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EFFECT OF TILLAGE AND MULCHING PRACTICES ON SOIL PROPERTIES AND GROWTH AND YIELD OF COWPEA (*VIGNA UNGUICULATA (L), WALP*) IN SOUTHEASTERN NIGERIA.

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ABSTRACT
This paper reports the field evaluation of the effect of tillage [tilled (MT) and untilled, (NT)], mulching material [Panicum maximum (p) and Chromolaena odorata (c)] and mulching method [incorporated (b), surface (s) and no mulch (o)] on soil properties and growth and yield of cowpea (Vigna unquiculata) in 2000 and 2001 cropping seasons, in Akwa Ibom State, Southeastern Nigeria. The study was a three-factor factorial in randomize complete block (RCB). The soil in 2000 and 2001 was strongly acidic. Organic C increased by about 83.6% at harvest in 2000 and declined by 16.4% in 2001. Available P declined by about 15.9% in 2000 and 59.6% in 2001. Base saturation increased by 9.6% in 2000 and decreased by 6.8% in 2001. Tillage and mulching practices improved water-stable aggregates >2mm by 16.6% in 2001. Bulk density was similar between MT and NT in 2000, but significantly lower ($P<0.05$) in MT ($1.27 g/cm^3$) than NT ($1.35 g/cm^3$) in 2001. Soil water content was similar in 2000 (mean = 7.74%) and 2001 (mean = 9.87%), but significantly lower in 2000 than 2001, whether MT or NT was used. Hydraulic conductivity (Ks) was almost similar among the tillage and mulching treatments, even as significantly higher values were obtained in tilled (mean = 10.37 cm/h) than untilled (mean = 7.87 cm/h) soil. Sorptivity and transmissivity were generally significantly lower in tilled than no-till soil, whether mulch was applied on the surface, incorporated or not. Equilibrium infiltration rate was significantly higher in no-till than tilled soil, and that Panicum maximum was significantly suited on tilled soil, while Chromolaena odorata was suited on no-till soil. It was also significantly higher in mulch-tilled soil than no-till soil. Cumulative infiltration was significantly higher in mulched no-till (mean = 77.7 cm) soil than mulched tilled (mean = 60.3 cm) soil, whether mulch was Panicum maximum or Chromolaena odorata. A similar trend was observed in the method of mulch application in no-till (mean = 78.3 cm) or tilled (mean = 70.4 cm) soil. Total root length was significantly greater in mulch-tilled plot (mean = 175.3 cm) than in no-till plot (mean = 144.3 cm). Cowpea yield was significantly greater in tilled (mean = 130.2 g/m^2) than no-till plot (mean = $16.0 g/m^2$), and in mulched plots in 2001 (mean = $152.8 g/m^2$) than in 2000 (mean = $77.0 g/m^2$). The study demonstrates that residue mulch, incorporated in tilled soil or applied on the soil surface of tilled and no-till soil could improve soil properties and increase cowpea growth and yields.

Keywords: Tillage, residue mulch, Cowpea, *Vigna unguiculata*

INTRODUCTION
Inappropriate land use and cultivation methods have resulted in severe soil erosion and degradation, and declining crop yields in southeastern Nigeria. The predominant farming system in this area is the traditional shifting cultivation, also known as land rotation, involving the cultivation of a parcel of land once, followed by fallowing with a land use factor (ratio of cropping period plus fallow period to cropping period) >5 (Okigbo, 1977). The system is characterized by low-input agroecosystem and low productivity. Lal (1986) stated that the principal reason for improving the traditional farming system is its low productivity. This is distinguished from classical shifting cultivation, involving the cultivation of a parcel of land for 2 to 3 years and with a land use factor >10 (Sanchez, 1976; Okigbo, 1977). Shifting cultivation and the associated natural system of fallow is a land management strategy for restoring and

maintaining soil quality, its agronomic productivity and environmental regulatory functions (Karlen *et al.,* 1997; Lal, 1993, 1997). Soil degradation or decline in soil quality (Lal 1993) is principally due to the shortening of the length of the natural fallow period and land use factor from >5 to <4 (Ogban *et al.,* 2005), and bare cultivation method, both of which enhance the losses of soil organic C and the colloidal fractions and their physico-chemical properties (Lal and Bruce, 1999; Woomer *et. al*., 1994). Decrease in fallow length or land use factor, annual fires or the slash-and-burn practice make the vegetation immature and the natural fallow unable to restore and maintain soil biodiversity and productivity (Areola, 1990).

Tillage systems and residue management practices are beneficial in Nigeria, where the bulk of the potential arable land, consisting of Alfisols, Ultisols and Oxisols, have low-activity clay and low inherent fertility, various nutrient imbalances, poor structural stability, low water-holding capacity and high susceptibility of the soils to erosion (Opara-Nadi, 1990; Agboola *et. al.,* 1997). These soil management practices are being used to improve the quality and productivity of the soils, maintain the diversity and stability of the ecosystem, and increase crop growth and yield (Opara-Nadi, 1990).

Tillage systems in Nigeria include ridge-tillage, mound-tillage and flat-tillage, which are labour-intensive. The ridge-tillage and mound-tillage techniques consist in heaping the surface soil for both root and non-root crops (commonly) grown. Flat-tillage is either zero-tilled or plough-tilled. These tillage systems are specifically used to enhance rainwater infiltration and control noxious weeds that damage the potential of the land and take up more than 50% of the time the farmers spend on the field. However, Nye and Greenland (1960) have reported that simple as these tillage systems are in the low-input agroecosystems, they are associated with a decline in soil organic matter, especially (Swindale, 1988) as little or no agricultural residues are returned to the soil.

Lal (1975) had questioned the usefulness and feasibility of ridges and mounds without mulch as a soil-protecting device, particularly for unstable soil of coarse texture. This is especially so because, despite the potential of crop/plant residues to increase the resistance of soil to erosion, improve nutrient retention and storage (Woomer and Ingram, 1990), increase the buffering capacity in low-activity clay soils (Lal, 1975; Swift and Sanchez, 1984), and increase their poor water-holding capacity (Lal, 1986), as well as being available and inexpensive (Agboola, 1978), residue mulching is not commonly practised in Nigeria. Also, although there is growing awareness about the benefits of inorganic fertilizers, their use is not common, because it is expensive and unavailable when needed. Consequently, the small-holder farmers mine their agricultural capital, i.e. the chemical fertility of their low, resilient, tropical soils.

Inspite of Lal's (1975) concerns, Lal (1990) recommended the minimum tillage practices (hoe-ridging, hoe-mounding and flat-tillage) for the root and tuber crops grown in the humid tropics and plant residues that could be managed as mulch. Ogban and Ekerette (2001) recommended the slash-and-mulch rather than the slash-and-burn residue management system, to protect the soil against erosion and loss of physical and chemical fertility.

Residue mulch is reported to reduce soil particle detachment and transport (Iwuafor *et al*., 1990; Opara-Nadi, 1993), improve organic matter content and soil fertility, soil water storage capacity, and infiltration rate (Mbagwu, 1991; Obatolu and Agboola, 1993; Opara-Nadi, 1993; Owaiye, 1993; Ogban *et al*., 2001) and increase crop growth and yield (Mbagwu, 1991; Owaiye, 1993; Ogban et al., 2001). Lal (1975) demonstrated that residue mulch on mounds or ridges improved infiltration characteristics, stability of aggregates, water storage capacity and crop yield on coarse-textured soils. Hulugalle *et al* (1985, 1987) observed that tillage reduced soil bulk density, but that soil infiltration increases only when tillage and mulch were combined.

This study evaluated the effect of tillage and mulching material and application methods on soil properties, growth and yield of cowpea on the soils of "acid sands" in Akwa Ibom State, southeastern Nigeria.

MATERIAL AND METHODS

Study Area

The study was conducted on the University of Uyo, Teaching and Research Farm, located at Uyo in Akwa Ibom State, southeastern Nigeria, between latitudes 4^{O} 30^{1} and 5^{O}N, and longitudes 7^{O} and 7^{O} 30^{1} E. The area is located in a typical tropical humid climate, characterized by distinct wet and dry seasons. The wet season begins in April and continues through October. The rainfall regime is characterized by heavy storms of limited duration, which contribute to the erosion hazard on uncovered soils. The maximum rainfall occurs during the months of July and September, with a slight decrease in the month of August. The dry season last from November to March and is influenced by the hot northeasterly winds, blowing from the Sahara desert. Some climate data for the area are given in Table 1.

Table 1: Weather data in the study area, 1999 – 2002

Year	Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total mean
1999	Rainfall (mm)	60.4	8.5	510.2	412.0	177.2	154.9	211.1	327.0	468.6	443.9	95.1	-	2456.8
	Temp ^{O}C	29.2	29.1	29.8	30.0	29.6	29.1	27.7	28.1	27.8	27.9	28.0	29.2	28.8
	RH%	76	84	-	-	-	82	83	87	87	83	82	79	82
2000	R/fall	31.5	0	106.5	125.3	320.4	146.2	252.0	262.7	281.0	172.6	95.1	45.6	1844.9
	Temp ^{O}C	29.5	31.7	32.1	30.0	29.6	28.7	27.8	26.9	27.0	28.2	29.0	29.4	29.2
	RH %	79	60	69	79	80	84	85	87	87	84	85	76	79
2001	R/fall	0	8.6	229.9	219.3	339.7	503.2	219.0	182.6	270.6	225.6	118.8	0.4	2317.2
	Temp ^{O}C	29.9	32.2	29.9	29.3	29.5	28.5	27.8	27.3	27.5	28.6	29.1	29.7	29.1
	RH %	76	74	82	83	81	80	85	87	86	84	82	78	81
2002	R/fall	0	10.8	135.1	261.4	312.4	255.8	205.0	347.0	320.0	404.9	70.1	9.0	2331.5
	Temp ^{O}C	29.6	31.3	30.4	30.0	29.8	29.2	29.2	28.2	28.7	28.6	29.2	29.7	29.5
	RH %	58	68	78	82	81	82	85	88	84	84	80	76	79

The area is located on the level to gently undulating Coastal Plains (Tahal Consultants, 1982; Petters *et al.,* 1989). The geological parent material is tertiary sandstones, directly influencing the characteristics of the soils. The soils are highly weathered, deeply permeable, weakly structured, with a low to moderate nutrient and water retention capacity. They are classified as Ultisol, mostly Kandic Paleudult, with an isohyperthermic temperature regime, and belong locally to the Etinan series. The soils are also characterized by high soil erodibilty, which relates directly to the high rainfall and runoff erosion. Soil erosion is increasing with intensification of agriculture. Soil deterioration by erosion is caused by a combination of factors, such as the heavy storms, undulating relief, lack of structural soil stability, over cultivation and unsuitable agro-techniques. The common type of erosion is inter-rill erosion, in agricultural systems where bare cultivation is the rule. Some of the properties of the soil of the study area are shown in Table 2.

Field Study

The site was cleared and the residues physically removed to the experimental plot boundaries. The plot was marked into blocks measuring 16 m long and 11m wide, and subsequently into sub-plots 2 m x 11m wide. The study was a three factor factorial in randomize complete block (RCB) with tillage, mulching material and mulching method as factors. The treatments were:

(1) two tillage methods [till (MT) and no-till (NT)], (MT was done by ploughing the surface 10 cm soil with a hoe),

(2) two mulching materials [*Panicum maximum* (p) and *Chromolaena odorata* (c)] readily available; and

(3) three mulching methods [incorporated (b) surface (s) and no-mulch (o)]. In (b), the mulch was spread on the surface and ploughed with the soil. In (s), the soil was ploughed before mulch was applied. The treatment combinations are MTpb, MTps, MTcb, MTcs, MTo, NTps, NTcs and NTo. The no-mulch treatment corresponded to the farmers' practice. Mulch, which consisted of plant residues (shrubs, herbs and grasses) collected at site, was applied at the rate of 6 t/ha. Lal (1975) recommended 4 to 6 t/ha as appropriate for soils of the tropical region. We adopted the upper limit to account for rapid decomposition favoured by the high moisture and elevated temperature conditions in the area. Weeds were controlled with the short handle hoe commonly used in the area.

Separate trials were initiated in August (the beginning of the second rainfall in 2000 and 2001, with cowpea (*Vigna unguiculata* L. Walp) var 3354 as test crop. Three cowpea seeds were planted at a spacing of 1 x 1 m, rather than the recommended 50 x 25 cm and thinned to one plant/hill two weeks after emergence, giving a plant population of 10^4 ha^{-1}. Singh and Rachie (1985) reported that cowpea is traditionally grown in a mixed-cropping system at wide spacing, giving a total plant population from 10,000 to 20,000 plants/ha. Mixed cropping is the rule in the southeast as in other parts of

Nigeria and West Africa, especially the yam-based systems that are common in these areas. Wide spacing was adopted because it is compatible with the traditional cropping systems. NPK fertilizer (15:15:15) was applied at the rate of 300 kg/ha (FMANR, 1990), amounting to 26 kgN/ha, 18 kgP/ha and 48 kgK/ha, one week after germination. The use of mineral fertilizer was to supplement fertility of the soil, and to also demonstrate its benefit in crop production.

At harvest in 2000 and 2001, soil sampling and infiltration runs were carried out in the inter-row and intra-row spacing of each treatment. Composite soil samples were collected from the 0 – 30 cm depth zone for particle size analysis by the hydrometer method (Gee and Or, 2002) and chemical analysis for organic carbon and nutrient levels (Page *et al*., 1982). Because the results were similar, the data were averaged (Table 2). Duplicate soil core samples were also collected from the intra-row spacing of each treatment for the determination of hydraulic conductivity using the steady-flow soil column method (Reynolds and Elrick, 2002) and dry bulk density (Grossman and Reinsch, 2002). *In-situ* water content was determined 2 and 10 days after saturation by flooding an enclosed area of soil surface in each treatment (Gardner, 1965). Composite soil samples were also collected from each treatment for the determination of water stable aggregates >2.0 and >0.5 mm diameter, using the wet sieving technique (Kemper, 1965). Infiltration runs were conducted using the double ring infiltrometer technique (Reynolds *et al*., 2002), and the infiltration data fitted into Philip (1957) and Kostiakov (1932) models, and analysed to estimate the sorptivity and transmissivity parameters.

Duplicate root samples were collected at harvest from the middle row of each treatment, with core cylinders at depth increments of 7.2 cm to a 36 cm of the profile (Bohm, 1979). Root length was measured with the grid intersection method (Tennant, 1975).

The data collected were subjected to the analysis of variance, the Duncan multiple range test, and multivariate analysis to reveal correlations among the soil attributes and plant parameters.

RESULTS AND DISCUSSION

Particle-size distribution

The predominant particle-size fraction is sand, averaging more than 89% (Table 2). Soil texture was loamy sand, and was attributed to the parent material, the coastal plain sands of sandstone origin.

Table 2: Effect of Cultivation on Soil Physical and Chemical Properties of the top 30 cm Depth at Planting and Harvest

		Planting	Harvest	
Soil Parameters		**2000**	**2000**	**2001**
Sand (%)		82.70	81.00	89.40
Silt (%)		7.20	7.80	3.00
Clay (%)		10.10	11.20	8.60
Texture		Ls	Ls	Ls
pH		4.80	4.70	4.50
Org. C (%)		12.2	22.4	14.2
Total N (%)		0.8	1.9	0.9
Avail P mg/kg		250.33	210.45	101.21
Exc bases (Cmol/kg):				
Ca	“	2.56	2.78	2.49
Mg	“	1.10	1.29	1.13
Na	“	0.08	0.05	0.06
K	“	0.19	0.20	0.09
Exc acidity	“	1.92	1.35	2.50
ECEC	“	5.77	5.72	6.22
Base satn (%)		66.70	76.20	59.9
% water stable aggregates			29.8*	46.4
			41.3**	20.7

Ls = loamy sand;* = >2 mm; ** = >0.5 mm

The soil is strongly acidic (Table 2), and pH was further depressed by about 6% from planting in 2000 to harvest in 2001. This is attributed to the acid sand parent material, the high rainfall which leaches and increases the deficiency of exchangeable bases, and to cultivation which accelerates acidifying process in the soil (Udo, 1987). Soil organic C (SOC) level increased remarkably by about 83.6% at harvest in 2000 and about 16.4% in 2001 (Table 2). The large percentage increase in SOC in 2000 could be attributed to residue mulching a soil that was fallow for two years prior to present cultivation. Equally, the small percentage increase in 2001 could be attributed to cultivation, exposing the stored SOC to degradation. Residue mulching, besides improving soil quality, has the potential to mitigate the radiative losses and atmospheric sequestration of carbon (Lal and Bruce, 1999; Duiker and Lal, 2000). The decline in SOC in 2001 was attributed to more favourable weather conditions, mainly rainfall (Table 1), which enhanced microbial decomposition and soil erosion.

Available P declined by about 15.9% in 2000 and about 59.6% in 2001. This is attributed to the increasing erosion of SOC since it is reported to be the sink and pool of P in tropical soils (Agboola and Unamma, 1991), and acidity which decreases P availability in the soil. Base saturation increased by about 7.8% in 2001, and is attributed to the mulch treatments (Agboola and Unamma, 1991; Agbim and Adeoye, 1991). Consequently, increases in residue application will improve the chemical fertility of the soil.

Bulk Density, Aggregate Stability, Water Content and Hydraulic Conductivity of the 0 – 30 cm Depth

Bulk density in tilled (MT) and untilled (NT) plots was similar in 2000 but significantly higher in 2001 (Table 3). In 2001, bulk density was significantly lower in tilled than until plots. The lower bulk density in 2001 is also attributed to residue mulching (whether incorporated or surface applied), although its contribution may have been obscured by tillage.

Table 3: Effect of Season X Tillage on Bulk density

Treatment	Bulk density (g/cm^3)
S_1MT	1.46a
S_1NT	1.45a
S_2MT	1.27c
S_2NT	1.35b

Means followed by the same letters are not significant at *P<0.05* using the Duncan multiple range test; S_1 = 2000, S_2 = 2001; MT = tilled soil; NT = control, untilled soil

The stability of aggregates >2.0 mm and >0.5 mm diameter was significantly affected by tillage and mulching practices. The size ranges, respectively, averaged 29.9% and 41.3% in 2000 and 46.4% and 20.7% in 2001 (Table 2). The proportion of aggregates >2 mm diameter increased in 2001, and was attributed to residue mulching. The mechanism of aggregates formation and breakdown in soil are fairly well understood. Mulches generate the organic matter that binds soil particles and stabilize aggregates, reduce the kinetic energy of the impacting raindrops, and soil compaction and aggregate disintegration. Moreover, % WSA >0.5 mm was generally > 60% and beneficial to soil conservation, because these sizes of aggregates resist erosion (Bryan, 1969) and soil loss, in a climate zone with torrential and high intensity downpours and soil erosion.

Soil water content (SWC) was significantly lower in 2000 than 2001 (Table 4). However, the tillage methods were similar in SWC in either 2000 or 2001. Further, while MT had high SWC in 2000, a higher value was obtained in NT in 2001. The significantly higher SWC in S_1NT in 2001, may be related to soil water properties, mainly bulk density and pore-size distribution. Bulk density is significantly higher in S_2NT than S_2MT (Table 4).

Table 4: Effect of Season X Tillage on Soil Water Content

Treatment	Soil Water (%)
S_1MT	8.10bc
S_1NT	7.38c
S_2MT	9.35a
S_2NT	10.39a

Means followed by the same letters are not significant at *P<0.05* using the Duncan multiple range test; S_1 = 2000, S_2 = 2001; MT = tilled soil; NT = control, untilled soil

Pore-size distribution would follow a similar pattern, with a greater proportion being micropores or soil water retention pores. This may explain the higher SWC in S_2NT than S_2MT in 2001. The intra-season similarity and inter-season differences may be due to the prevailing weather conditions especially rainfall (Table 1), which would be similar throughout each sampling period. Heat flux into the soil would also be similar (uniform average soil temperatures, Table 1) but differing evaporative flux into the atmosphere due to the tillage and mulch treatments. High rate of internal drainage favoured by the sandy texture of the soil, may also have contributed to the general low SWC. The effect of both evaporative flux and internal drainage may have obscured the influence of the residue mulch practices.

Tillage and mulching significantly increased hydraulic conductivity, Ks, with higher values in MT than NT soil (Table 5). The observed pattern of differences point out the relative effect of tilled and no-till techniques on pore-size distribution. Ks is generally, usually higher in tilled soil with a preponderance of macropores than in untilled soil with pore-size distribution skewed toward the micropores. This effect may have been enhanced in the tilled plots by the mulching techniques. The significantly high values of Ks in MTo could still be attributed to soil loosening, and that soil settling lagged behind the compacting effect of rainfall.

Table 5: Effect of Tillage X Mulching Material X Mulching Method on Hydraulic Conductivity in 2000 and 2001 Planting Seasons

Treatment	Hydr. Conductivity (cm/h)
MTpb	10.72ab
MTps	8.60abc
MTcb	10.64ab
MTcs	10.19ab
	11.68a
MTo	9.35abc
NTps	7.89bc
NTcs	6.66c
NTo	

Means followed by the same letters are not significant at *P<0.05* using the Duncan multiple range test; MT = tilled; NT = untilled; p = *Panicum maximum*; c = *Chromolaena odorata*; b = incorporated mulch; s = surface mulch; o = no mulch

Generally, Ks was very rapid (Landon, 1984) in all tillage and mulch treatments, and was attributed to the improvement and maintenance of transmission pores in the soil. The results therefore demonstrate the beneficial effect of soil loosening (by tillage) and formations of stable aggregates by mulch-generated organic matter on soil hydraulic properties, principally, Ks and soil water retention. The results further indicate that residue mulching with *Chromolaena odorata* appears more suitable on tilled soil, while *Panicum maximum* appears suitable on untilled soil. A basic principle of water erosion control is that the downward flux of the rain water must be high by improving the rate of water movement in the soil. Therefore, mulching a tilled soil will improve soil infiltrability (see Tables 6 and 7) and control runoff erosion during the crop production phase.

Infiltration characteristics

Tillage and mulching method significantly affected soil water sorptivity and transimissivity (Table 6). Sorptivity, computed from the Philip two parameter model, was significantly higher in untilled + surface mulch (NTs) and tilled + no mulch (MTo) plots, indicating high rainwater acceptance than the tilled + mulch incorporated (MTb) or tilled + surface mulch (MTs) and untilled + no mulch (NTo) plots. It is well known that sorptivity increases or is dominant at the initial stages of infiltration when the flux of water into an apparently dry soil is absorption – driven. However, as time increases, the infiltration flux changes to gravity – driven and sorptivity decreases. The high values of sorptivity in NTs and MTo may be due to both mulch and absence of crusting and preservation of the macropore system. Data in Table 6 also show that transmissivity by Philip and Kostiakov models was equally higher in NT plot which may indicate that both sorption and gravity were dominant. In other words, the plots had high soil infiltrability and surface ponding and runoff may not readily occur.

Table 6: Effect of Tillage X Mulching Method on Sorptivity (S) and Transmissivity (A or K) in 2000 and 2001 Planting Seasons

Treatment	Sorptivity (S) ($cm/min^{1/2}$)	Transmissivity (cm/min) (A)	(K)
MTb	2.38 bcd	0.72d	1.01cdb
MTs	2.33 cd	0.67d	1.04bcde
MTo	2.58a	1.28c	0.99e
NTs	2.75a	1.55a	1.01de
NTo	2.24d	1.37b	1.37a

The sorptivity (S) and transmissivity (A) are obtained by analysis of Philip's (1957) infiltration model whereas the transmissivity (K) was obtained by analysis of the Kostiakov (1932) infiltration model. Means followed by the same letters are not significant at *P<0.01* using the Duncan multiple range test; MT = tilled; NT = untilled; b = incorporated mulch; s = surface mulch; o = no mulch

Quasi-steady infiltration rate was significantly different among the mulch application methods (Table 7). The higher quasi-steady infiltration rate in the unmulched plots appears to reflect sorptivity and transmissivity in those plots. The low value of equilibrium infiltration rate in the mulch incorporated plot indicates pore sealing and surface crusting which may explain the low values of sortivity and transimissivity in the soil. Data in Table 7 show that quasi-steady infiltration rate was significantly higher when *Panicum maximum* was applied on tilled plot and also higher when *Chromolaena odarata* was applied on untilled plot. The differences in steady infiltration rate may be related to decomposition enhanced in tilled soil and slowed or impeded in untilled soil. Consequently, *Chromolaena odorata* may easily decay in tilled soil but preserved in untilled soil.

Table 7: Effect of (a) Mulching Method, and (b) Tillage X Mulching Material on Equilibrium Infiltration rate (i eq) in 2000 and 2001 Planting Seasons

	Treatment	i eq (cm/h)
(a)	B	0.30
	s	0.46
	o	0.61
	LSD $_{(0.01)}$	0.10
(b)	MTp	0.51a

MTc	0.42c
NTp	0.40d
NTc	0.49b

Means followed by the same letters are not significant at *P<0.01* using the Duncan multiple range test; c = incorporated mulch; s = surface mulch; o = no mulch; MT = tilled; NT = unbtilled; p = *Panicum maximum*; c = *Chromolaena odorata.*

Time to the asymptotic steady infiltration rate (i_{eq}) was significantly differently affected by tillage and mulching method interaction (Table 8). The data indicate that i_{eq} occurred at large time, where mulch was incorporated in tilled plot, decreasing significantly to the unmulched tilled plot. The data further indicate that the treatments (NTs, MTo) with shorter time to i_{eq} had high values of S, which was maintained even at large times. Conversely, treatments with large times to i_{eq} had lower values of S with the possibility of surface runoff in the plots.

Table 8: Effect of Tillage X Mulching Method on time to attain Equil. Infiltration rate (i eq) in 2000 and 2001 Planting Seasons

Treatment	Time to i eq (cm/h)
MTb	111.3 a
MTs	105.0 b
MTo	80.3 e
NTs	92.2c
NTo	84.7 d

Means followed by the same letters are not significant at *P<0.01* using the Duncan multiple range test; MT = untilled; NT = untilled; b = incorporated mulch; s = surface mulch; o = no mulch

The interaction of tillage and mulch material significantly increased cumulative infiltration (I) where *Panicum maximum* and *Chromolaena odorata* were applied on untilled than tilled soils (Table 9).

Table 9: Effect of Tillage X Mulching Material on Cum. Infiltration (I) in 2000 and 2001 Planting Seasons

Treatment	**I (cm)**
MTp	62.1 bc
MTc	58.5 c
NTp	74.2 a
NTc	81.2 a

Means followed by the same letters are not significant at *P<0.01* using the Duncan multiple range test; MT = tilled; NT = untilled; p = *Panicum maximum*, c = *Chromolanea odorata*

These results agree partly with the data in Tables 6 and 7, respectively, where S and i_{eq} were high with mulch applied on untilled soil, indicating that the mulch, aided by continuity in the pore system, increased soil infiltrability. This is shown by the similarity in the interaction of *Panicum maximum* and *Chromolaena odorata* with no-tillage. The method of application, interacting with tillage systems, generally produced significant results which were mostly similar (Table 10).

Table 10: Effect of Tillage X Mulching Method on Cum. Infiltration (I) in 2000 and 2001 Planting Seasons

Treatment	**I (cm)**
MTb	71.0 ab
MTs	73.2 ab
MTo	67.0 b
NTs	76.8ab
NTo	79.8 a

Means followed by the same letters are not significant at *P<0.01* using the Duncan multiple range test; MT = tilled; NT = untilled; b = incorporated mulch; s = surface mulch; o = no mulch

However, the highest values were obtained in the untilled plot, which partly agrees with the data on sorptivity and transimissivity in Table 6. This indicates that whatever the method of tillage and mulch would favour high soil infiltrability. The data however, indicate that tillage (MT) with *Panicum maximum* or *Chromolaena odorata*, incorporated or surface applied would alleviate soil compaction (lower bulk density), stabilize soil aggregates, control the disruption of pore geometry by the high kinetic energy of rain-drops, and improve soil infiltrability and transmission properties. This is demonstrated by the fact that although the average (overall treatments) cumulative infiltration of 690 mm after 120 minutes was about 30.8% of the average total annual rainfall of 2236.9 mm in the area, the lowest equilibrium infiltration rate of 217 mm/h obtained in the *Panicum maximum* mulched and untilled plot was greater than the higher intensity (165 mm/h) of the average tropical rainstorms in the area. Hence these soils have very good water transmission characteristics and the increased infiltration obtained from the mulch application will not mean much in terms of soil loss and runoff water management.

Table 11 shows that soil bulk density was not significantly related to SOC but that the generally low values of the latter accounted for 36% of the values of bulk density obtained. The table also shows that SOC significantly accounted for 60% formation of aggregates >0.5 mm diameter. As already explained, this is beneficial to soil conservation because these and larger diameter aggregates are resistant to soil erosion and soil loss. Although not significant, the table also shows that SOC influenced the values of soil water transmissivity by 30%.

Table 11: Relationship Between Percent Organic Carbon (SOC) levels and selected Physical Properties of the Soil

Independent Physical Parameter	Regression Model	R^2
Soil water content (SWC)	SWC = 9.39 – 0.20 (SOC)	0.01^{ns}
Bulk density (BD)	BD = 1.29 + 0.05 (SOC)	0.36^{ns}
Water stable aggregates: (WSA > 2.0 mm)	WSA = 39.8 + 2.52 (SOC)	0.02^{ns}
WSA > 0.5 mm)	WSA = 54.0 – 14.73(SOC)	0.60*
Sorptivity (S)	S = 0.42 – 0.0063(SOC)	0.0015^{ns}
Transmissivity (A)	A = 2.50 – 0.79(SOC)	0.30^{ns}

*Significant at 5% level

Total root length and yield of cowpea

Data in Table 12 show that total root length of cowpea was significantly higher where mulch was incorporated or surface applied on tilled soil than on the untilled soil, especially, the unmulched tillage control (NT) treatment. This indicates that although the soil is generally less cohesive and may not severely inhibit root growth during the rainy season (Lal, 1990), tillage is needed for unrestricted root penetration and proliferation in the soil. Tillage will recreate the pore structure by reducing soil strength, and mulching will sustain the pore-size distribution and increase in root activity. The soil fertility value of the high total root length is the interception of mineralized nutrients from soil organic matter thus, preventing their leaching loss beyond the rooting depth.

Table 12: Effect of Tillage X Mulching Method on Total Root Length of Cowpea in the 30 cm Depth in 2000 and 2001 Planting Seasons.

Treatment	Total Root Length (cm)
MTb	189.5 a
MTs	176.5 abc
MTo	159.9 bc
NTs	159.8 c
NTo	128.8 d

Means followed by the same letters are not significant at *P<0.01* using the Duncan multiple range test; MT =tilled; NT = untilled; b = incorporated mulch; s = surface mulch; o = no mulch

Data in Table 13 show that cowpea grain yield was greatly increased in tilled than untilled soil in 2000 and 2001 but that the increase was about 50.5% greater in 2001 than the about 24.3% in 2000.

Table 13: Effect of Season X Tillage Method on the Yield of Cowpea in 2000 and 2001 Planting Seasons.

Treatment	Yield (g/m^2)
S_1MT	87.7 bcd
S_1NT	66.4 d
S_2MT	172.7 a
S_2NT	85.5 cd

Means followed by the same letters are not significant at *P<0.01* using the Duncan multiple range test; S_1 = 2000; S_2 = 2001; MT = tilled; NT = untilled

Similarly, cowpea yield increased significantly where mulch was incorporated or surface applied in 2001 than in 2000 (Table 14). The results demonstrate that either incorporating or applying mulch on the surface of tilled soil is a soil management practice that can be used to improve the physical and chemical fertility of the "acid soils" and increase the yield of cowpea in the area.

Table 14: Effect of Season X Tillage Method on the Yield of Cowpea in 2000 and 2001 Planting Seasons.

Treatment	Yield (g/m^2)
S_1b	73.4 e
S_1s	80.6 cde
S_1o	77.2 de
S_2b	161.7 a
S_2s	143.8 a
S_2o	81.8 bcde

Means followed by the same letters are not significant at *P<0.01* using the Duncan multiple range test; S_1 = 2000; S_2 = 2001; b = incorporated mulch; s = surface mulch; o = no mulch

The relationship between cowpea grain yield and some soil physical properties is presented in Table 15. The results indicate that apart from water stables aggregates (WSA); bulk density, organic carbon, soil water content and soil water sorpitivity, soil water transmissivity explained 83% variability in cowpea yield. However, the influence of soil water transmissivity can only be indirect since it is a function and therefore the integrated effect of soil physical and biological conditions, principally, soil bulk density, aggregation and organic carbon content. Among these soil quality characteristics, soil organic carbon (SOC), which although not significant, are accounted for 48% variability in cowpea grain yield (Table 15). The non-significant relationship between yield and other soil properties may indicate that these properties were optimum for cowpea production but that their effect may have been obscure by their interaction.

Table 15: Relationship Between Cowpea Grain Yield (Y = g/m^2) and some Physical Properties of the Soil

Dependent Variable	Regression Model	r^2
Water Stable aggregates (% WSA > 2.0 mm)	Y = 45.2 – 0.008 WSA (>2.0mm)	0.0047^{ns}
(% WSA > 0.5 mm)	Y = 31.4 – 0.04 WSA (>0.5mm)	0.07^{ns}
Bulk density (BD)	Y = 1.38 – 0.0002 (BD)	0.0009^{ns}
Organic Carbon (SOC)	Y = 1.23 + 5.18 (SOC)	0.48^{ns}
Soil Water Content (SWC)	Y = 9.21 – 0.002 (SWC)	0.01^{ns}
Sorptivity (S)	Y = 0.47 – 0.0005 (S)	0.19^{ns}
Transmissivity (A)	Y = 2.20 + 0.0099 (A)	0.83**

**Significant at 1% level

CONCLUSION

Agricultural production on the acid soils of southeastern Nigeria is declining due to degradative land use, such as bare cultivation, and harsh environmental (high rainfall erosivity and soil erodibility) and the shortening of the natural bush fallow, and associated inability of the immature vegetation to restore physical and chemical properties of the soil. Soil physical and chemical properties (especially organic carbon level) are essential to sustainable crop production systems of the traditional low resource setting in the tropics. If crop yields must increase to meet food needs of the growing population, present soil and crop management systems must be improved. This study has demonstrated that tillage with mulching (incorporated or surface applied) is beneficial to both soil and crop. This study also demonstrated that mulching an untilled soil is equally beneficial to soil and crop, and may be a soil management practice with the potential to reduce human energy input in traditional tillage operation (flat, ridging and mounding). The benefits of these soil management practices include improved water transmission characteristics, formation of stable soil aggregates, reducing soil bulk density, and increases in organic matter content and crop yields. Considering that cowpea was grown in the second season when natural fallow period normally commences, adopting cowpea cropping at this time of the year will not only increase food production, but will also improve the productivity of the rural farm-families in southeastern Nigeria.

REFERENCES

Agbim, N. N. and Adeoye, K. B. (1991). The Role of Crop Residue in Soil Fertility Maintenance and Conservation. *In:* Organic Fertilizer in the Nigerian Agriculture: Present and Future. Proc. National Organic Fertilizer Seminar. Fed. Min. Agric. Nat. Resources, Abuja. Pp 21 - 42.

Agboola A. A. (1978). The Influence of Organic Matter on Cowpea's Response to N. Fertilizer. *Agrion* J. 70: 25 – 28

Agboola, A. A. and Unamma, P. A. (1991). Maintenance of Soil Fertility under Traditional Farming Systems. *In:* Organic Fertilizer in the Nigerian Agriculture Present and Future. Proc. National Organic Fertilizer Seminar. Fed. Min. Agric Nat. Resources, Abuja. Pp. 7 – 20

Agboola, A. A., Eneji, A. E, Aiyelari, E. A. and Tijani-Eniola, A. (1997). Marginal lands, water quality, and agricultural land pollutants in Nigeria. Pp. 303 – 315. Proc. 23rd Annual Conf. Soil Sci. Soc. Nigeria. Held at Usmanu Danfodiyo Univ., Sokoto. 2nd – 5th March, 1977.

Areola, O. (1990). The Good Earth. University of Ibadan, Inaugural Lecture Series. 40p

Bohm, W. 1979. Methods of Studying Root Systems. Springer-Verlag. Berlin.

Bryan, R. B. (1969). The relative erodibility of Soils developed in the Peak District of Derbyshire. Geogr Annual No. 3:145 – 159.

Duiker, S. W. and Lal. R. (2000). Carbon Budget Study using CO_2 Flux Measurement from a no-till system in Central Ohio. *Soil Till. Res*. 54 21 – 30.

FMANR, (Fed. Min. Agric. Nat. Resources) (1990). Literature Review on Soil Fertility Investigations in Nigeria. FMANR, Lagos, Nigeria. 281p.

Gardner, W. H. (1965). Water Content. Pp 82 – 127. *In* C. A. Black (ed). Methods of Soil Analysis, No. 9(1). Physical and Mineralogical Properties. Am. Soc. Agron, Madison, WI.

Gee G. W. and Or, D. (2002). Particle-Size Analysis. Pp 255 – 293. *In:* J. H. Dane and G. C. Topp (eds). Methods of Soil Analysis, Part 4, Physical Methods. Soil Sci. Soc. Am., No. 5. Madison, WI.

Grossman, R. B. and Reinsch, T. G. (2002). Bulk density and linear extensibility in J. H. Dane and G. C. Top (eds) Methods of Soil Analysis, Part 4, Physical Methods. *Soil Sci. Soc. Am*. No. 5. Madison, WI.

Hulugalle, N. R., Lal, R. and Opara-Nadi, O. A (1985). Effect of Tillage systems and mulch on Soil Properties and Growth of yam (*Diascorea rotundata*) and Cocoyam (*Xanthosoma sagittifolium*) on an Ultisol. *J. Root Crops* 11 : 9 – 22.

Hulugalle, N. R. Lal, R. and Opara-Nadi, O. A. (1987). Management of Plant Residue for Cassava (*Manihot escullenta*) Production on an Acid Ultisol in Southeastern Nigeria. Field Crops Res. 16 : 1 – 18.

Iwuafor, E. N. O., Dantagwa, Y. and Chude, V. O. (1990). Potentials of Millet thresh Waste as a Soil Amendment. Paper Presented at 11th Annual Conference of the Soil Science Society of Nigeria. Maiduguri, Nigeria.

Kemper, W. D. (1965). Aggregate Stability. Pp 511 – 519. *In*: C. A. Black (ed) Methods of Soil Analysis, No. 9 (1), Physical and Mineralogical Properties. Am. Soc. Agron. Madison, WI.

Karlen, D. L. Maushach, M. J., Doran, J. W., Cline, R. G., Harries, R. F. and Schuman, G. E. (1997). Soil Quality: A Concept, Definition and Framework for Evaluation. Soil Science Soc. Am. J. 61 : 4 – 10.

Kostiakov, A. N. (1932). On the Dynamics of the Coefficient of Water Percolation in Soils and on the Necessity for Studying it from a dynamic Point of View for Purpose of Amelioration. Trans. Int. Congr. Soil Sci. A, Paris. Pp. 17 – 21.

Lal, R. (1975). Role of Mulching Techniques in Tropical Soil and Water Management. Tech. Bull. No. 1. Int. Inst. Trop. Agric (IITA), Ibadan, Nigeria. 38p.

Lal, R. (1986). Soil surface management in the tropics for intensive land use and high and sustained production. *Adv. Soil Sci.* 5 : 1 –109.

Lal, R. (1990). Tropical soils: Distribution, properties, and management. *Resource Management and Optimization*.7 : 39 – 52.

Lal, R. (1993). Tillage effects on soil degradation, soil resilience, soil quality, and sustainability. *Soil Tillage Res*. 27 : 1 – 8.

Lal, R. (1997). Degradation and resilience of soils. Phil. Trans. Royal Soc. London. Series B352 : 997 – 1010

Lal, R. and Bruce, J. P. (1999). The Potential of World Cropland Soils to Sequester C and Mitigate the Greenhouse Effect. *Envir. Sci. and Policy*. 2 : 177 – 186.

Landon, J. R. (1984). Booker Tropical Manual: A Handbook of Soil Survey and Agricultural Land Evaluation in the Tropics and Sub-Tropics.

Mbagwu, J. S. C. (1991). Mulching an ultisol in Southern Nigeria: Effects on physical properties and maize and cowpea yields. *J. Sci Food Agric.* 57:517-526.

Nye, P. H. and Greenland, D. J. (1960). Soil under shifting cultivation. Tech. Comm. 51. Harpenden, UK: Commonwealth Bureau of Soils.

Obatolu, C. R. and Agboola, A. A. (1993). The Potential of Siam Weed (*Chromolaena odorata*) as a Source of Organic matter for Soils in the Humid Tropics. pp.89 – 100. *In*: K. Mulongoy and R. Merckx (eds) Soil Organic Matter Dynamics and Sustainability of Tropical Agriculture. John Wiley and Sons.

Ogban, P. I., Etim, E. A, Ekanem, T. P and Effiong, G. S. (1999). Mulching Practices on a tropical soil: Effect on physical and chemicalproperties. *Env. Anal.* 2:88.97.

Ogban, P. I., Ekanem, T. P and Etim, E. A. (2001), Effect of Mulching Methods on Soil Properties and Growth and Yield of Maize in Southeastern Nigeria. *Trop. Agric.* (Trinidad). 78(2) : 82 – 89.

Ogban, P. I. and Ekerette, I. (2001). Managing the Coastal Plain Soils for Erosion Control and Crop Production in Southeastern Nigeria. *J. Sustainable Trop. Agric Res.* 2: 131 – 138.

Ogban, P. I., Ukpong, U. K. and Essien, I. G. (2005). Influence of bush fallow on the physical and chemical fertility of acid sands in southeastern Nigeria. *Nig. J. Soil Res.* 15 : 96 – 101.

Okigbo, B. N. (1977). Farming systems and Soil erosion in West Africa. Pp. 151 – 163. *In*: D. J. Greenland and R. Lal (eds) Soil Conservation and Management in the Humid Tropics. John Wiley and Sons Ltd. Chichester, UK.

Opara-Nadi, O. A. (1990). Tillage practices and their effect on soil productivity. pp. 87 – 111. *In:* Organic-Matter management and Tillage in Humid and Sub-humid Africa. IBSRAM Proc. No. 10. Bangkok.

Opara-Nadi, A. O. (1993). Effect of Elephant Grass and Plastic Mulches on Soil Properties and Cowpea yield on an Ultisol in Southeastern Nigeria. Pp. 351 – 260. *In:* K. Mulongoy and R. Merckx (eds) Soil Organic Matter Dynamics and Sustainability of Tropical Agriculture. Johm Wiley and Sons.

Owaiye, A. R. (1993). Effect of Residue Mulch on Characteristics and Productivity of two Soil Classes under Coffee in Nigeria. Pp. 339 – 344. *In:* Mulongoy and R. Merckx (eds) Soil Organic Matter Dynamics and Sustainability of Tropical Agriculture. John Wiley and Sons.

Page, A. I., Miller, R. H. and Keeney, D. R. (eds). (1982). Methods of Soil Analysis, No. 9 (2), Chemical and Microbiological Properties. Am. Soc. Agron., Madison, WI.

Petters, S.W. (ed). (1989). Akwa Ibom State: Physical Background, Soils and Land Use and Ecological Problems. Govt. Print Office, Uyo, Nigeria. 603p.

Philip, J. R. (1957). The Theory of Infiltration. 4. Sorptivity and algebraic Infiltration Equations. *Soil Sci*. 84 : 257 – 264.

Reynolds, W. D. and Elrick, D. E. (2002). Constant head Soil Core (Tank) Method. Pp. 804 – 808. *In:* J. H. Dane and G. C. Topp (eds) Methods of Soil Analysis, Part 4, Physical Methods. Soil Sci. Soc. Am No. 5. Madison, WI.

Reynolds, W. D., Elrick, D. E. and Youngs, E. G. (2002). Ring or Cylinder Infiltrometers (Vadose Zone). Pp. 818 – 826. *In:* J. H. Dane and G. C. Topp (eds) Methods of Soil Analysis, Part 4, Physical Methods. Soil Sci. Soc. Am. No. 5. Madison, WI.

Sanchez, P. A. (1976). Properties and Management of Soils in the Tropics. John Wiley and Sons, Inc. New York. 618p

Singh, S. R. and Rachie, K. O. (1985). Cowpea Research, Production and Utilization. Int. Inst. Trop. Agric (IITA), Ibadan, Nigeria. 460p.

Swift, M. J. and Sanchez, P. A. (1984). Biological management of tropical soil fertility for sustainable productivity. *Nature and Resources.* 20 (4) : 1- 10.

Swindale, L. D. (1988). Sustainability, the impact of agricultural development on the environment:' An IARC point of view. Proc. CGIAR Mid-Term Meeting, Berlin, Germany. Washington, DC, USA : CGIAR

Tahal Consultants. (1982). Qua Iboe River Basin Feasibility Study. Vol. 2. Soil Survey and Land Capability Classification. Cross River Basin Dev. Authority, Calabar, Cross River State, Nigeria.

Tennant, D (1975). A Test of a Modified line Intersect method of estimating root Length. *J. Ecol*. 63 : 995 – 1001.

Udo, E. J. (1987). Soil Acidity and Soil Productivity. Paper Delivered at the National Workshop on Soil Productivity: The Lifeline of Agricultural Productivity, held at the University of Jos, Makurdi Campus, Makurdi, June 9 – 11, 1987.

Woomer, P. L. and Ingram, J. S. I. (1990). The Biology and Fertility of Soils: TSBF Report (1990). Nairobi, Kenya : TSBF

Woomer, P. L. Martin, A, Albretcht, A. Swift, M. J. and Barrios, E. (1994). The importance and management of soil organic matter in the tropics. Pp 47 – 80. *In* P. L. Woomer and M. J. Swift (eds) The Biological Management of Tropical Soil Fertility.