



International Journal of Plant & Soil Science
4(11): 1490-1503, 2014; Article no. IJPSS.2014.11.010

SCIENCEDOMAIN international
www.sciencedomain.org



Effect of Tillage, Fertilizer and Sorghum/Desmodium Intercrop Cultivation on Soils' Quality and Yield of Sorghum in an Alfisol of a Northern Guinea Savanna of Nigeria

Odunze Azubuiké Chidowe^{1*}, Tseja Majiyébo Joshua¹, Abu Sunday¹
Tarfa Bitrus Dawi¹, Mel Oluoch² and Khan Zeyaur³

¹Department of Soil Science/IAR, Faculty of Agriculture, Ahmadu Bello University, Zaria, Nigeria.

²International Institute of Tropical Agriculture (IITA), Ibadan, Kano Station, Nigeria.

³International Centre of Insect Physiology and Ecology, Nigeria.

Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

Original Research Article

Received 8th February 2014

Accepted 8th April 2014

Published 30th July 2014

ABSTRACT

Soil quality protection under intensive land use and fast economic development has become a major challenge for sustainable resource use in the developing countries such as Nigeria. Conventional tillage practice is commonly practiced at land preparation and effect of this on soil quality for sustainable productivity was investigated in this study, in comparison with No Till, Conservation tillage, and split old ridge practices in combination with four nitrogen and three phosphorus fertilizer rates. Sorghum was the test crop. Results show that the soils were initially acid (pH 5.0 to 6.0), had low organic carbon (2.3 to 2.5gkg⁻¹), total nitrogen (0.05gkg⁻¹) and low to moderate available phosphorus (6.7 to 8.5mgkg⁻¹) and needed restoration to support sustainable agricultural production. Tillage, sorghum/*Desmodium* and N and P fertilizer managements imposed showed that No Till practice (SDNT) sequestered significantly ($P < 0.05$) higher organic carbon value (6.9 gkg⁻¹), followed by Conservation tillage with incorporated and relayed *D. Uncinatum* (SDIC 5.8 gkg⁻¹), Split old ridges with relayed *D. uncinatum* (SDOR 4.9gkg⁻¹) and least, Conventional tillage (SC) without *D. uncinatum* (SC3.6 gkg⁻¹). Total nitrogen content of the

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

soils significantly improved under SDIC (0.17gkg^{-1}), followed by SDOR (0.16gkg^{-1}), SC (0.15gkg^{-1}) and SDNT (0.13gkg^{-1}) that were significantly different between treatments. Conservation tillage with incorporated and relayed *D. uncinatum* treatment (SDIC) resulted in significantly ($P < 0.05$) higher (1.48tha^{-1}) sorghum grain yield, followed by No-Till (SDNT) with *D. uncinatum* live mulch (1.32tha^{-1}) that was significantly higher than yield under Split old ridges (1.20tha^{-1}) with *D. uncinatum* live mulch (SDOR). Phosphorus fertilizer rates significantly enhanced stover yield, as 26.4kgPha^{-1} rate resulted in the highest Stover yield (4.50tha^{-1}) and the least (4.11tha^{-1}) from 13.2kgPha^{-1} . Also, 50kgNha^{-1} significantly enhanced Stover yield of sorghum (4.83tha^{-1}) greater than the other treatments. Conservation tillage practice therefore resulted in high sorghum grain yield (1.48tha^{-1}), attributed to improved soil quality conditions; optimum soil pH, available phosphorus, soil carbon and total nitrogen, that prevailed to support high sorghum grain yield. Soil quality (SQ) under the Conservation tillage practice (SDIC) was therefore rated SQ₁ for being superior over other management practices evaluated.

Keywords: Conservation tillage; soil quality; sorghum productivity; land use management.

1. INTRODUCTION

Protection of soil quality under intensive land use and fast economic development has become a major challenge for sustainable resource use in the developing world (Doran et al. [1]; Doran and Safley, [2]; Karlen et al. [3]. In order that soil quality must be adequately protected, basic assessment of soil health and quality is necessary to evaluate the degradation status and changing trends following different land use and smallholder management interventions (Lal and Stewart [4]; Larson and Pierce) [5]. Soil tillage is among important management practices affecting soil quality and crop yield. It contributes up to 20% of all crop production factors (Khurshid et al.) [6], and appear indispensable if food crop production must balance food demand by the growing human and livestock populations and attain national food security on a sustainable basis. Tillage method affects sustainable use of soil resources through its influence on soil quality (den Biggelaar et al.) [7]. Tillage systems; particularly conventional tillage system, adversely affect soil quality by damaging soil structure, decreasing soil moisture content, increasing soil bulk density and root penetration resistance (Rashidi and Keshavarzpour) [8]. Bationo et al. [9] and Derspsch et al. [10] reported that continuous cultivation under conventional or intensive tillage leaves soil bare and unprotected, thereby promoting accelerated soil erosion, soil nutrient depletion, soil structure deterioration and leading to excessive high soil temperature. However, No-tillage system improves the soil's moisture retention, aeration, infiltration and reduces runoff and evaporation (Duiker and Myers, [11]). Also, annual disturbance and pulverizing caused by conventional tillage produce a finer and loose soil structure as compared to conservation and no-tillage methods which leaves the soil intact (Rashidi and Keshavarzpour) [8].

Measures to mitigate adverse effects of soil tillage on the basis of ecology and soil orders need to be evaluated for the purpose of advancing appropriate land use management practices compatible with specific soil orders, sustainable soil quality and optimal agricultural production.

Currently, research has largely focused on Conservation Agriculture (CA) to manage soils and conserve the environment while optimally exploiting the soil for sustainable productivity (Thiombiano and Meshack [12]; Bundy et al. [13]). Conservation Agriculture is a concept for

natural resource-saving that strives to achieve acceptable profit with high and sustained production levels while concurrently conserving the environment (Thiombiano and Meshack [12]. Conservation Agriculture (CA) employs minimum soil disturbance/reduced tillage, permanent soil cover/zero tillage and/or crop rotation practices to achieve sustainable agricultural productivity and would be evaluated in this study for their potential to improve soil quality and ensure sustainable sorghum production in the Savanna zone Alfisols of Nigeria.

Alfisols of the Nigerian arid and semi-arid region Savannas have poor water retention capacity, low inherent fertility status, very low organic matter content and are dominated by low activity clays such as kaolinite clay (Jones and Wild, [14]; Lombin, [15]; Odunze, [16]) and sesquioxides. Frequently in the area, dry spell occurs during rain fed cropping seasons and are severely eroded both by wind and water (Odunze et al. [17]). Also, crop residues are commonly harvested to feed livestock, for fencing or fuel wood in the arid and semi-arid Savanna zones of Nigeria (Balasubramania and Nnadi, [18]; Tarawali et al. [19]); thus deterring soil carbon sequestration and quality improvement through residue incorporation in soils. The incorporation of crop stover/residues improves crop productivity by increasing C sequestration and reducing emission of greenhouse gases among other parameters (Hobbs et al. [20]; Odunze et al. [17]; Biau et al. [21]). *In situ* grown permanent soil cover crops or residues retention on farms is often constrained in the zone by the need to provide adequate feed for livestock in the dry season (Bundy et al. [13]; Standford, [22]; Tarawali et al. [19]), as well as the fact that free grazing is a common practice in the zone. The safe guard of *ex situ* residues has largely accounted for communal and nomadic herdsman clashes, as they contest for crop residue to feed livestock or for improving the soil in their farms (Tarawali et al. [19]; Balasubramania and Nnadi, [18]). Crop rotation and reduced tillage practices are integral parts of CA that are practiced in various forms in the Nigerian Savannas but without adequate management of crop residues. Therefore, for the full benefit of CA to accrue, farmers need to move from continuous monocropping under conventional tillage practice to reduced tillage and rotation practices that support incorporation of crop residues. The incorporation of stover/residues prevents soil erosion, maintains soil organic matter (SOM) and soil structure by humification, is a source of macronutrients (NPK) and micronutrients (S, Cu, B, Zn and Mo), as well as a source of energy for biota (Lal, [23,24]; Mubarak et al. [25]; Biau et al. [21]). The contribution of tillage practices, fertilizer (N & P) application and intercrop of sorghum and *Desmodium uncinatum* to soil quality improvement and yield of sorghum in the Nigerian Savanna zone Alfisols will therefore be evaluated in this study.

Objectives of the present study therefore include investigating the effect of conservation tillage practices, fertilizer rates and sorghum/*Desmodium* intercrop on quality of Alfisols in the arid and semi-arid Savanna of Nigeria, as well as the effect of these on yield of sorghum. This is for the purpose of ensuring that the soil is sustainably exploited for sorghum grain and stover yields as well as conserved in the process for future use.

2. MATERIALS AND METHODS

2.1 Site Location and Description

This study was conducted at the Institute for Agriculture Research (IAR) experimental farm Samaru, Zaria (Longitude 7°30' and 7°50' E and latitude 11°00' and 11°10', with an altitude of 686m above sea level) in the Guinea Savanna ecology of Northern Nigeria. Soils of the

study area were classified as TypicHaplustalf according to USDA Soil Taxonomy (Soil Survey Staff, [26]) as cited by Ogunwole [27] and Acrisol in the FAO-UNESCO legend as cited by [28], Valette and Ibanga [29] and Uyovbisere et al. [30]. Rainfall pattern of the area is mono modal, having a long term mean annual rainfall between 1979 and 2008 to be 986.5mm and is received mainly between May and September with peak rainfall in August (Odunze, 2011 [31,16,32,17,33]). The mean daily air temperature of the area attains 24°C (Oluwasemire and Alabi, [34]).

The main treatments of this study included tillage practices and N-rates as follows;

1. Sorghum mono crop under conventional tillage (SC)
2. Sorghum with *Desmodium uncinatum* live-mulch under No-till (SDNT)
3. Sorghum intercrops with *Desmodium uncinatum* on splitold ridges (SDOR)
4. Intercrop of Sorghum and *Desmodium* under Conservation tillage after incorporation of previous years' *Desmodium* (SDIC)

The trial field in 2011, was cleared, ploughed, harrowed and ridged with disc harrow and disc ridging respectively and planted to *Desmodium uncinatum* except for plots SDNT and SC that were left un-tilled and another ploughed but left bare without *Desmodium uncinatum* in the first year. In 2012, the experiment was laid out using split plot in Randomized Complete Block Design (RCBD). The main plot size was 10m by 32m (320m² or 0.032ha) and replicated four times. Each replicate contained four sub plots and one control plot, each measuring 10m by 8m with twelve ridges/rows. Three out of the sub plot of each replicate were planted to *Desmodium uncinatum* during the first year. *Desmodium* was planted on the ridge slope of every ridge in the sub plots. Ridges of sub plot SC and SDIC were remoulded at beginning of 2012, using ox drawn implements while SDNT remained unploughed. Thereafter Sorghum (Samsorg 14) was planted on ridge peaks of SC, SDIC and SDOR. The Nitrogen rate treatments include 30, 40, 50 and 60kgNha⁻¹ and this experiment was conducted as split plot based on randomized complete block design (RCBD). The sub subplot treatments include three Phosphorous rates; i.e. 6.6, 13.2 and 26.4kgPha⁻¹ that were randomized, each in one ridge/N rate sub plot.

2.2 Soil Quality and Changing Trends

Basic soil indicators selected for a minimum data set in this study were relevant soil data (Doran and Parkin, [35,36,1,2]; Andrew and Carroll, [37]) obtained in this study for the Nigerian Northern Guinea Savanna zone Alfisols. They were:

- i). Data on total carbon, nitrogen, available phosphorus and pH of the soils after crop harvest.
- ii). Data on sorghum grain yield for the study period.

Soil quality was assessed by using the Parr et al. [38] equation; i.e.

$$SQ = f(SP, P, E, H, ER, BD, FQ, MI),$$

Where SQ= soil quality, SP= soil properties, P= potential productivity, E= environmental factors, H= Health (Human/animals), ER= erodibility, BD= biodiversity, FQ= food quality and MI= management input. A score scale of 1 to 5 was used in the assessment of parameters in the model; where 1 is best and 5 is worst condition. However, E, H, ER, FQ, and MI were each scored 1.0 because the research field used for the experiment had been on long-term

research use (1922 to date) and is being optimally managed to satisfy optimal environmental conditions for sustainability, health factors for human and livestock, optimal food quality obtained, biodiversity and input management. Therefore, SQ= f(SP,P) was used to assess quality of the Alfisols in the Nigerian Guinea Savanna zone.

2.3 Soil Analysis

Initial and end of year soil samples obtained at depths 0-5, 5-15 and 15-30cm from the field, were air dried, sieved through 2 mm diameter sieve and subjected to laboratory analysis. Parameters evaluated in the laboratory of Department of Soil Science Ahmadu Bello University were:

- i) Soil particle size distribution by hydrometer method (Gee and Bauder, [39]).
- ii) Soil pH in water at water: soil ratio of 2:1 using the Pyeunican pH meter (Mc Lean, [40]).
- iii) Soil organic carbon; by Walkley Black wet oxidation method (Nelson and Sommers, [41]).
- iv) Available phosphorus; by Bray 1 method (Olson and Sommers, [42]).
- v) Total nitrogen was analysed by the Kjeldahl digestion method (Bremner and Mulvaney, [43]).
- vi) Cation exchange capacity of the soils were determined using the 1NNH₄OAC method (Rhoades, [44]).

2.4 Yield Analysis

At physiological maturity, sorghum was harvested from the treatment plots in each replicate, air-dried, shelled to separate grains from husks. The grains were further air-dried to 12.5% moisture content, weighed and calculated for a hectare (t/ha). All sorghum stalks for each treatment were harvested, air-dried for four weeks, weighed to obtain stover weights per treatment and calculated for a hectare.

Data obtained were subjected to analysis of variance and significant ($P < 0.05$) mean values were separated using Tukey's Honest Significant Difference test (HSD).

3. RESULTS AND DISCUSSION

3.1 Effect of One Year Fallow on Soil Properties

Table 1 presents information on initial properties of soils at the experimental site. It shows that top soils (0-30 Cm) were slightly acid both in water and CaCl₂ solution, but at the range of pH 5.0 and 6.0 that is adequate for nutrient availability to plant roots (Marschner, [45]) and a mean value of pH 5.8 in water and 5.1 in CaCl₂ solution. Also, organic carbon content of the soils were very low (2.3gkg⁻¹ at 0-5 Cm, 2.4 gkg⁻¹ at 5-15 Cm, and 2.5 gkg⁻¹ at 15-30 Cm), with low levels of total Nitrogen (0.05gkg⁻¹ at 0-5Cm and 5-15Cm; 0.05gkg⁻¹ at 15-30 Cm depths). Available phosphorus was moderate at all depths (0-5Cm depth 8.3 mgkg⁻¹; 5-15 Cm depth 8.7mgkg⁻¹ and 15-30Cm 7.1mgkg⁻¹), but decreased at lower depth of 15-30Cm (7.1mgkg⁻¹). Cation exchange capacity (CEC) of the soils were also low (<10 Cmolkg⁻¹) across depths (4.6, 5.2 and 5.3 Cmolkg⁻¹) to suggest that the soils are dominated with low activity clays; kaolinites and sesquioxides in particular (Odunze et al. [31]) and low in organic

matter content, but increased at depth 15-30 Cm, perhaps due to decomposed plant roots in the sub soil depths.

Particle size distribution of the soils show a dominance of silt fractions (56.3gkg⁻¹, 58.3gkg⁻¹ and a mean value of 57.3gkg⁻¹ at 0-5 and 15-30 Cm depths respectively), followed by sand (35.4 and 25.4gkg⁻¹ at respective depths) with a mean value of 29.4gkg⁻¹ sand. Clay separates were low (8.3 and 18.3gkg⁻¹ at respective depths of 0-15 and 15-30 Cm) for the soils to be classified as Silt loam across depth.

Table 1. Initial physicochemical properties of the experimental field

Soil Properties	Depth (Cm)			Mean (Cm)
	0-5	5-15	15-30	0-30
pH (H ₂ O)	5.9	6.0	5.6	5.8
pH (CaCl ₂)	5.2	5.0	5.0	5.1
Available P. (mgkg ⁻¹)	8.3	8.7	7.1	8.03
CEC (cmolkg ⁻¹)	4.6	5.2	5.3	5.03
Organic Carbon (gkg ⁻¹)	2.3	2.4	2.5	2.4
Total Nitrogen (gkg ⁻¹)	0.05	0.05	0.05	0.05
Particle size analysis (gkg⁻¹)				
Sand	35.4	23.4	29.4	
Silt	56.3	58.3	57.3	
Clay	8.3	18.3	13.3	
Textural Class	Silt Loam			

Table 2 shows that the soils were less acid, as against initial acidity conditions of the soils before planting of *Desmodium*. Soil reaction following one year short planted *Desmodium* fallow (Table 2) therefore reveals a range of pH 6.0, 5.8 and 5.7 in water and pH 5.3, 5.3 and 5.2 in CaCl₂ respectively across depths 0-5Cm, 5-15Cm and 15-30 Cm, that is optimum for plant nutrients extraction (Marschner, 1998 [45]) within the crop rooting zone. However, the less acid conditions of the 0-5 and 5-15 Cm depths suggests improved soil conditions for sustainable crop production.

Available phosphorus in the surface soils ranged from 8.5mgkg⁻¹ at 0-5 Cm and 5-15 Cm depths to 6.7mgkg⁻¹ at 15-30Cm depth, suggesting higher phosphorus availability at the top soil zones to support optimal root uptake of phosphorus.

Cation exchange capacity (CEC) of the soils were low (<10 Cmolkg⁻¹), despite the one year in-situ grown *Desmodium*, but was higher at the 0-5 Cm depth (6.7 Cmolkg⁻¹) than the initial at same depth (4.6 Cmolkg⁻¹). CEC values decreased with depth (5-15 and 15-30Cm depths (5.1 and 4.8 Cmolkg⁻¹ at respective depths) compared to the initial at similar depth (5.2 and 5.3 Cmolkg⁻¹). This suggests some improvement in the capacity of the soils to exchange nutrients; in particular at the 0-5 Cm depths due to one year planted short fallow with *Desomdium uncinatum*.

Organic carbon values were also very low, but was higher at the 0-5Cm (5.3gkg⁻¹) than the initial (2.3 gkg⁻¹) and decreased with increase in depths. Perhaps, this will suggest that the 0-5 Cm depths soil quality were better improved for sustainable crop production under this management practice. Total nitrogen in the soil was low and showed appreciable change with planted one year *Desmodium uncinatum* short fallow practice.

Table 2. Chemical properties of soils following tillage with *Desmodium* live mulch (Before incorporation)

Soil properties	Depth (Cm)			Mean (Cm)
	0-5	5-15	15-30	0-30
pH (H ₂ O)	6.0	5.8	5.7	5.8
pH (CaCl ₂)	5.3	5.3	5.2	5.3
Available P (mgkg ⁻¹)	8.5	8.5	6.7	7.9
CEC (cmolk ⁻¹)	6.7	5.1	4.8	5.53
Organic Carbon (gkg ⁻¹)	5.3	2.1	1.9	3.1
Total Nitrogen (gkg ⁻¹)	0.12	0.12	0.05	0.1

NB: CEC=Cation exchange capacity

Following one year intercrop of sorghum and imposition of tillage and fertilizer treatments (Table 3), soil acidity in water generally increased; though not significantly ($P < 0.05$) different between tillage practices, and were not less than pH 5.0 to limit optimal nutrients uptake by plant roots (Marschner, [45]) in water. However in CaCl₂ solution, soil acidity was significantly ($P < 0.05$) less under split old ridges (SDOR) with *Desmodium uncinatum* live mulch (pH4.8), followed by pH 4.75 under Conservation tillage with incorporated and relayed *Desmodium uncinatum* (SDIC) live mulch, and pH 4.78 under No till with *Desmodium uncinatum* (SDNT) live mulch that were both not significantly different. Conventional tillage (SC) however, had the highest acidity value of pH 4.69 that was significantly ($P < 0.05$) different from the other tillage practices. These findings could show that planting of sorghum under these tillage practices would increase soil acidity, but increasing acidity trend could be mitigated by split old ridge with *D. uncinatum* live mulch, conservation tillage with incorporated *D. uncinatum* and live mulch relayed, or No Till practice with *D. uncinatum* live mulch practice. Organic carbon values generally increased, but No Till practice sequestered significantly ($P < 0.05$) higher value (6.9gkg⁻¹), followed by SDIC (5.8 gkg⁻¹), SDOR (4.9gkg⁻¹) and conventional tillage (3.6gkg⁻¹). This implies that Conventional Tillage practice resulted in the least soil carbon credit that could hasten soil degradation for sustainable agricultural production and increase greenhouse gas emission to impact adversely on global warming (Lal and Stewart, [36]; Larson and Pierce; Odunze et al. [17]). Available phosphorus values under the tillage practices were significantly ($P < 0.05$) higher with No Till (10.19mgkg⁻¹), followed by Conservation tillage with incorporated and relayed *D. uncinatum* live mulch (SDIC) that had 9.48mgkg⁻¹, SDOR (8.14mgkg⁻¹) and Conventional Tillage (SC) with 8.21 mgkg⁻¹. Total nitrogen content of the soils was significantly improved under SDIC (0.17gkg⁻¹), followed by SDOR (0.16gkg⁻¹), SC (0.15gkg⁻¹) and SDNT (0.13gkg⁻¹) that were all significantly different between treatments. This suggests that the incorporation and relayed *D. uncinatum* under conservation tillage practice significantly improved total nitrogen content of the soils compared to the other tillage practices. In a study by Nwaogu et al. [31] on soil quality improvement using short duration grain legume, they stated that inclusion of short duration grain legume has the capacity to improve not only the total N, but also the organic matter, in confirmation of findings from the current study.

The application of phosphorus fertilizer rates did not cause any significant change in soil acidity (H₂O and CaCl₂) and organic carbon contents of the soil (Table 3). However, 13.2 kgPha⁻¹ resulted in significantly ($P < 0.05$) higher available phosphorus (9.21 mgkg⁻¹) and total nitrogen (0.16 gkg⁻¹) better than the other treatments (Table 3). The 40 kg Nha⁻¹ fertilizer rate caused significantly higher acidity (pH 5.1) in water, followed by 60kg Nha⁻¹ (pH5.41). The N-rate treatments had no significant effects on acidity reactions in CaCl₂ solution. However, the

50kgNha⁻¹ treatment significantly enhanced organic carbon content (6.8gkg⁻¹) of the soil better than 60kgNha⁻¹ (5.5gkg⁻¹) that was also significantly higher than the 40 and 30kgNha⁻¹ treatments respectively (Table 3). This suggests that the combined application of 13.2kgPha⁻¹ and 50 kgNha⁻¹ under the tillage management practices would enhance sustainable sorghum productivity. Nitrogen rates treatment significantly affected phosphorus availability in the soils with 40 kgNha⁻¹ (9.35mgkg⁻¹) and 60kgNha⁻¹ (9.01mgkg⁻¹) being highest and not significantly different. The 30 and 50 kgNha⁻¹ treatments were not significantly different in enhancing phosphorus availability but were significantly less than 40 and 60kgNha⁻¹ N-rates (Table 3). Also, 30 and 50 kgNha⁻¹ significantly enhanced total nitrogen contents (0.16gkg⁻¹ each) of the soil than 60 kgNha⁻¹ rates (Table 3). These findings suggest that combined 50kgNha⁻¹ with 13.2kgPha⁻¹ under this tillage treatment would best enhance optimal soil acidity conditions, soil carbon sequestration, available phosphorus and total nitrogen for sustainable sorghum productivity in the Savanna Alfisols of Nigeria (Odunze et al. [17]; Odunze et al. [31]).

Table 3. Effect of management (Mgt.) practices on selected soil chemical properties of the experimental site: Dec 2012

Treatment	pH		Org. C. gkg ⁻¹	Avail. P. mgkg ⁻¹	Total N. gkg ⁻¹
	H ₂ O	CaCl ₂			
Tillage Practices					
SDOR	5.54a	4.80ab	4.9b	8.14c	0.16ab
SDIC	5.53a	4.75ab	5.8ab	9.48b	0.17a
SDNT	5.46a	4.78ab	6.9a	10.19a	0.13c
SC	5.38a	4.69b	3.6c	8.21c	0.15b
SE±	0.031	4.69b	0.19	0.27	0.005
P rates (kgPha⁻¹)					
6.6	5.47a	4.74a	5.1a	8.84b	0.15b
13.2	5.50a	4.72a	5.5a	9.21a	0.16a
26.4	5.46a	4.73a	5.4a	8.95b	0.15b
SE±	0.031	0.021	0.17	0.234	0.004
N rates (kgNha⁻¹)					
30	5.50a	4.71a	4.5c	8.83ab	0.16a
40	5.1b	4.74a	4.8c	9.35a	0.14c
50	5.50a	4.75a	6.8a	8.81ab	0.16a
60	5.41ab	4.72a	5.5b	9.01a	0.15bc
SE±	0.031	0.044	0.190	0.270	0.005
Depth (Cm)					
0-5	5.48a	4.77a	6.0a	9.02a	0.16a
5-15	4.47a	4.72ab	5.3b	9.00a	0.16a
15-30	5.50a	4.70ab	4.7c	8.98a	0.13b
SE±	0.027	0.021	0.17	0.234	0.004

Table 3 also show that the treatments resulted in soil acid range of pH 5.47 and 5.50 (in water) over the depth range of 0-30 cm that were not significantly different and were within the acidity range optimal for nutrients uptake by plant roots. However, organic carbon, available phosphorus and total nitrogen (each) were highest at the 0-5 and 5-15 Cm depths. These suggest that the tillage practice, *D. uncinatum* management and fertilizer rates treatments resulted in improved quality of top soils (0-15 Cm) better than the sub soil depth. Table 4 presented data on effect of treatments on yield of sorghum and shows that conservation tillage with incorporated and relayed *D. uncinatum* treatment (SDIC) resulted in

significantly ($P < 0.05$) higher (1.48tha^{-1}) sorghum yield, followed by No-Till (SDNT) with *D. uncinatum* live mulch (1.32tha^{-1}) that was significantly higher than yield under split old ridges (1.20tha^{-1}) with *D. uncinatum* live mulch (SDOR). However the tillage treatments had no significant ($P < 0.05$) influence on the 1000 sorghum grains weight but stover yields differed significantly ($P < 0.05$) between treatments. The highest stover yield (5.09tha^{-1}) was obtained under SDIC and was significantly greater than 4.43tha^{-1} under SDNT, 4.01tha^{-1} under SDOR, and 3.74tha^{-1} under SC. Conservation tillage practice therefore would result in significantly higher sorghum stover yield when compared to the other tillage practices.

Phosphorus fertilizer rates significantly ($P < 0.05$) enhanced stover yield, with the 26.4kgPha^{-1} rate resulting in the highest stover yield (4.50tha^{-1}), followed by 6.6kgPha^{-1} (4.26tha^{-1}) and the least (4.11tha^{-1}) from 13.2kgPha^{-1} . Also, The 60, 40 and 30 kgNha^{-1} nitrogen fertilizer rates (each) resulted in significantly ($P < 0.05$) higher 1000 grain weight than the 40kgNha^{-1} rate (Table 4). However, 50kgNha^{-1} significantly enhanced stover yield of sorghum yield (4.83tha^{-1}) greater than the other treatments.

Table 4. Effects of Tillage, *D. uncinatum* N & P fertilizer treatments on yield of Sorghum

Treatments	Sorghum grain tha^{-1}	1000 grains g	Stover tha^{-1}
Tillage Practices			
SC	1.17d	33.79a	3.74d
SDIC	1.48a	34.02a	5.09a
SDOR	1.20c	33.79a	4.01c
SDNT	1.32b	33.85a	4.34b
SE±	0.08	0.366	0.245
P rates (kgPha^{-1})			
6.6	1.30a	33.62a	4.26b
13.2	1.28a	33.69a	4.11c
26.4	1.30a	33.90a	4.50a
SE±	0.68	0.32	0.212
N rates (kgNha^{-1})			
30	1.30a	33.66a	3.54d
40	1.20a	33.55a	4.50b
50	1.35a	34.08b	4.83a
60	1.32a	33.67a	4.31b
SE±	0.78	0.366	0.245

3.2 Trends in Soil Quality Changes Following Tillage, *D. uncinatum*, Fertilizer N & P Management Practices

Table 5 presents information on soil properties changes following imposed management practices. Soil acidity (in water) under each of the tillage practices increased from the initial value (pH 5.8) to a stronger acidity reaction, though remaining in the range of pH 5.0- 6.5 that is optimum for plant nutrients uptake. However, SDOR (pH 5.54) and SDIC (pH 5.53) caused the least acidity increase and the highest increase in acidity was recorded in Conventional tillage (SC) practice (pH 5.38). In CaCl_2 solution, the least increase in acidity was under SDOR (pH 4.80), followed by SDNT (pH 4.78) and SDIC (pH 4.75). The highest increase in acid reaction was under Conventional tillage (SC) practice, implying that

conventional tillage increased soil acid conditions more than the other treatments; thus, degrading the soils for sustainable use in agricultural production. However, soil acidity (CaCl_2) conditions were mitigated by the one year planted fallow with *D. uncinatum* by 3.92 %. Available phosphorus decreased in value from 8.03 mgkg^{-1} in 2011 to 7.90 mgkg^{-1} in 2012 (-1.62%) following one year planted fallow with *Desmodium uncinatum*; perhaps because legumes use more phosphorus for protein synthesis (Marschner, [45]; Odunze et al. [31]). However, the No Till (SDNT) practice after harvest of sorghum credited more phosphorus (10.19 mgkg^{-1}) into the soil, followed by Conservation tillage (SDIC) practice (9.48 mgkg^{-1}) and SC practice (8.21 mgkg^{-1}) and the least phosphorus value was from SDOR (8.14 mgkg^{-1}). The No till practice (SDNT) therefore improved the soil available phosphorus contents better than the other treatments but was followed by SDIC. Also, organic carbon increased from the initial value (2.4 gkg^{-1}) to 3.1 gkg^{-1} (29.17 %) after one year planted *Desmodium uncinatum* fallow (Table 5), indicating that the short fallow practice sequestered organic carbon into the soil to improve soil quality. However, following tillage practices and cultivation of sorghum, SDNT sequestered 6.9 gkg^{-1} (122.5%) organic carbon (Table 5); compared with 3.1 gkg^{-1} before planting sorghum in 2012, after harvest of sorghum in 2012 to be superior to the other tillage practices in soil carbon credit. However, SDIC treatment resulted in 5.8 gkg^{-1} (87.10 %) organic carbon credits, while SDOR sequestered 4.9 gkg^{-1} (58.07%) to improve the soil quality for sustainable crop production. Conventional tillage (SC) however resulted in 3.6 gkg^{-1} (16.13%) organic carbon credits to have poorly sequestered carbon for sustainable agricultural production activity.

Total nitrogen content of the soils show significant increase 0.17 gkg^{-1} (70.0%) under Conservation tillage practice (SDIC), followed by SDOR (0.16 gkg^{-1} or 60%) and SC (0.15 gkg^{-1} or 50%) to have significantly improved total nitrogen content of the soils over SDNT (0.13 gkg^{-1} or 30%). Conservation tillage practice resulted in high sorghum grain yield (1.48 tha^{-1}), and is attributed to improved soil quality conditions (optimum soil pH, available phosphorus, soil carbon and total nitrogen) that prevailed. Soil quality under SDIC was therefore rated SQ_1 . Optimal soil conditions (pH, available P, organic carbon, and total nitrogen) also prevailed under SDNT to have supported (1.32 tha^{-1}) high sorghum grain yield. The relatively lower yield under SDNT could be accounted for by the lower total nitrogen (30%) content of the soils compared to 70% obtained under SDIC. Soils under SDNT practice were therefore rated SQ_2 in quality. Soil conditions under SDOR resulted in lower sorghum grain yield (1.20 tha^{-1}) than SDIC and SDNT; perhaps, because the soils had optimal pH, lower available P, lower organic carbon, though total nitrogen was high (Table 5). Soils under SDOR was therefore rated SQ_3 . Conventional tillage practice resulted in the least sorghum grain yield (1.17 tha^{-1}), had higher acid conditions, moderate available P, low carbon and low total nitrogen contents to qualify as SQ_4 in soil quality rating.

Table 5. Changes in Chemical Properties of Experimental Soil following short fallow, Tillage, *D. uncinatum* and fertilizer N & P practices and sorghum grain yield; 2011-2012

Treatment	Depth (Cm)			Tillage practices				
	2011	2012	% Diff. ₁	SC	SDIC	SDNT	% Diff. ₂	SDOR
pH (H_2O)	5.8	5.8	nil	5.38	5.53	5.46		5.54
pH (CaCl_2)	5.1	5.3	3.92	4.69	4.75	4.78		4.80
Avail. P (mgkg^{-1})	8.03	7.9	-1.62	4.69	9.48	10.19	28.99	8.14
Org. C. (gkg^{-1})	2.4	3.1	29.17	3.60	5.80	6.90	122.5	4.90
Total N. (gkg^{-1})	0.1	0.1	nil	0.15	0.17	0.13	30.0	0.16
Sorghum grain yield	-	-	-	3.74	5.09	4.34		4.01

% Diff.₁ = % difference between 2011 and 2012; % Diff.₂ = % difference between SC and SDNT

4. SUMMARY AND CONCLUSION

Findings from this study show that under one year planted fallow with *D. uncinatum*, soil reactions were acid (pH 6.0, 5.8 and 5.7 in water and pH 5.3, 5.3 and 5.2 in CaCl₂ respectively across depths 0-5 Cm, 5-15Cm and 15-30 Cm), but the less acid conditions of 0-5 and 5-15 Cm depths suggest improved soil conditions for sustainable crop production. Also, organic carbon content of the soil was very low, though slightly improved at the 0-5 Cm (5.3 gkg⁻¹) than the initial (2.3gkg⁻¹). Total nitrogen was low and did not show any appreciable change with even with planted one year *Desmodium uncinatum* short fallow practice. These findings suggest that the soils are inherently poor in fertility status and would require remediation to support sustainable agricultural production venture.

Tillage practices, *D. uncinatum* management, and fertilizer N and P integrated trial on the soil reveal that soil acidity (CaCl₂) was significantly (P<0.05) less under split old ridges (SDOR) with *Desmodium uncinatum* live mulch (pH4.8), followed by pH 4.75 under Conservation tillage (SDIC), pH 4.78 under No till with *Desmodium uncinatum* (SDNT) live mulch Conventional tillage (SC) had the highest acidity value of pH 4.69. Also, organic carbon values generally increased, but No Till practice (SDNT) sequestered significantly (P<0.05) higher value (6.9gkg⁻¹), followed by SDIC (5.8 gkg⁻¹), SDOR (4.9 gkg⁻¹) and conventional tillage (SC) (3.6gkg⁻¹). This implies that Conventional Tillage practice (SC) resulted in the least soil carbon credit that could hasten soil degradation for sustainable agricultural production and increase greenhouse gas emission to impact adversely on global warming. Available phosphorus values under the tillage practices increased with No Till (10.19 mgkg⁻¹), followed by Conservation tillage (9.48 mgkg⁻¹), SDOR (8.14 mgkg⁻¹) and least with Conventional Tillage (8.21mgkg⁻¹). Total nitrogen contents improved under SDIC (0.17gkg⁻¹), followed by SDOR (0.16gkg⁻¹), SC (0.15gkg⁻¹) and SDNT (0.13gkg⁻¹), suggesting that incorporation and relayed *D. uncinatum* under conservation tillage practice significantly improved total nitrogen content of the soils compared to the other tillage practices.

Combined 50kgNha⁻¹ with 13.2kgPha⁻¹ best enhanced optimal soil acidity conditions, soil carbon sequestration, available phosphorus and total nitrogen for sustainable sorghum productivity in the Savanna Alfisols of Nigeria. Also, conservation tillage with incorporated and relayed *D. Uncinatum* treatment (SDIC) resulted in significantly (P<0.05) higher (1.48tha⁻¹) sorghum yield, followed by No-Till (SDNT) with *D. uncinatum* live mulch (1.32tha⁻¹), Split old ridges (1.20tha⁻¹) with *D. uncinatum* live mulch (SDOR) and least sorghum grain yield was received under Conventional (SC) tillage (1.17tha⁻¹).

In conclusion therefore, Conservation tillage practice resulted in high sorghum grain yield (1.48 tha⁻¹), attributed to improved soil quality conditions (namely; optimum soil pH, available phosphorus, soil carbon and total nitrogen) that prevailed to support high sorghum grain yield and soil quality under SDIC was therefore rated SQ₁ to be superior over SDNT as SQ₂, SDOR as SQ₃ and SC as SQ₄.

ACKNOWLEDGEMENT

The authors are immensely grateful to Bill and Melinda Gates foundation, International Institute of Tropical Agriculture (IITA, Ibadan Nigeria) and International Centre of Insect Physiology and Ecology (ICIPE) Kenya, for sponsoring this study and the Institute for

Agricultural Research (IAR), Ahmadu Bello University (ABU), Zaria, Nigeria for logistic support towards facilitating this publication.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Doran JW, Sarrantonio M, Liebig M. Soil health and sustainability. In Sparks, D. L (eds) *Advances in Agronomy*, Vol. 56. Academic Press. San Diego. 1996;1-54.
2. Doran JW, Safley M. Defining and Assessing soil health and sustainable productivity. In: Pankhurst C. et al. (eds.). *Biological indicators of soil health*. Wallingford, UK. CAB International. 1997;1-28.
3. Karlen DI, Varvel GF, Johnson JMF, Baker JM, Osborne SI, Novak JM. Monitoring soil quality to assess the sustainability of harvesting corn stover. *Agron. J.* 2011;103:288-295. DOI:10.2134/agronj2010.060s.
4. Lal R, Stewart B. (eds.) In: "Soil Management: Experimental Basis for Sustainability and environmental Quality". CRC Press. Boca Raton; 1995.
5. Larson WE, Pierce FJ. The dynamics of soil quality as a measure of sustainable management. In: Doran JW, Coleman DC, Bezdicek DF, Stewart BA (eds.). *Defining soil quality for a sustainable environment*. SSSA-special Publication 35. Soil Science Society of America, Madison, WI USA. 1994;37-51.
6. Khurshid KM, Iqbal MS, Arif, Nawaz A. Effect of tillage and mulch on soil physical properties and growth of maize. *Int. J. Agric. Biol.* 2006;8(5):593-596.
7. Den Biggelaar, Christoffel Lal, Rattan Wiebe, Keith Breneman Vince. The global impact of soil erosion in productivity 1: Absolute and relative erosion-induced yield losses. *Advances in Agronomy*. 2004;81:1-48.
8. Rashidi M, Keshavarzpour F. Effect of different tillage methods on grain yield and yield components of maize (*Zea mays L.*). *Int. J. Agric. Biol.* 2007;9:274-277.
9. Bationo AZ, Traore J, Kimetu M, Bagayoko J, Kihara V, Bado M, Lompo R, Tabo Koata S. *Cropping Systems in the Sudano-Sahelian Zone: Implications on Soil Fertility Management*; 2003. Available: <http://www.sygentafoundation.org/db/1/432.pdf>.
10. Derpsch R, Friedrich T. Development and Current Status of No-till Adoption in the World. *Proceedings on CD, 18th Triennial Conference of the International Soil Tillage Research Organization (ISTRO)* Izmir, Turkey; 2006. June 15-19 2009.
11. Duiker S, Myers JC. Steps towards a successful transition to No-till. *Coll. Agric. Sci. Agric. Res. Coop. Ext. Penn State University*. 2005;36.
12. Thiombiano L, Meshack M. *Scaling Up Conservation Agriculture in Africa: Strategies and Approaches*. FAO Subregional Office for Eastern Africa. Addis Ababa. 2009;32.
13. Bundy LG, Andraski TW, Ruark MD, Peterson AE. Long-term continuous corn and nitrogen fertilizer effects on productivity and soil properties. *Agronomy Journal*. 2011;103:1346-1351. DOI:10.2134/agronj2011.0094.
14. Jones MJ, Wild W. *Soils of the West African Savanna*. Technical Communications No. 55. Commonwealth Bureau of Soils. CAB Harpenden. 1975;240.
15. Lombin G. Soil and Climate constraints to crop production in the Nigerian savanna region. 15th Annual Conference of Soil Science Society of Nigeria. Kaduna, 21-24 September. 1987;33.
16. Odunze AC. Northern Guinea Savanna of Nigeria and Rainfall Properties for Erosion Control. *African Soils Soil African Journal*. 2003;33:73-81.

17. Odunze, Azubuike Chidowe, Jinshui Wu, Liu Shoulong, Zhu Hanhua, GeTida, Wang Yi and LuoQiao. Soil Quality Changes and Quality Status: A case study of the Subtropical China Region Ultisols. *British Journal of Environment and Climate Change*. Sciencedomain International. 2012ap;2(1):37-572012.
18. Balasubramania V, Nnadi LA. Crop residue management and soil conservation in savanna areas. In *FAO Soils Bulletin No. 43*, Rome. 1980;15.
19. Tarawali SA, Keatinge JDH, Powell JM, Hiernaux P, Lyasse O, Sanginga N. Integrated natural resource management in West African crop-livestock systems. In. *Sustainable crop-livestock production for improved livelihoods and natural resource management in West Africa* (Williams TO, Tarawali SA, Hiernaux P, Fernandez-Rivera S eds.). 2001;349-370.
20. Hobbs PR, Sayre K, Gupta R. The Role of Conservation Agriculture in Sustainable Agriculture. *Philosophical Transactions of Rural Sociology B*. 2008;363:543-555.
21. Biau A, Santiveri F, Lloveras J. Stover Management and Nitrogen Fertilization Effects on Corn Production. *Agronomy, Soils and Environmental Quality Journal*. 2013;105(5):1264-1270.
22. Standford S. Crop residue/livestock relations. Soil, crops and water management systems for rainfed agriculture in the Sudanno-Sahelian Zone. Pantercheru, India: International Crops Research Institute for the Semi-Arid Tropics; 1989.
23. Lal R. Role of mulching techniques in tropical soils and water management. *IITA Technical Bulletin 1*. Ibadan, Nigeria. 1975;38.
24. Lal R. World crop residues production and implications of its use as a biofuel. *Environ. Int*. 2005;31:575-584. DOI:10.1016/j.enviromt.2004.09.005.
25. Mubarak A, Rosenani A, Anuar A, Zauyah S. Decomposition and nutrient release of maize stover and groundnut haulm under tropical field conditions of Malaysia. *Commun. Soil Sci. Plant Anal*. 2002;33:609-622. DOI:10.1081/CSS-1200027676.
26. Soil Survey Staff, USDA Soil Taxonomy. *Soil Taxonomy. A basic system of soil classification for making and interpreting soil surveys*. Washington D.C. 1999;745.
27. Ogunwole JO, Babalola OA, Onyinlola EY, Raji BA. A Pedological Characterization of soils in the Samaru area of Nigeria. *Samaru Journal of Agricultural Research*. 2001;17:71-77.
28. Fao-Unesco Legend. *Soil Map of the World*. International Soil Reference and Information Centre. Reversed Legend. *World Soil Resource Report 60*. Rome. 1989;138.
29. Valette JA, Ibangi IJ. The detailed soil survey of the experimental farm of the Institute for Agricultural Research Farm, Samaru, Zaria, Nigeria. *Soil Survey Bull*. Ahmadu Bello University, Zaria, Nigeria; 1984.
30. Uyovbisere EO, Chude VO, Bationo A. Promising Nutrient Ratios in Fertilizer Formulations for Optimal Performance of maize in the Nigerian Savanna: The need for a Review of current Recommendation. *Nigerian Journal of Soil Resources*. 2000;1:29-34.
31. Nwaogu EN, Odunze AC, Nwauzor EC, Ebeniro CN, Ewuziem JE. Effect of short duration grain legume crop inclusion in a ginger-based system on soil quality, growth and yield responses of ginger (*Zingiber officinale rosc*) in south eastern Nigeria. *Academia Journal of Agricultural Research*. 2013;1(5):075-082.
32. Odunze AC. Use of meteorological data in Agriculture. Training Manual: Training of monitoring and evaluation staff handling weather data collection of Kaduna State Agricultural Development Project. Farming Systems Research Programme (FSRP), Institute for Agricultural Research (IAR), Ahmadu Bello University, Zaria. Special Publication No. 1. 3rd & 4th February. 2011;1-6.

33. Odunze Azubuike Chidowe, EBIRERI Onome Felicia, Ogunwole, Joshua Olalekan, TARFA, Bitrus Dawi, ECHE, Nkechi Mary. Effect of Tillage and Fertilizer on Soil Quality and Yield of Maize in an Alfisols of a Northern Guinea Savanna of Nigeria. *Journal of Agriculture and Biodiversity Research*. 2013;2(8):167-177.
34. Oluwasimire KO, Alabi SO. Ecological Impact of Changing Rainfall Pattern, Soil processes and Environmental Pollution in Nigerian Sudan and Northern Guinea Savanna Agro-ecological zones. *Nigerian Journal of Soil Research*. 2004;5:23-31.
35. Doran JW, Parkin TB. Defining and assessing soil quality. In: Doran JW, Coleman DC, Bezdicek DF, Stewart BA. (Eds.). *Defining soil quality for a sustainable environment*. Soil Science Society of America Special Publication. Soil Science Society of America, Madison, Wisconsin, 1994;35:3-21.
36. Doran JW, Parkin TB. Defining and Assessing Soil Quality. In Doran FW, Coleman DC, Bezdicek DF, Stewart BA. (eds). *Defining Soil Quality for a Sustainable Environment*. Soil Science Society of America special publication. Soil Science Society of America, Madison, Wisconsin. 1994;35:3-21.
37. Andrew SS, Carroll CR. Designing a soil quality assessment tool for sustainable agro-ecosystem. *Ecological Applications*. 2001;11:1573-1585.
38. Parr JF, Papendick RI, Hornick SB, Meyer RE. Soil quality: attributes and relationship to alternative and sustainable agriculture. *Am. J. Alternative Agric*. 1992;7:5-11.
39. Gee GW, Bauder JW. Particle-size Analysis. In *Methods of Soil Analysis: Physical and Mineralogical Methods* (Klute et al. eds.). Agronomy Number 9 Part 1. American Society of Agronomy, Soil Science Society of America Inc. Madison, Wisconsin. 1986;377-381.
40. Mc Lean EO. Soil pH and Lime Requirement. In: *Methods of Soil Analysis Part 2: Chemical and Microbiological Properties*. Second edition. (Page et al., eds.) Agronomy Number 9(Part 2). American Society of Agronomy, Soil Science Society of America, Madison, Wisconsin. 1982;199-223.
41. Nelson DW, Sommers LE. Total Carbon, organic carbon and organic matter. *Methods of Soil analysis. Part 2. Chemical and Microbiological Properties*. 2nd edition. In Page et al. (eds.) *Agronomy*. 9. American Society of Agronomy, Madison, Wisconsin, USA. 1982;539-580.
42. Olsen SR, Sommers LE. Phosphorus. *Methods of Soil analysis. Part 2. Chemical and Microbiological Properties*. 2nd edition. In Page et al. (eds.) *Agronomy*. 9. American Society of Agronomy, Madison, Wisconsin, USA. 1982;403-430.
43. Bremner JM, Mulvaney CS. Nitrogen-Total. In *Methods of Soil Analysis Part 2: Chemical and Microbiological Properties*. Second edition. (Page et al eds.) *Agronomy Number 9(Part 2)*. American Society of Agronomy, Soil Science Society of America, Madison, Wisconsin. 1982;595-622.
44. Rhoades JD. Cation Exchange Capacity. *Methods of Soil analysis. Part 2. Chemical and Microbiological Properties*. 2nd edition. In Page et al. (eds.) *Agronomy*. 9. American Society of Agronomy, Madison, Wisconsin, USA. 1987;1490-1589.
45. Marschner H. *Mineral Nutrition of Higher Plants*. Second edition. Academic Press. 1989;889.

© 2014 Chidowe et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/3.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Peer-review history:

The peer review history for this paper can be accessed here:

<http://www.sciencedomain.org/review-history.php?iid=610&id=24&aid=5589>