

## Tillage Effects on Soil Quality of an Alfisol in South western Nigeria

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### Abstract

Crop and soil management decisions may produce either detrimental or beneficial effects on soil quality. Experiments were conducted between 2001 and 2004 with the aim of quantifying the effects of tillage on soil quality. An hectare of land at the I A R & T, Moor Plantation, Ibadan, in south western Nigeria, that had been left to bush regrowth for about 35 years, was opened up for the study. The experiment was sited on an Alfisol (Iwo series). Two contrasting tillage (minimum-till and plough-till) systems were imposed. The treatments, in four replicates, were laid out in a randomized complete block design, with maize (*Zea mays* L. var. suwan-1-YR) planted as a test crop. Data on soil quality indicators and grain yields were taken during the period of four years of cropping. Soil quality was assessed using Soil Management Assessment Framework (SMAF). The results showed that the ratings of soil quality increased from 70.2% in year 1 to 73.5% in year 2 under minimum-till system. Thereafter, the quality decreased from year 2 to 63.8% in year 4. However, soil quality ratings of plough-till reduced from 65.1% in year 1 to 51.9% in year 4. The overall quality changes over the period of four years were -3.0% in minimum-till and -6.7% in plough-till plots. The negative changes in soil quality imply that there was soil quality degradation under the two tillage systems which were also reflected in the grain yields obtained for the period. The beneficial effect of plough-till plots in producing the highest grain yield in year 1 was curtailed as a result of soil compaction and structural degradation in year 2 and thereafter. Although there were no significant differences in most of the soil quality indicators between the two tillage systems the negative impact of tillage was more pronounced under plough-till than minimum-till system.

**Key words:** Soil quality, Indicators, Tillage systems, Alfisol, Structural degradation.

### INTRODUCTION

Soil quality emphasizes the integration of physical, chemical and biological soil properties for the purpose of sustainable agricultural management. The concept has captured the attention of farmers and researchers as soil degradation from intensive cultivation, mechanization, drastic

reduction of fallow period, limited crop rotation and lack of organic matter additions have reduced crop yield potential (Karlen and Scott, 1994). This is either because of lack of understanding of the negative effects of these management practices or the lack of better alternatives. Hence, it is

becoming difficult to leave behind for future generations, crop and soil management practices to maintain or improve the soils ability to perform its essential functions.

In agricultural systems, soil and crop management decisions (crop rotation, residue management, the intensity and frequency of tillage) produce long-term effects on soil quality. These effects may be detrimental or beneficial. For instance, tillage can degrade soil quality by mechanically destroying soil aggregates and exposing protected soil organic matter to microbial attack (Follet and Schimel, 1989). However, tillage also increases residue mixing with the soil, aiding decomposition of both crop residues and native soil organic matter, thereby enhancing mineralization and release of nutrients (Gadja *et al.*, 2001). Investigators have reported that greater bulk density can be expected in some soil types with no-till vis-à-vis plough-till practices (Bruce *et al.*, 1990). Also, Bowman *et al.* (1999) found a 20% increase in soil organic carbon (SOC) contents in the surface soils of continuously cropped no - till managed dry land systems, which previously were managed under conventional-till wheat - fallow. These conflicting results of individual soil attributes often further complicate the assessment

of management effects on soil quality. Larson and Pierce (1991) suggested that dynamic assessments were needed to determine temporal variations in attributes and identify trends in management effects. Combining a variety of selected soil attributes can partially resolve conflicting results and assist in assessing management effects. Therefore, this study was aimed at quantifying changes in soil quality by tillage and cropping systems over time, and to evaluate changes in crop yield in response to minimum-till and plough-till systems.

## MATERIALS AND METHODS

### Study Site

This study was carried out at the Institute of Agricultural Research and Training (I.A.R.&T.), Moor Plantation, Ibadan, Nigeria in the fringe of dry rain forest region of south western Nigeria. The study site is located on latitude  $7^{\circ}22'N$  to  $7^{\circ}23'N$  and longitude  $3^{\circ}50'E$  to  $3^{\circ}51'E$ . Ibadan has a tropical humid climate characterized by high humidity. The I. A. R & T. has a mean annual rainfall of 1414.85 mm, temperature of about  $27.9^{\circ}C$  and humidity ranging from 73 to 87%, 38 to 74% and 83 to 95% at 09 hrs, 15 hrs and 21 hrs, respectively.

The study area is underlined by Precambrian Basement Complex rock consisting basically of upper

older granites, gneisses and quartzite schist. The soil was mapped as Iwo series (fine, kaolinitic, hyperthermic, Kanhaplustalf) with a sandy clay texture.

#### **Field Work**

A hectare of land that had been left to bush regrowth for about 35 years was opened up for the study. Two contrasting tillage systems (plough-till and minimum-till) were employed for this study. The soil was cropped to sole maize (*Zea mays* L. var. SUWAN-1) for four years, with the two tillage systems arranged in a randomized block of eight plots (1,250 m<sup>2</sup> each). Plough-till method involved the use of disc plough mounted on the tractor. Ploughing was however done twice (at 0.20 m) with no harrowing. Minimum-till involved the use of hoe and cutlass for the land preparation.

#### **Sampling Procedure**

Thirty (30) random samples were taken prior to tillage operation for the base line properties of the soil. The subsequent sampling was carried out at the end of cropping seasons for 4 years in each replicated plots. Sampling was carried out using ten quadrants (25 m<sup>2</sup>) located in a grid pattern across individual field. Soil samples were taken at 0-0.20 m depth using stainless steel auger and cylindrical core (5.0 cm height and diameter). Five auger samples were then taken

in a grid pattern within each quadrant into 10 liter plastic buckets, representing a sampling point and mixed thoroughly. Soil samples for microbial analysis were taken in-situ. Physical, chemical and biological analyses were carried out on the soil samples to quantify soil quality indicators. Maize cobs and weed samples were also obtained with the same grid pattern as soil samples on each tillage system for weed and yield analysis. Weed sampling was done before cropping and at the end of the fourth year from each tillage system. Weeds were counted, identified by species and percentage occurrence of weed species was calculated.

#### **Soil quality assessment and indicator selection**

The soil quality was assessed yearly using a tool called soil management assessment framework (SMAF). The tool was designed to measure the effect of management on soil quality based on selected indicators. The SMAF follows three basic steps: indicator selection, indicator interpretation and integration into quality index value. The soil quality was assessed yearly using a tool called soil management (Andrews, 1998). The criteria for indicator selection given by Idowu *et al.* (2006) were adopted. These include sensitivity to management, functional relevance, consistency and

reproducibility, ease and cost sampling, cost of laboratory analysis and opportunity to be estimated by regression method.

Based on these criteria, physical, chemical and biological indicators were selected for the study. These were textural classes, aggregate stability, bulk density, compaction ratio, total porosity and available water holding capacity, pH, organic carbon, total nitrogen, available phosphorus, base Saturation, ECEC, and microbial biomass and weed pressure/seed bank, respectively.

Particle size distribution was carried out using the hydrometer method as described by Gee and Or (2002). Water stable aggregates were determined following Kemper and Rosenau's procedure, as described by Nimmo and Perkins (2002). Bulk density was determined using the method described by Grossman and Reinsch (2002). The increment ratio of bulk density ( $\Gamma_n$ ), as described by Fujii (1992), was used as a compaction criterion, and this is defined as:

$$\Gamma_n = (\rho_n - \rho_0) / \rho_0 \equiv (\rho_n / \rho_0) - 1 \dots (1)$$

Where  $\rho_0$  is the initial density as the bush regrowth was open up for the first year, while  $\rho_n$  is the density after the nth (one to four) years of tillage.

Total porosity (TP) was calculated using the equation and relationship developed by

Danielson and Sutherland (1986) as:

$$TP = 1 - \rho_b / \rho_s \dots \dots \dots (2)$$

Where  $\rho_s$  is the particle density with a constant value of 2.65 Mgm<sup>-3</sup>. Available water capacity (AWC) was determined using the equation:

$$AWC = \partial v_{FC} - \partial v_{PWP} \dots \dots \dots$$

Where  $\partial v_{FC}$  is the volumetric moisture content at field capacity (cm<sup>3</sup>cm<sup>-3</sup>) and  $\partial v_{PWP}$  is the volumetric moisture content at permanent wilting point.

Soil reaction (pH) was determined in a soil: solution of 1:2 in CaCl<sub>2</sub> using a glass electrode pH meter (Thomas, 1996). Organic carbon (OC) was determined using the chromic acid digestion procedure of Walkley and Black (1934). Total nitrogen (N) was determined by dry combustion using Leco CHN Analyser (Bremner, 1965). Available phosphorus (P) was determined using bicarbonate extraction, with acid reductant (Bray and Kurtz 1945). Microbial biomass was determined using the ninhydrin-reactive nitrogen assay (Doran, 1987).

The different processes relating to crop production function were also identified and soil quality indicators relating to each process were selected. The processes identified with their appropriate indicators were as follows:-

- i. Nutrient availability - total nitrogen,

- ii. pH, available P, exchangeable K.
- iii. Nutrient retention - Organic matter, ECEC<sub>clay</sub>, base saturation
- iv. Root penetration - bulk density, porosity, compaction ratio
- v. Resist degradation-aggregate stability, texture.
- vi. Biotic environment-microbial biomass
- vii. Noxious weed infestation-species.

#### **Indicator Interpretation and integration into soil quality index value**

This involved the transformation of observed indicator using non-linear scoring curves (Andrews *et al.*, 2002a; 2002b; 2004) and Standard Scoring Functions (SSF) (Wymore, 1993). The measured values of indicators were transformed into unit less values (0 to 1) based on the critical values of the indicators (Lal, 1994; Adeoye and Agboola, 1986) for easy combination into single value. Relative weights were assigned to the indicators and the identified processes according to their levels of importance to crop production function as shown in Table 1.

The soil quality indicators and their processes were integrated into quality index value. All indicators affecting a particular process were grouped together, given scores and relative weights

based on importance. The score for each indicator was multiplied by the appropriate weight and summed to provide soil quality rating for each process. The soil quality (s.q.) rating of each process was also multiplied by the appropriate weight, producing a matrix that was summed to provide soil quality index for crop production as follows:-

$$Q = qt.nav \times wt + qt.nr \times wt + qt.rp \times wt + qt.rd \times wt + qt.be \times wt \dots (4)$$

Where

Q = Over all soil quality (s.q) index for crop production

qt.nav = s.q rating for nutrient availability process

qt.nr = s.q rating for nutrient retention process

qt.rp = s.q rating for root penetration

qt.rd = s.q rating for resisting degradation

qt.be = s.q rating for biotic environment

wt = relative weight

The percentage changes in soil quality over the years ( $dQ/dt$ ) were calculated using the equation (5).

The relationship between the plough-till and minimum-till methods on soil quality was evaluated and treatment effects were fitted into general linear model and means separated by one way analysis of variance (SAS, 2002)

$$dQ/dt = f \left[ \frac{q_{it} - q_{ito}}{dt} \dots \dots \dots \frac{q_{nt} - q_{ito}}{q_{ito}} \right] \dots (5)$$

Where  $q_{it}$  = quality index of the year under measurement  
 $q_{ito}$  = initial quality index when the field was opened up.  
 $q_{nt}$  = quality index of the nth year  
 $dt$  = change in time (years)

**Table 1: Soil processes and quality indicators relating to crop productivity and their relative weights**

Soil processes relating to crop productivity	Relative Weight	Soil quality indicators	Relative Weight
Nutrient availability	0.10	Total Nitrogen (T.N.)	0.25
		pH	0.25
		Avail. Phosphorus (P.)K	0.25
			0.25
Nutrient retention	0.30	Organic matter	0.35
		CEC clay	0.35
		Base Saturation (B.S.)	0.30
Root penetration	0.20	Bulk density (B. D.)	0.50
		Total Porosity (T. P.)	0.20
		Compaction ratio (Tn)	0.30
Ability to resist degradation	0.30	Wet stable aggregates	0.80
		Texture	0.20
Biotic environment	0.10	Microbial biomass (M.B.)	0.10

Source: Doran et al. (1994)

**RESULTS**

**Initial soil properties**

The soil of the experimental site had a sandy loam texture with pH (CaCl<sub>2</sub>) value of 6.4. The mean bulk density at the surface (0-15 cm depth) was 1.43 Mgm<sup>-3</sup> and thus, soil porosity was 46.1%. The concentration of water stable aggregates (WSA > 0.25mm) and available

water capacity (AWC) at 0-0.20 m depth were 0.758 KgKg<sup>-1</sup> and 0.376 cm<sup>3</sup>cm<sup>-3</sup> respectively. Microbial biomass was 2800 Kggha<sup>-1</sup> while Cation Exchange Capacity (CEC) was 3.28 cmolkg<sup>-1</sup>. Other chemical properties include OC (9.22 gkg<sup>-1</sup>), total N (0.87 gkg<sup>-1</sup>), available P (10.94 mgkg<sup>-1</sup>) and exchangeable bases made up of calcium (Ca),

magnesium (Mg), potassium (K) and sodium (Na) were 0.89, 1.57, 0.24 and 0.49  $\text{cmolkg}^{-1}$ , respectively.

#### **Effects of tillage systems on soil properties and weed species**

Tables 2-5 show properties (quality indicators) of the soil, amenable to changes by the imposed two tillage systems, over the four growing seasons. After year-1 growing season, tillage methods influenced significantly ( $\alpha \leq 0.05$ ) the percentage base saturation (%BS), available P, WSA, AWC, microbial biomass, bulk density and expectedly, compaction ratio ( $\Gamma_n$ ) and porosity (Table 2). After the second growing season (year 2), it was WSA, AWC and microbial biomass that were significantly affected by the tillage operations imposed (Table 3).

However, in the third year growing season, total N, bulk density, compaction ratio, porosity, WSA and microbial biomass were significantly different (Table 4). The significant variations in the soil properties in the fourth growing season (Table 5) followed trends similar to those of the third year except total N that was not influenced significantly by the tillage methods. Weeds encountered at the onset of the trial on the 35 year fallow land belonged to ten species, grouped into eight families

(Table 6). *Ipomoea involucrate* (Morning glory) and *Aspilia Africana* were the dominant species making up 28.7 and 27.1% of the total weed population, respectively. After four years of continuous maize cultivation under the two tillage methods, there was a significant reduction in the number of weed species (Table 7). *Pennisetum purpureum*, a grass weed, emerged on the plots where minimum-till was imposed.

#### **Effects of tillage systems on soil quality and maize grain yields**

The percentage ratings of soil quality under minimum and plough-till methods after four years of cultivation are presented in Figure 1. Under minimum-till, soil quality ratings ranged from 63.8% in year 4 to 73.5% in year 2. However, under plough-till, the quality ratings of the soil ranged from 51.9% in year 4 to 65.1% in year 1. Percentage changes in soil quality over these years under the two-tillage methods were shown in Fig. 2. There were contrasting changes in the soil quality values under minimum-till system, where a positive change of 4.7% was recorded from year 1 to year 2. Even then, the changes from year 0 to 1, 2 to 3 and 3 to 4 experienced negative changes of -5.0, -10.3 and -3.2%, respectively. On the other hand, there were negative changes throughout the four year period under plough-till (Fig. 2) with year

**Table 2: Mean values of soil quality indicators after year one growing season, as influenced by tillage systems**

Tillage method	pH 1:1 (H <sub>2</sub> O)	Texture (gkg <sup>-1</sup> )			Exchangeable bases (cmolkg <sup>-1</sup> )				CEC cmolkg <sup>-1</sup>	B.S. %	Org. C gkg <sup>-1</sup>	N. gkg <sup>-1</sup>	P gkg <sup>-1</sup>	B. D Mgm <sup>-3</sup>	Γ <sub>n</sub> %	WSA Kgkg <sup>-1</sup>	AWC cm <sup>3</sup> cm <sup>-3</sup>	T. P %	M. B. Kgha <sup>-1</sup>
		Sand	Silt	Clay	Ca	Mg	K	Na											
Minimum-till	6.7	733	222	45	1.1	1.9	0.2	0.5	3.8	97.9	9.9	1.0	11.0	1.5	7.0	0.8	0.3	42.3	29.5
Plough-till	6.3	720	231	49	1.0	1.5	0.3	0.5	3.4	97.1	10.9	0.9	17.9	1.5	2.8	0.7	0.2	44.5	19.5
LSD <sub>(0.05)</sub>	0.5	66.7	55.2	52.4	0.2	0.7	0.2	0.02	0.5	0.8*	4.3	0.3	3.6*	0.1*	4.1*	0.1*	0.9*	2.1*	389.4*

\* indicates significant difference at 5% probability level

**Table 3: Mean values of soil quality indicators after year two growing season, as influenced by tillage systems**

Tillage method	pH 1:1 (H <sub>2</sub> O)	Texture (gkg <sup>-1</sup> )			Exchangeable bases (cmolkg <sup>-1</sup> )				CEC molkg <sup>-1</sup>	B. S. %	Org. C gkg <sup>-1</sup>	N. gkg <sup>-1</sup>	P gkg <sup>-1</sup>	B.D. Mgm <sup>-3</sup>	Γ <sub>n</sub> %	WSA Kgkg <sup>-1</sup>	AWC cm <sup>3</sup> cm <sup>-3</sup>	T. P %	M. B. Kgha <sup>-1</sup>
		Sand	Silt	Clay	Ca	Mg	K	Na											
Minimum-till	7.2	753	222	32	1.1	1.9	0.4	0.5	3.9	98.6	15.3	1.5	9.0	1.6	8.4	0.8	0.3	41.5	2588
Plough-till	7.3	740	215	38	1.1	1.5	0.5	0.5	3.6	98.8	10.7	1.2	10.1	1.6	11.9	0.7	0.2	39.6	1313
LSD <sub>(0.05)</sub>	0.7	86.8	92.6	16.7	0.1	0.7	0.3	0.1	0.8	0.9	7.1	0.6	2.6	0.1	9.2	0.1*	0.1*	4.9	453.4*

\* indicates significant difference at 5% probability level

**Table 4: Mean values of soil quality indicators after year three growing season, as influenced by tillage systems**

Tillage method	pH 1:1 (H <sub>2</sub> O)	Texture (gkg <sup>-1</sup> )			Exchangeable bases (cmolKg <sup>-1</sup> )				CEC cmolkg <sup>-1</sup>	B.S %	Org. C gkg <sup>-1</sup>	N gkg <sup>-1</sup>	P gkg <sup>-1</sup>	B.D. Mgm <sup>-3</sup>	Γ <sub>n</sub> %	WSA Kgkg <sup>-1</sup>	AWC cm <sup>3</sup> cm <sup>-3</sup>	T.P %	M.B Kggha <sup>-1</sup>
		Sand	Silt	Clay	Ca	Mg	K	Na											
Minimum-till	6.7	760	215	25	0.9	1.2	0.4	0.5	3.1	98.0	13.6	1.3	18.1	1.6	9.1	0.7	0.3	41.1	1762
Plough-till	6.6	733	222	45	0.9	1.1	0.5	0.5	3.1	96.1	10.1	1.0	16.6	1.7	17.5	0.5	0.2	36.6	938
LSD(0.05)	0.2	52.4	37.0	26.2	0.5	1.6	0.1	0.1	1.7	2.6	4.6	0.3*	3.0	0.1*	4.9*	0.2*	0.5	2.6*	119.2*

\* indicates significant difference at 5% probability level

**Table 5: Mean values of soil quality indicators after year four growing season, as influenced by tillage systems**

Tillage method	pH (H <sub>2</sub> O)	Texture (gkg <sup>-1</sup> )			Exchangeable bases (cmolkg <sup>-1</sup> )				CEC cmolkg <sup>-1</sup>	B.S %	Org. C gkg <sup>-1</sup>	N gkg <sup>-1</sup>	P gkg <sup>-1</sup>	B.D. Mgm <sup>-3</sup>	Γ <sub>n</sub> %	WSA Kgkg <sup>-1</sup>	AWC cm <sup>3</sup> cm <sup>-3</sup>	T.P %	M.B (Kggha <sup>-1</sup> )
		Sand	Silt	Clay	Ca	Mg	K	Na											
Minimum-till	6.2	740	215	45	0.9	1.1	0.5	0.5	3.2	92.7	12.4	1.2	15.2	1.6	9.1	0.7	0.3	41.1	900
Plough-till	6.2	740	215	45	1.0	1.1	0.4	0.5	3.1	92.9	9.5	1.0	15.9	1.7	17.5	0.5	0.2	36.6	750
LSD(0.05)	0.7	71.7	69.3	52.4	0.4	0.5	0.1	0.1	0.4	7.9	6.1	0.6	5.9	0.1*	3.6*	0.1*	0.8	2.0*	101.4*

\* indicates significant difference at 5% probability level

**Table 6: Initial weed population encountered on experimental field in 2001**

Weed species	Family	Morphological group*	% Occurrence
<i>Ipomoea involucrate</i> P. Beav.	Convolvulaceae	B	28.7
<i>Aspili Africana</i> (Pers.) C. D. Adams	Asteraceae	B	27.1
<i>Commelina benghalensis</i> L.	Commelinaceae	-	14.4
<i>Centrosema pubescens</i> Benth.	Papilionaceae	B	10.6
<i>Gomphrena celosioides</i> Mart.	Amaranthaceae	B	6.5
<i>Ipomoea triloba</i> Linn.	Convolvulaceae	B	5.6
<i>Chromolaena odorata</i> (L.) R.M. King & Robinson	Asteraceae	B	5.2
<i>Sida rhombifolia</i> L.	Malvaceae	B	1.3
<i>Talinum triangulare</i> (Jacq.) Willd	Portulacaceae	B	0.4
<i>Euphorbia hirta</i> Linn.	Euphorbiaceae	B	0.2

\*B broadleaf

**Table 7: Weed species after 4 years continuous maize cropping**

Weed species	Morphological group*	Minimum-till	Plough-till
		% occurrence	
<i>Ipomoea involucrate</i>	B	53.9	81.0
<i>Pennisetum purpureum</i> Schumach	G	33.0	-
<i>Centrosema pubescens</i>	B	4.5	2.0
<i>Commelina benghalensis</i>	-	4.8	-
<i>Commelina erecta</i> L	-	1.8	5.4
<i>Euphorbia hirta</i>	B	1.4	-
<i>Ageratum conyzoides</i> Linn.	B	-	2.5
<i>Tridax procumbens</i> Linn	B	0.6	-
<i>Phyllanthus amarus</i> Schum. et Thonn.	B		1.7
<i>Calapogonium mucunoides</i> L	B		2.1
<i>Synedrella nodiflora</i> Gaertn.	B	-	5.3

\*B – broadleaf G – grass

0 to 1 being the worst. Maize grain yields obtained from the plots under the two-tillage methods are shown in Fig. 3. Under plough-till system, grain yield decreased from year 1 to year 4 with mean yield value of 2.60 Mgha<sup>-1</sup> in year 1 and 1.40 Mgha<sup>-1</sup> in year 4. Conversely, under minimum-till system, grain yield followed trends similar to the quality ratings of the soil, as there was an increase in the yield from 2.30 Mgha<sup>-1</sup> in year 1 to 2.70 Mgha<sup>-1</sup> in year 2. Thereafter, the grain yield reduced from year 2 to year 4 with mean a value of 1.80 Mgha<sup>-1</sup>

## DISCUSSION

### Soil quality

The percentage changes in soil quality were greatly influenced by the tillage systems. However, under minimum-till system, soil quality in year 1 was significantly lower than in year 2 despite the fact that the land was newly opened up (Fig. 1). Therefore soil quality improved from year 1 to 2 and thereafter decreased from year 2 to 4.

Although there was no significant difference between soil quality ratings in years 1 and 2 under plough-till system, soil quality changes did not show trends similar to those of minimum-till.

Plough-till resulted in degradation of soil quality from year 1 to 4.

The increase in soil quality rating from year 1 to year 2 under minimum-till system may not be unconnected with the fact that most mineral nutrients and soil organic matter were still occluded in year 1 but perhaps released in year 2. The degradation of soil quality after year 2 under minimum-till and after year 1 under plough-till systems might be due to continuous soil disturbance and exposure of the soil to climatic elements and micro-organisms. The mineralization of soil organic matter over time is known to lead concomitantly to soil structural breakdown (Pagliai *et al.*, 1998). The mineralized nutrients are partly consumed by the crops and weeds and partly leached.

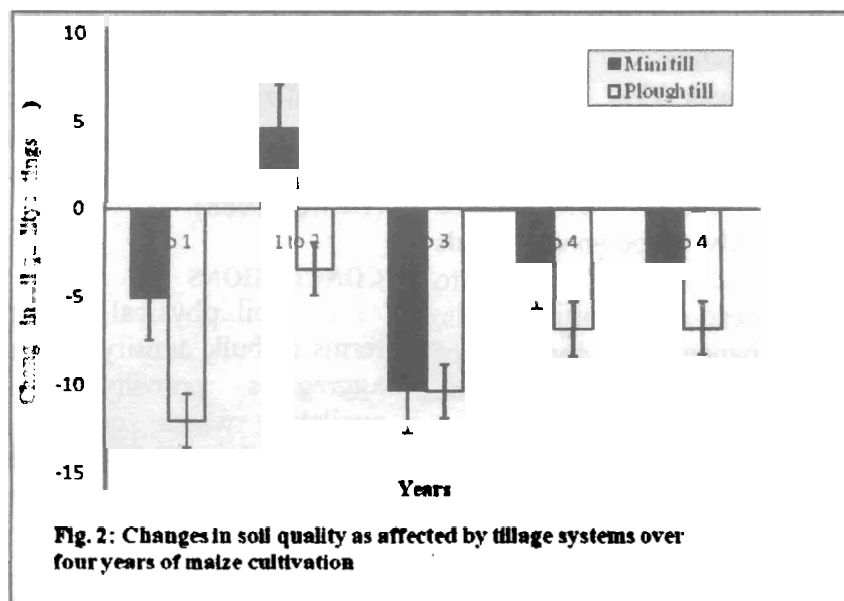
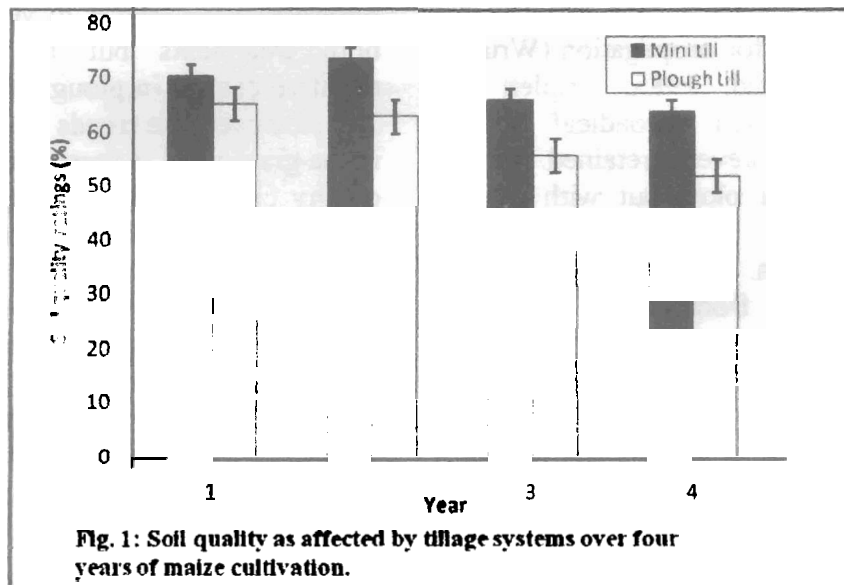
Soil organic matter has been identified as a key ingredient of soil quality (Harris and Bezdicsek, 1994; Chen, 1999). The soil organic carbon as affected by the tillage systems used in this study influenced all the other soil quality indicators. Many studies have linked loss of organic matter in the top soil to tillage. Tillage, especially the plough till system, decreased soil organic matter by exposing inaccessible organic matter to microbial decomposition. The consequence is the reduction in CEC, total N, available P, aggregate stability, aggregate mean weight diameter (MWD), pore

continuity water holding capacity and infiltration rate (Dexter, 1988; Beare *et al.*, 1994; Arshad *et al.*, 1990; Carter, 1992; Pagliai and Vittori, 1993).

The results indicated that soil quality was reduced when Alfisol (Iwo series) was subjected to conventional plough till. This was reflected in the significant lower concentration of water stable aggregates after year 1. Pagliai *et al.* (1998) submitted that much of the environmental damage caused by erosion, desertification and crusting originated from soil structural degradation. The rate of soil disturbance was higher under plough-till, and thus affected soil properties adversely. Bowman *et al.* (1999) recorded about 20% increase in the soil organic carbon content in the surface soils continuously cropped under minimum-till system which previously had been under conventional tillage. Cropping systems with reduced tillage operation (minimum-till) were also found to possess more soil microbial biomass than plough-till (Doran, 1980).

#### **Tillage systems and weeds**

The type of tillage treatments directly affected weed species and composition. This was also reported by Egley and Williams (1990). Minimum tillage promoted grass species and perennial weed species (Table 7) because less soil



disturbance favoured plants that rely on underground reproductive structures for propagation (Wruckle and Arnold, 1985; Triplett and Lytle, 1972). Broadleaf species were, however, retained in the plough-till plots but with a wide variation from the initial population. *Ipomoea involucrate* increased from 28.7% to 81.0% while five new weed species emerged in the plough-till treatment. Soil disturbance promoted the germination of many weed seeds (Robert, 1981; Cavers and Benoit, 1989) as a result of exposure to climatic elements and improved soil aeration (Egley, 1986). On the other hand, *Ipomoea involucrate* weed increased to 53.9% while *Pennisetum purpureum* was 33% of the total weed population on minimum-till plots. Here, annual weed spectrum that was initially encountered shifted rapidly to perennial weeds under minimum-till. In order to curb the spread of perennial weeds, soil disturbance with the use of conventional tillage may be employed.

#### Soil quality and crop yield

Changes in soil quality associated with tillage systems were reflected in the yield of maize over the years. Percentage change in soil quality and maize grain yields over four growing years as influenced by the two tillage systems are shown in Figs. 2 and 3,

respectively. The soil quality improved from year 1 to year 2 in both treatments but it was a negative change in plough-till (Fig. 2). However, the trends of change in the grain yield in response to soil quality change were not similar in both treatments. The positive increase in the soil quality under minimum-till in year 2 led to a change in maize grain yield from 2.3 Mgha<sup>-1</sup> in year 1 to 2.7 Mgha<sup>-1</sup> in year 2. Under plough-till the grain yield decreased from 2.6 Mgha<sup>-1</sup> in year 1 to 2.2 Mgha<sup>-1</sup> in year 2.

The higher grain yield obtained under plough-till vis-à-vis minimum-till in year 1 showed that plough-till system might have aided quick decomposition and mineralization of soil organic matter thereby making nutrients available for crop plant uptake (Dexter, 1988).

#### CONCLUSIONS

Soil physical properties in terms of bulk density, water stable aggregates, porosity and plant available water capacity were significantly affected by the two tillage systems over the years of study. In terms of chemical conditions of the soil, tillage system brought about a significant change in base saturation and available P in year 1; and total N in year 3. The beneficial effect of plough-till as enhanced release of

nutrients in year 1 for crop uptake was short lived as a result of soil compaction and structural breakdown in year 2 and thereafter. Although there were no significant differences between the two tillage systems on most of the soil quality indicators, the detrimental effects of tillage were more pronounced in plough-till than minimum-till plots. Soil organic matter maintenance through rotational cover cropping and reduced tillage system may be the panacea for sustaining crop production and soil quality.

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