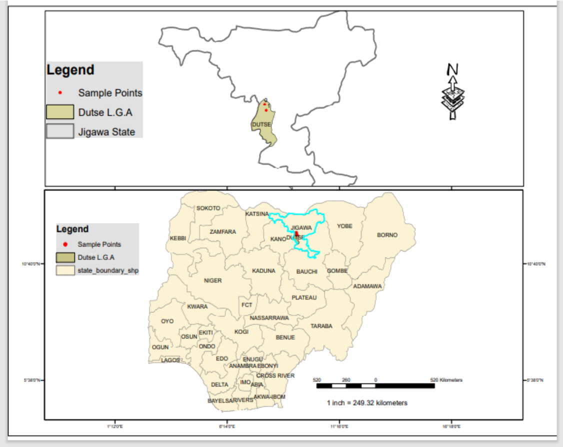

Fig. 1. Map of Nigeria showing the study area

Field study

A reconnaissance survey was conducted using a handheld Geographical Position System (GPS) to delineate the study area and identify representative sampling locations across different topographic positions in the study area. GPS coordinates were recorded for each site, including latitude and longitude. The morphological properties of the soil were examined from the topsoil (0-30 cm) to a depth of (30-60 cm) to determine the soil properties and Munsell soil color chart was used as described in the Food and Agriculture Organization (FAO, 2006) guidelines for soil description.

Soil sampling and preparation

A total of 60 composite samples were taken from 1.4 hectare of farms, each portion is comprised of 0.7hactare, the system involved taking representative soil samples at intervals of 100 cm apart using random soil sampling techniques. Topsoil and subsoil for each plot were mixed separately. The samples collected were properly placed in polythene bags, labelled, and taken for laboratory analysis. Collected samples were air-dried, gently crushed, and sieved through a 2 mm sieve.

Laboratory analysis

The particle size distribution was determined using the Bouyoucos hydrometer method (Gee and Boulder, 1986). Bulk density was measured by the core sampler method, and particle density was also obtained as described by Blake and Hartge (1986), while porosity was computed from the measurements of soil bulk density and soil particle density using the formula below:

P (%) = [1 - BD/PD] X 100

Soil pH was obtained using a pH meter in the supernatant suspension of a 1:2.5 soil-to-water ratio described by Carter and Gregorich (2008). Electrical conductivity was measured with a conducting meter in a soil water extract (Okalebo *et al.,*2002), whereas organic carbon was determined by the wet digestion method (Walkley and Black, 1934). Total nitrogen was analyzed by the wet-oxidation procedure of the Kjeldahl method (Breamer and Mulvancy, 1982). Available phosphorus was extracted by Bray-1 extractant (Bray and Kurtz, 1945). Exchangeable acidity (Al^{3+} + H^{+}) was extracted with 1.0 M KCl and titrated with sodium hydroxide. Exchangeable bases were extracted with 1.0 m ammonium acetate (NH_4OAc) and pH 7. Calcium and magnesium were measured with an atomic absorption spectrophotometer, whereas potassium and sodium were measured in a flame photometer (Vanreuwijk, 2006). Cation exchange capacity was determined at soil pH 7 after displacement using the 1-N ammonium acetate method as described by Chapman (1965). Base saturation was determined by dividing the value of the total sum of exchangeable bases by the CEC value and multiplying the equation by one hundred.

Statistical analysis

The soil data were analyzed using both descriptive statistics and independent sample t-tests to determine significant differences between the continuous and minimally disturbed cultivation plots, and to evaluate central tendencies and variations within the study area. The mean values were employed to describe the average distribution of the measured soil variables.

Results and Discussions

Morphological properties of the soils

Table 1 shows the morphological properties of the soil, the topsoil and subsoil of disturb were characterized by brown color (7.5 YR 5/4) to (7.5 YR 5/3), while the topsoil and subsoil of minimal disturb were dark yellowish brown (10 YR 3/6) to brown (7.5 YR 3/3), respectively. The texture of the soil was sandy clay loam to loam at the topsoil and subsoil of plot CS, while it was sandy loam at the topsoil and subsoil of plot MDS. The color difference can be explained as movements of some materials at subsoil as a result of illuviation. Similar results were stated by Plaster (2014), who mentioned that soil materials moved from topsoil to subsoil due to illuviation. Generally, the structure of the soil was sub angular blocky, whereas the consistency remained very friable to friable throughout the plots.

Physical characteristics of the study area

The physical properties of the soil were summarized in Table 2. Sand content decreases with an increase in depth. The sand values ranged from 36-48% at topsoil and subsoil for CS with an average value of 42%, while the values ranged from 38-44% at topsoil and subsoil of MDS with an average value of 41% (Table 2). Silt fraction was less in the topsoil than in the subsoil. The silt may be attributed to the nature of parent material which are formed from aeolian. This corroborated Santuraki *at al.* (2021), who also stated that aeolian deposit are also found in Dutse. The values ranged from 27-37% for topsoil for CS, with an average value of 32%, whereas for MDS, the values ranged from 31-35% for topsoil and subsoil, with an average value of 33%. Clay content increases with depth; this was due to illuviation of soil materials at subsoil. According to Idoga and Azagaku (2005), the increase in clay with depth could be attributed to eluviation-illuviation processes. The higher bulk density values recorded in the subsoil (1.69–1.87 g cm^{-3}) compared with the topsoil (1.58–1.66 g cm^{-3}) under both the continuously cultivated (CS) and minimally disturbed (MDS) plots indicate soil compaction and a decline in pore space with depth. The topsoil recorded bulk density values ranging from 1.58 to 1.66 g cm^{-3} and porosity between 38.5% and 40.4%. These moderate measurements indicate that the soil retains a stable structure capable of supporting root development and biological processes (Imran Khan, 2024). Bulk density in the topsoil plays an important role in determining the ease with which roots penetrate the soil and access essential water and nutrients. At moderate levels, the soil retains adequate pore spaces for air and water movement, which promote vigorous root growth. Similarly, porosity is essential as it regulates the soil's air–water balance, ensuring sufficient oxygen for root respiration and providing habitats for soil microorganisms that aid nutrient mineralization (Brady and Weil, 2017). When bulk density exceeds about 1.6 g cm^{-3}, pore spaces become restricted, hindering root elongation and limiting nutrient absorption (Hazelton and Murphy, 2007). The physicochemical properties of soil are fundamental to nutrient mobility and their availability for plant uptake (Suleiman et al., 2025). The physical properties of soil play a vital role in determining soil fertility, as the size and proportion of soil particles influence porosity and bulk density, which in turn affect the soil's capacity to retain or lose nutrients through leaching.

Chemical characteristics of the study area

The soil pH ranged from 6.2 to 6.6, with a mean value of 6.4, indicating a slightly acidic to neutral reaction that is generally suitable for most crops (Yang et al., 2025). in the topsoil and subsoil for CS, whereas they ranged from 6.2 to 6.7 with a mean value of 6.45 in the topsoil and subsoil for MDS (Table 2). There was no significant difference ($p < 0.05$) in soil pH between the two plots. Soil pH has an influence on soil suitability evaluation and management, as it provides necessary details about the soil solubility and potential availability of elements for plant growth. The electrical conductivity varied from 0.05 -0.09 at topsoil and subsoil with mean value of 0.07 dSm^{-1} for CS, while it was 0.03 -0.02 dSm^{-1} at topsoil and subsoil with mean value of 0.03 dSm^{-1} for MDS. The electrical conductivity was very low and suitable for the land utilization type for most dominate crops cultivated in the area. The organic carbon values ranged from 0.2 to 0.3 gkg-1 at topsoil and subsoil with mean value of 0.25 gkg-1 for CS and 0.34 to 0.40 gkg-1 with mean value of 0.37 gkg-1 for MDS which are not statistically different ($p < 0.05$). The organic carbon content is low, with values below 15 g kg^{-1}, which is considered the threshold for productive soils (Blanco et al., 2013). The topsoil contained higher organic matter than the subsoil, which could be attributed to the accumulation of plant litter, roots, and animal residues near the surface. This observation agrees with the findings of Brady and Weil (2017), who noted that organic matter tends to concentrate in the upper horizons due to active biological processes and the continuous deposition of organic residues. Similarly, Suleiman et al. (2025) reported that the topsoil generally exhibits higher organic matter levels because of enhanced microbial activity and the decomposition of surface-applied organic materials. Soil characteristics were different in the two cultivated land in terms of organic matter and organic carbon. Soil organic carbon was higher at MDS compared with CS, due to less intense farming.

The decline in total nitrogen under continuous cultivation can be attributed to increased soil disturbance, which enhances organic matter decomposition and nitrogen mineralization, leading to greater losses through leaching and volatilization. Brandy and Weil (2017) who found that continuous cultivation significantly reduce soil nitrogen reserves compared with reduced or no-tillage practices. The available P significantly increased with CS (1.98%) than to to the MDS (1.49%). According to (Kilic, and Kocyigit, 2012) revealed that available P increases with cultivation due to fertilizer application. The CEC in the MDS was greater (10.89 cmol/kg) compared to the CS (7.69 cmol/kg) which could be attributed to lower organic matter at topsoil at the CS due to intense cultivation which destroy soil aggregates and expose organic matter to rapid oxidation and promotes erosion. Ramose et al. (2018) found that less farming allowed CEC to build up for up to ten years.

Conclusion

Continuous soils showed lower organic matter, total nitrogen, cation exchange capacity and available phosphorus and were significant difference, indicating the effect of continuous tillage and residue removal on soil. Whereas minimal disturbed soils retained higher organic matter and Cation exchange capacity, available phosphorus and total nitrogen highlighting the role of reduced disturbance in sustaining soil management practices. The study also found that the mean soil nutrients of all the plots fell within the lower to medium range. Therefore, for sustainable agricultural land management practices, the addition of organic fertilizer and retention of crop residue during weeding should be continued to enhance nutrient accumulation.

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Conflict of Interest

The authors have no conflicts of interest to declare

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Table 1. Morphological characteristics of continuous and minimally disturb soil of the study area

Soil Properties	Mean value of DS	Mean value of MDS	Std Dev DS	Std Dev MDS	t-value	p-value	Significance (α=0.05)
pH	6.40	6.45	0.28	0.35	-0.20	0.85	NS
EC (dS m⁻¹)	0.07	0.03	0.03	0.05	1.07	0.36	NS
OC (g kg⁻¹)	0.25	0.37	0.07	0.08	-1.83	0.13	NS
Organic matter (%)	0.52	1.78	0.25	0.90	-2.37	0.04	S
TN (g kg⁻¹)	0.07	0.19	0.07	0.09	-2.05	0.048	S
AVP (Mg kg⁻¹)	1.98	1.49	0.32	0.27	2.16	0.043	S
CEC (cmol(+) kg⁻¹)	7.69	10.89	0.09	0.69	-5.72	0.008	S
BS (%)	92.38	94.58	1.65	1.44	-1.48	0.19	NS

CS; Continuous soil MDS; Minimally disturb soil

Table 2. Soil Physical Characteristics of continuous and minimally disturb soil of the study area

Depth (cm)	Horizon	Description
CS		
0-30	A	(7.5 YR 5/4) brown; sandy loam; weak sub angular blocky; very friable
30-60	B	(7.5 YR 5/3) brown; loam; weak sub angular blocky; very friable
MDS		
0-30	A	(10YR 3/6) Dark yellowish brown; sandy loam; weak sub angular blocky; very friable
30-60	B	(7.5 YR 5/3) brown; sandy loam; weak sub angular blocky; very friable

Table 3: Independent t-test comparing chemical properties between continuous and minimally disturb soil of the study area

Depth (cm)	Horizon	Particle size distribution (%) Sand	Silt	Clay	Textural class	BD (Mgcm^{-3})	PD (gcm^{-3})	Porosity (%)
Continuous soil								
0-30	A	48	27	25	SCL	1.58	2.65	40.4
30-60	B	36	37	27	L	1.69	2.63	35.7
Mean		42	32	26		1.63	2.64	38.05
Stdv		7.07	1.41	8.49		0.08	0.01	3.32
SE		72	50	2		0.06	0.02	11.05
Minimally disturb soil								
0-30	A	44	31	25	SL	1.66	2.70	38.5
30- 60	B	38	35	27	SL	1.87	2.71	28.6
Mean		41	33	26		1.76	2.70	33.55
Stdv		2.24	2.83	1.41		0.08	0.01	3.32
SE		1.80	0.80	0.20		0.02	0.05	49.01

Electrical conductivity, OC = Organic carbon, OM = Organic matter, TN = Total nitrogen, AVP = Available phosphorus; CEC = Cation's exchange capacity, BS = Base saturation

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