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Effect of Long-term Cultivation on Physical Properties of a Sandy Soil in Sokoto, Northwestern Nigeria

M. M. Sauwa[1*], U. U. Waniyo[2], A. Salisu[1], S. A. Lukman[1], D. Wadatau[3], S. A. Yusif[1] and S. Abdulkadir[1]

[1]Department of Soil Science and Agricultural Engineering, Faculty of Agriculture, Usmanu Danfodiyo University, P.M.B 2346, Sokoto, Sokoto State, Nigeria.
[2]Department of Soil Science, Faculty of Agriculture, University of Maiduguri, Nigeria.
[3]Department of Agriculture, Shehu Shagari College of Education, Sokoto, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. Author MMS designed the study, wrote the protocol, and wrote the first draft of the manuscript. Author UUW helped in statistical analysis while authors AS and SAL managed the literature searches. Authors DW, SAY and SA helped in soil sample collection and analyses. All authors read and approved the final manuscript.

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ABSTRACT

The experiment was carried out in peasant (local) farmers' farms in Usmanu Danfodiyo University Sokoto to investigate the effect of long-term cultivation (involving organic fertilization) on physical properties of a sandy soil in Sokoto, Northwestern Nigeria. The experiment consisted of two treatments (cultivated and uncultivated lands) which were replicated 5 times. Measurement of Physical (texture, bulk density: Bd, total porosity: TP, and gravimetric moisture content: Øm) properties of the soil were made at 0-15 cm and 15-30 cm soil depths. Data obtained was analyzed using two-sample t-test. The results revealed that, long-term farmers cultivation practices has no

**Corresponding author: E-mail: sauwamm4u@gmail.com;*

significant (p> 0.05) effect on physical properties of the soil, except Øm, sand and silt contents. However, long-term continuous cultivation slightly deteriorated physical quality of the soil (at 0-15 cm soil depth), which is reflected by increased Bd, reduced TP and Øm contents of the soil. The study further revealed that, cultivation encourages redistribution of silt within measured depths. Cultivated soil had highest silt (103.40 g/kg) and lowest sand (876.60 g/kg) at the 0-15 cm soil depth compared to the uncultivated soil, while a reverse trend was observed at the 15-30 cm soil depth. From the results, it can be concluded that, the farmers' long-term cultivation practice is still normal soil tillage that is capable of maintaining the soil's physical properties for sustainable agricultural crop production over longer (20-25 years) period of cultivation.

Keywords: Long-term cultivation; physical properties; physical quality; Savanna; Sokoto.

1. INTRODUCTION

Savanna soils are often characterized with weak structure, poor water infiltration capacity, higher rate of erosion, runoff and depleted in soil nutrients due to long-term continuous cultivation [1]. Rainfall is erratic in savanna regions [2] and thus, sustainable production on soils of the savanna is threatened under long-term continuous cultivation with little consideration for soil ability to recover.

Sustainability in crop production may be achieved through proper management of the soil to maintain both its physical status, likewise its nutrient reserve capacity [3]. Proper farm management through fallow systems had been shown to significantly improve soil physical quality to withstand agricultural crop production, over its long-term continuously cultivated counterparts [4]. However, this may vary from soil to soil, from one farm management practice to the other, and from one agro ecological zone to another. Thus, the need for more research on the effect of long-term cultivation on physical properties of savanna soils became pertinent, so as to proffer solutions to the devastating effects of long-term cultivation on soil physical quality in many regions of the world.

Majority of soils in Sokoto, Nigeria are sandy in texture, characterized by poor structure, higher macroporosity and low water retention capacity, which implies poor physical quality. Thus, continuous cultivation over longer periods which characterized most farmers in Sokoto, could have deleterious consequences on physical quality of already fragile coarse textured soils of Sokoto, Sudan Savanna Zone of Northwestern Nigeria. However, the extent of damage caused by continuous long- term cultivation on soil physical properties could be less in long-term organically fertilized plots.

It is against this background that the current study was envisaged to assess the effects of peasant (local) farmers' long-term cultivation practices on physical quality of a coarse textured soil in semi-arid Sokoto, Nigeria.

2. MATERIALS AND METHODS

2.1 The Study Area

The study was conducted on cultivated and uncultivated peasant (local) farmers farms around Usmanu Danfodiyo University Sokoto. Sokoto State is located on latitude 15^0N and 13°E, 315 m above the sea level and belongs to the Sudan Savanna agro-ecological zone of northwestern Nigeria. The vegetation of Sokoto is characterized by scattered trees and grasses with mono-model type of rainfall. The rainfall is erratic and scanty in nature throughout the rainy period [5,6]. The area experiences two distinct seasons which are wet and dry seasons. The average annual minimum and maximum temperatures are 15°C and 40°C [7].

2.2 Treatments and Experimental Design

The experiment comprised of two treatments (cultivated and uncultivated lands) and five replications. The experimental sites were located around Gumburawa village, adjacent to the livestock farm, Usmanu Danfodiyo University Sokoto. The land use history of the two sites are as follows:

<u>2.2.1 SITE 1: Cultivated land</u>

The site comprised of a cultivated land that is under local farmers' management for 20-25 years. The commonly grown crops include millet and cowpea or groundnut. Tillage practices on this site involved 1 camel traction and 1-2 hand hoe cultivation per season (year). Camel or cow dung manure is the fertilizer applied by farmers in this site.

2.2.2 SITE 2: Uncultivated (Fallow) land

This site comprised of an uncultivated land (left fallow) for a period of 5-8 years. The land was left under natural vegetation that comprises of some grasses and scattered *Azadiracta indica* trees.

2.3 Soil Sample Collection and Preparation

Systematic sampling technique was employed for soil sample collection. For the determination of particle size distribution (texture) of the soil, each of the 2 experimental sites was systematically divided into 5 segments. Within each segment, 3 random samples were systematically obtained using auger, thoroughly mixed to get a composite samples. The composite samples were then air dried, screened through 2 mm mesh, and kept for analysis.

Three random undisturbed core samples from the five (5) segments (replications) in each of the experimental sites (treatment plots) were obtained using core samplers (24 hours after a major rain) and used for the determination of other soil physical properties. The means of the three random undisturbed core samples for each parameter were obtained and used as replications. All sampling for the determination of physical properties of the soil were done at surface (0-15 cm) and subsurface (15-30 cm) soil depths.

2.4 Determination of Soil Physical Properties

Physical properties of the soil were determined using standard methods as follows:

Bulk density of the soil was determined by the core method as described by [8], while **Total porosity** of the soil samples was determined as described by [9] using the following relations:

$$TP = \left(1 - \frac{Db}{Pd}\right) \times 100$$

Where Db = bulk density
Pd = particle density (2.65 g/cm^3)

The **gravimetric moisture content** of individual treatments was determined using the gravimetric method as described by [10] as:

$$Øm = \left(\frac{Øw - Ød}{Ød}\right) X \quad 100$$

Where Øw = mass of moist soil
Ød = mass of oven dry soil
Øm = gravimetric moisture content

The **particle size distribution** of the soil samples was determined using Bouyoucous hydrometer method as described by [11]. Values obtained were read using U.S.D.A. textural triangle to know the texture of the soil.

2.5 Statistical Analysis

The data obtained was subjected to student two-sample t-test using SAS 2002 [12] analytical software at 5% level of probability.

3. RESULTS

3.1 Effect of Long- term Cultivation on Physical Properties of the Soil

3.1.1 Effect of long-term cultivation on soil bulk density (Bd) and total porosity (TP)

The results of effect of long-term cultivation on bulk density (Bd) and total porosity (TP) of the soil are presented in Table 1. The results revealed that, cultivation practices had no significant (P>0.05) effect on Bd and TP of the soil at both surface (0-15 cm) and subsurface (15-30 cm) soil depths. In addition, values of Bd in cultivated soils decreases while those of uncultivated soil increased across sampling depths (Table 1). However, the results further revealed a slight deterioration in physical quality of the soil due to long-term continuous cultivation at the surface soil depth, due to dereased TP, increased Bd and decreased Øm in cultivated soils.

3.1.2 Effect of long-term cultivation on gravimetric (Øm) moisture content

Results of the effect of long-term cultivation on gravimetric moisture (Øm) content of the soil are presented in Table 1. The results shows that, cultivation systems significantly (p<0.05) affected

Øm content of the soil at the subsurface (15-30 cm) soil depth.

Table 1. Physical properties of the soil as influenced by cultivation practices in semi arid Sokoto, Nigeria 2014

Treatments	Soil depth (cm)	Bd (g/cm^3)	TP (%)	Øm (%)
	0-15			
Cultivated soil		1.80	31.92	4.56
Uncultivated soil		1.74	34.11	4.83
SE (±)		0.04	1.69	0.16
Significance		Ns	Ns	Ns
	15-30			
Cultivated soil		1.78	32.70	5.40[a]
Uncultivated soil		1.78	32.75	3.60 [b]
SE (±)		0.04	1.44	0.39
Significance		Ns	Ns	* *

*1- Means followed by different letters in the same column are significantly different at 5% probability level using two-sample t-test, 2- Bd- bulk density, TP-total porosity, Øm-gravimetric moisture content., 3- ** highly significant, Ns-not significant.*

The cultivated soil has significantly higher Øm content, compared to the uncultivated soil. This could be due to increased organic matter (OM) content in the cultivated soil, compared to the uncultivated soil at the subsurface soil depth. This observation is further strengthen as uncultivated soils having highest OM content at the surface soil layer (data not shown) recorded the highest Øm at the surface (0-15cm) soil depth (Table 1).

3.2 Effect of Long-term Cultivation on Soil Texture

Table 2 presents results of the effect of long-term cultivation on particle size distribution (texture) of the soil. The results reveals that, treatments (cultivation and no-cultivation) effects on sand and silt contents of the soil were significant (P<0.05). The cultivated soil had significantly higher sand and lower silt content compared to the uncultivated soil at surface (0-15 cm) soil depth (Table 1). However, the trend reversed at the subsurface (15-30 cm) soil depth, where the uncultivated soil recorded lowest sand and highest silt contents, compared to their cultivated counterpart. Treatments effects on clay content where not significant (P>0.05) at both surface and subsurface soil depths (Table 2).

4. DISCUSSION

4.1 Effect of Long- term Cultivation on Physical Properties of the Soil

4.1.1 Effect of long-term cultivation on soil bulk density (Bd) and total porosity (TP)

The higher Bd and lower TP in cultivated soil compared to the uncultivated one at the surface soil layer (depth) could be attributed to soil consolidation after pulverization and aggregate destruction due to mechanical shearing by tillage implements. The results are in line with findings of [1314]. The results further shows that, long-term cultivated soils, if recompacted, compaction could exceed that of adjacent uncultivated soil. In addition, the non-significant effect of long-term cultivation practices on Bd and TP of the soil observed, could be attributed to the addition of organic manure (cow dung and/or camel dung) by the farmers in cultivated soils. Organic manure add organic matter to the soil [15], which upon decomposition could help in maintaining soil Bd and TP at acceptable limits for crop

Table 2. Particle size distribution (texture) of the soil as influenced by cultivation practices in semi arid Sokoto, Nigeria 2014

Treatments	Soil depth (cm)	Sand (g/kg)	Silt (g/kg)	Clay (g/kg)	Textural class
	0-15				
Cultivated soil		876.60[b]	103.40[a]	20.00	Sandy
Uncultivated soil		900.00[a]	80.00[b]	20.00	Sandy
SE (±)		6.75	6.75	0.00	-
Significance		**	**	Ns	-
	15-30				
Cultivated soil		904.00[a]	76.00[b]	20.00	Sandy
Uncultivated soil		880.40 [b]	99.60 [a]	20.00	Sandy
SE (±)		6.13	6.13	0.00	-
Significance		* *	* *	Ns	-

1- Means followed by different letters in the same column are significantly different at 5% probability level using two-sample t-test,
*2 - ** highly significant, Ns-not significant.*

production, despite long-term continuous cultivation. Generally, the bulk densities observed in both treatments were below the critical Bd limit (1.90 g/cm^3) considered to be limiting to agricultural crop production in coarse textured soils [16].

4.1.2 Effect of long-term cultivation on gravimetric (Øm) moisture content

The increase in Øm observed in cultivated soil at the subsurface soil depth is attributed to increase in OM content of the treatment at the measured depth. This observation is further strengthen as uncultivated soils having highest OM content at the surface soil layer (data not shown) recorded the highest Øm at the surface (0-15cm) soil depth (Table 1). This is in accord with the findings of [4] and further confirms the assertion of [17] that, higher OM or organic carbon (OC) contents of treatments results in higher moisture contents. In addition, [18] added that, improved organic matter content results in improved water holding capacity and rainfall infiltration, which might have resulted in the higher Øm observed in uncultivated treatment at 0-15 cm and cultivated treatment at 15-30 cm soil depths (Table 1).

In general, the result shows that, both cultivation and no-cultivation have positive effect on gravimetric moisture content (moisture storage) of the soil depending on depth (Table 1), of which both management systems could benefit growing crops.

4.1.3 Effect of long-term cultivation on soil texture

The increase and decrease in sand and silt contents of the cultivated soil (respectively) across sampling depths could be attributed to the effect of cultivation which helps in mixing up of soil particles and constituents, resulting in their movement within a soil body. This agrees with the findings of [8] that, cultivation encourages movement of fine soil particles within a soil profile.

Generally, the result shows that, values of TP, Øm and sand contents of the soil increases in cultivated soil across sampling depths, while those of Bd and silt contents decreased. The reverse was observed in uncultivated soils (Tables 1 and 2). Furthermore, the results also confirmed that, cultivation could change textural composition of a soil but not its textural class, as both treatments across both sampling depths are sandy in texture (Table 2).

5. CONCLUSION

The study revealed that, although the treatments tested (cultivation and no-cultivation) significantly ($P<0.05$) affected Øm, sand and silt contents of the soil, on average, long-term cultivation did not deteriorate the soil physical properties to withstand agricultural crop production. However, cultivation encourages redistribution of silt particles within the soil profile. From the results, it can be concluded that, the farmers' cultivation practices had the capacity of maintaining the soils physical properties under long-term (20-25 years) continuous cultivation and should therefore, be encouraged.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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