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AGRONOMIC AND ECONOMIC EVALUATION OF DIFFERENT CONSERVATION AND CONVENTIONAL FARMING PRACTICES ON A SANDY CLAY LOAM SOIL AT MINNA, NIGERIA.

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ABSTRACT

Field trials were carried out in 2008 and 2009 cropping seasons to compare manual ridging (control) with ten conservation and conventional farming practices. The zero tillage treatments recorded significantly higher penetration resistance than manual ridging in both years. In terms of soil moisture content, seedling emergence, plant height, grain yield and stover + grain yield, however, the control and the test treatments were not significantly different. The insignificantly different pooled grain yield ranged from 2,043 kg ha^{-1} for slash-and-clear reduced tillage to 2,387 kg ha^{-1} for manual ridging. There was a wide variation in treatment costs from ₦9,000 ha^{-1} for slash-and-mulch zero tillage to ₦55,100 ha^{-1} for ploughing, harrowing and ridging. This resulted into slash-and-mulch, herbicide-based and slash-and-clear zero tillage treatment having significantly higher yield-cost ratio than the control. Slash-and-mulch and herbicide-based zero tillage practices are therefore recommended for promotion among Nigerian peasant farmers. The two other conservation farming practices, namely slash-and-mulch and herbicide-based reduced tillage, which recorded insignificantly higher yield-cost ratio than the control are also recommended.

Keywords: conservation agriculture, conventional agriculture, yield-cost ratio

INTRODUCTION

Conservation agriculture is a rapidly spreading trend in land management that seeks to optimize crop yields and farm profits, improve environmental quality and protect the soil for future use (Dumanski *et al.*, 2006; Sanginga and Woomer, 2009). It emerged as a refinement of no-till farming within large-scale mechanized field cropping in North and South America and is being modified to suit other farming systems and locations (Goddard *et al*., 2008). It is built around a suite of land management principles that integrate

ecological management with scientific agriculture. These principles may be summarized as (i) disturbing the soil as little as possible (ii) keeping the soil covered (iii) mixing and rotating crops, and (iv) promoting the use efficiency of applied agrochemicals through precision placement and timing (IIRR and ACT, 2005; Sanginga and Woomer, 2009).

Globally, conservation agriculture is practiced on approximately 99 million hectares with most of this production in Brazil (26 %), USA (25 %), Argentina (20 %) and Canada (13 %) and significant coverage also occurring in Australia (9 %) and Paraquay (2 %) (FAO, 2008). Conservation agriculture is used to cultivate over half of the crop land in Paraquay, about one-third of the land in Argentina, one-third in Brazil, and one-sixth in the United States. Increases in the hectarage of conservation agriculture over the past fifteen years are about nine-fold and the number of farmers practicing it is expected to increase substantially in the near future, particularly in South America. In Africa, on the other hand, conservation agriculture is not yet widespread with the exception of South Africa with 377,000 ha. However, the number of both large-scale and small-scale farmers practicing conservation agriculture is increasing in Zimbabwe, Zambia, Kenya, Namibia and Ghana. Conservation agriculture is also being actively promoted among small-scale farmers in Cameroon, Madagascar, Malawi, Tanzania and Uganda (IIRR and ACT, 2005; Derpsch, 2008). Notably, Nigeria is not yet part of this global agricultural trend as conservation agriculture is neither being practiced by farmers nor promoted.

Conservation agriculture provided 1.1 tons ha^{-1} additional maize among Zambian farmers and was more profitable despite higher costs of production. On-station trials in Zimbabwe showed an increase in maize yield from 3,200 to 4,000 kg ha^{-1} with conservation agriculture on well-drained soils as a result of reduced water runoff and erosion. In drier locations in Zimbabwe, conservation agriculture increased maize yields from 2,900 to 3,600 kg ha^{-1} (Elwell, 1995).

The inherently infertile and highly erodible soils common in sub-Saharan Africa combined with the high erosivity of tropical rainfall suggest that conservation agriculture is relevant for the attainment of agricultural sustainability and food security in the region. Conservation agriculture is also of interest in all areas within sub-Saharan Africa requiring water harvesting as a result of limited or poorly distributed rainfall. The necessity for water harvesting in such areas is accentuated by reduced rainfall effectiveness due to the tendency for rapid soil desiccation because of the poor water retention properties of the soils and the high evaporative demand of the tropical climate. Conservation agriculture ought therefore, to be developed and promoted with greater drive in sub-Saharan Africa because of its utility for soil and water conservation.

This study was conducted to compare the utility of conservation and conventional farming systems for sustainable maize production in the southern Guinea savanna of Nigeria. In pursuance of this objective, eleven treatments, including manual ridging as control, were evaluated, using penetration resistance, soil moisture condition, crop performance and yield-cost ratio as indices.

MATERIALS AND METHODS

Site Location and Characteristics

The study was conducted at the Teaching and Research Farm of Federal University of Technology, Gidan Kwano Campus, Minna which lies on latitude 9º 37′ N and longitude 6º 33′ E. Minna falls within the southern

Guinea savanna vegetation zone with a sub-humid tropical climate. The site was recovered from three years of bush fallow. Soil cover before imposition of treatments weighed 2,250 kg ha^{-1} in 2008 and 1,966 kg ha^{-1} in 2009 and comprised mainly growing weeds. The quantity of surviving crop and weed litter from previous dry season was negligible because of uncontrolled bush fires and grazing.

Soil Properties

The surface horizon (0 – 15 cm) of the soil at the experimental site contains 617 g kg^{-1} sand, 108 g kg^{-1} silt and 275 g kg^{-1} clay and is hence sandy clay loam and prone to waterlogging during the peak rainfall month (Table 1). The soil has very low N, moderate organic matter, P, K,

Table 1: Physico-chemical Properties of soil (0-15 cm depth) at the experimental site.

Soil properties	Values
Sand (g kg^{-1})	617
Silt (g kg^{-1})	108
Clay (g kg^{-1})	275
Textural class	SCL
pH(H_2O)	6.48
pH($CaCl_2$)	5.19
Organic matter (g kg^{-1})	11.4
Total nitrogen (g kg^{-1})	0.45
Available phosphorus (mg kg^{-1})	13
Exchangeable bases (cmol kg^{-1})	
Na^+	0.21
K^+	0.30
Mg^{2+}	2.40
Ca^{2+}	5.80
Exchangeable acidity (cmol kg^{-1})	1.50
Effective cation exchange capacity (cmol kg^{-1})	12.12
Base saturation (%)	60.7

SCL = sandy clay loam

Mg, Ca, ECEC and base saturation. The soil is thus, moderately fertile and requires good management to improve its fertility and long-term productivity.

Treatments and Experimental Design

Four zero tillage practices (slash-and-clear, slash-and-burn, slash-and-mulch, and herbicide-based); four reduced tillage practices (slash-and-clear, slash-and-burn, slash-and-mulch, and herbicide-based); two tractorized tillage practices (ploughing and harrowing, and ploughing, harrowing and ridging) were compared with manual ridging with hoe as control. The eleven treatments were laid out in a Randomized Complete Block Design with three replications and were assigned at random to plots within each replication. Individual plots had dimensions of 5 m x 5 m and were separated by intervals with a width of 5 m to permit tractor to turn without entering into an adjacent plot. For the zero and reduced tillage treatments, growing weeds and plant litter were cleared manually and removed from the plots (slash-and-clear) or burnt on the plots (slash-and-burn) or used as mulch on the plots (slash-and-mulch). For the herbicide-based zero and reduced tillage treatments, growing weeds were killed with 1.6 kg ha^{-1} of paraquat (1-1-dimethyl-4,4-bipyridinium ion) before planting. The dead weeds were left on the plots along with surviving litter of previous crops and weeds. On the zero tillage plots, no primary or secondary tillage was carried out. Soil disturbance was limited to manual clearing and opening of small slots with

cutlass or hand trowel for seed placement during planting. For the reduced tillage plots, on the other hand, each planting line (15 cm wide) was tilled with hoe to a depth of 15 cm. The two tractorized tillage treatments were ploughed to a depth of approximately 20 cm followed by harrowing only (ploughing and harrowing) or by harrowing plus ridging (ploughing, harrowing and ridging) thereby incorporating growing weed vegetation and plant litter into the soil. The treatments were applied to the same plots each year.

Cultural Practices

Treated open-pollinated maize seeds (cv. Suwan-1 Yellow) were hand-sown at three seeds per hole at a spacing of 90 cm x 40 cm. Seedlings were thinned to two per stand two weeks after planting to give a population of almost 55,000 plants ha^{-1}. Planting was done on the 9th of June in 2008 and on the 16th of July in 2009. All the plots were sprayed with 2.5 kg ha^{-1} of atrazine (2-chloro-4-ethylamino-6-isopropylamino-1-3-5-triazine) the day after planting. Weed regrowth on all the plots was controlled with 0.8 kg ha^{-1} of paraquat as directed spray with the aid of a spray shield. Chemical weed control was supplemented with intra-row weeding where necessary. The experimental plots received a uniform application of 120-60-60 kg ha^{-1} N, P_2O_5 and K_2O, with the N split-applied in equal doses at 2 and 6 weeks while the P_2O_5 and K_2O were applied once at 2 weeks after planting.

Soil, Crop and Economic Parameters

Soil water content was measured thermo-gravimetrically once in two weeks. A hand-driven auger with a screw diameter of 5 cm was used for taking triplicate soil samples within 0-20 cm soil depth for oven-drying to constant weight at 105 ^{o}C. A direct-reading pocket penetrometer with a piston needle diameter of 6 mm was used for the measurement of penetration resistance at 5 cm soil depth at 12 weeks after planting (WAP). At 14 days after planting (DAP), seedling count was done. The number of seedlings per plot was expressed as a percentage of the number of seeds planted. Vegetative growth was monitored by measuring the plant height of 20 randomly selected, tagged plants per plot at two-week intervals. Air-dried grain and stover+grain yields of each plot were determined. After dehusking and shelling the maize ears, the husks and shelled cobs were included in the stover+grain yield. Analysis of variance for Randomized Complete Block Design was performed on the maize growth and yield data. Least significant difference (LSD) was calculated for each parameter at P = 0.05 and 0.01 and used to separate the means of the test treatments from the mean of the control treatment.

The treatments were cost using prevailing wages, price of paraquat and tractor-hiring rate in Minna for 2009. Yield-cost ratio was computed as an index of cost effectiveness or economic efficiency by dividing the pooled yield with the cost of each treatment. Treatments with values higher or lower than that of the check ± standard deviation were rated as being significantly different from the check.

RESULTS AND DISCUSSION

Soil Parameters

In 2008, the penetrometer readings for the four reduced tillage treatments as well as ploughing and harrowing, and ploughing, harrowing and ridging were comparable with that of manual ridging (check), with values ranging from 62 to 75 kPa (Table 2). Each of the four zero tillage treatments, on the other hand, had a significantly higher penetration resistance than the check at 1 % level. The penetration resistance of the zero tillage treatments ranged from 127 to 151 kPa whereas that of the check was 62 kPa. A similar trend was observed in 2009 with reduced tillage treatments, ploughing and harrowing, and ploughing, harrowing and ridging recording similar penetration resistance with the check while the zero tillage treatments recorded significantly higher penetration resistance than the check at 5 or 1 % level. The values of penetration resistance were lower in 2008 than in 2009 for each of the treatments. The values ranged from

62 to 151 kPa in 2008 compared with 113 to 219 kPa in 2009, suggesting that the experimental plots were wetter when the measurements were taken in 2008 compared with 2009. Soil penetration resistance is a function of soil bulk density and moisture content. As a soil becomes wetter, its penetration resistance decreases.

The significantly higher soil strength observed in the zero tillage treatments did not translate to significant differences in crop growth and yield between each of the four zero tillage treatments on the one hand, and the check, on the other hand. This implied that the penetration resistance of the zero tillage treatments was not high enough to significantly inhibit root growth and reduce crop performance. The highest value of penetration resistance recorded in this trial was 219 kPa compared with the established critical level of 2,000 kPa that will stop root growth (Karunatilake *et al.*, 2000). While high penetration resistance is generally associated with zero tillage in the short term, penetration resistance may actually diminish with time if soil cover is preserved. For example, permitting dead roots to decompose intact thereby fostering soil macrofauna, especially earthworms, serve to naturally restructure soils through interconnective channeling, improving macro-aggregation, water infiltration and easing root penetration for the following crop (Sanginga and Woomer, 2009)

Average soil moisture content for the treatments varied from 10 to 12 g 100 g^{-1} in 2008 and 14 to 17 g 100 g^{-1} in 2009 (Table 2). Each of the ten test treatments had similar soil moisture condition with the check in both cropping seasons. The four zero tillage and reduced tillage treatments with surface residues did not conserve soil water better than the bare check. Water conservation might have been better under the conservation agricultural practices in this short- term experiment if

Table 2: Effect of ten conservation and conventional farming practices on soil penetration resistance and moisture content compared with that of manual ridging (check) in 2008 and 2009, using LSD test.

Conservation and conventional farming practices	Penetration resistance at 12WAP (kPa)		Average soil moisture content (g 100g^{-1})	
	2008	2009	2008	2009
Conservation				
Slash-and-mulch zero tillage	135**	219**	12 ns	15 ns
Herbicide-based zero tillage	138**	185*	11 ns	16 ns
Slash-and-mulch reduced tillage	67 ns	129 ns	12 ns	15 ns
Herbicide-based reduced tillage	68 ns	123 ns	13 ns	16 ns
Conventional				
Slash-and-clear zero tillage	151**	186*	10 ns	14 ns
Slash-and-burn zero tillage	127**	184*	12 ns	15 ns
Slash-and-clear reduced tillage	69 ns	132 ns	12 ns	15 ns
Slash-and-burn reduced tillage	68 ns	131 ns	12 ns	16 ns
Ploughing and harrowing	75 ns	121 ns	12 ns	15 ns
Ploughing, harrowing and ridging	63 ns	136 ns	12 ns	15 ns
Manual ridging (check)	62	113	11	17
$LSD_{.05}$	**45**	**66**	-	-
$LSD_{.01}$	**62**	**90**	-	-

Values of soil moisture content are averages of five measurements, WAP = weeks after planting, ns = not significantly different from the check, * = significantly different from the check at 5 % level, ** = significantly different from the check at 1 % level.

surface residues had been substantially more than 2,250 kg ha^{-1} in 2008 and 1,966 kg ha^{-1} in 2009. Aina *et al.* (1991) and Lopez *et al.* (1996) reported that no-till agriculture was ineffective for improving soil water conservation in their experiments because of low amounts of residue mulch. Conservation agriculture guidelines suggest that 5 – 8 t ha^{-1} of crop residues be applied as soil cover per year (Goddard *et al.,* 2008).

Crop Parameters

Seedling emergence varied from 64 to 76 % in 2008 and from 57 to 78 % in 2009 but the test treatments were not significantly different from the check in both cropping seasons (Tables 3 & 4). Vegetative growth of each of the ten test treatments measured as plant height did not differ significantly from that of the check at 2, 4, 6, 8 and 10 WAP in both years. The height of fully developed maize plants at 10 WAP ranged from 202.5 to 226.5 cm in 2008 and from 156.0 to 210.9 cm in 2009. Grain yield varied from 2,150 to 2,540 kg ha^{-1} in 2008, 1,817 to 2,530 kg ha^{-1} in 2009 and 2,043 to 2,387 kg ha^{-1} across both years (Table 3, 4 & 5). Stover+grain yield varied from 4,290 to 4,863 kg ha^{-1} in 2008 and from 3,450 to 4,850 kg ha^{-1} in 2009. However, no test treatment recorded significantly higher or lower yield than the check in either year or across both years.

A review of the results of field experiments in Nigeria in which conservation agriculture and no-till with mulch treatments were compared with various clean tillage practices showed that crop response was generally inconsistent, especially in the short term (Lal, 1976; Rodriquez and Lal, 1979; Ojeniyi, 1993; Odofin, 2005). In long-term experiments, however, higher productivity was associated with conservation agriculture and no-till with mulch treatments (Osuji, 1984; Lal, 1991).

Table 3: Maize response to ten conservation and conventional farming practices compared with that of manual ridging (check) in 2008, using the LSD test.

Conservation and conventional farming practices	Seedling emergence (%)	Plant height (cm)					Grain yield (kg ha^{-1})	Stover + grain yield (kg ha^{-1})
		2WAP	4WAP	6WAP	8WAP	10WAP		
Conservation								
Slash-and-mulch zero tillage	69^{ns}	19.1^{ns}	74.2	140.7^{ns}	201.3^{ns}	207.5^{ns}	2,300^{ns}	4590^{ns}
Herbicide-based zero tillage	64^{ns}	18.9^{ns}	75.2	141.1^{ns}	199.4^{ns}	202.5^{ns}	2,393^{ns}	4690^{ns}
Slash-and-mulch reduced tillage	69^{ns}	21.2^{ns}	87.3	152.2^{ns}	213.7^{ns}	215.4^{ns}	2,213^{ns}	4290^{ns}
Herbicide-based reduced tillage	68^{ns}	18.2^{ns}	80.6	144.3^{ns}	207.2^{ns}	212.2^{ns}	2,150^{ns}	4247^{ns}
Conventional								
Slash-and-clear zero tillage	68^{ns}	18.6^{ns}	72.5	133.9^{ns}	212.0^{ns}	218.5^{ns}	2,193^{ns}	4,460^{ns}
Slash-and-burn zero tillage	75^{ns}	17.9^{ns}	82.8	152.8^{ns}	220.5^{ns}	224.6^{ns}	2,540^{ns}	4863^{ns}
Slash-and-clear reduced tillage	74^{ns}	19.1^{ns}	87.1	155.1^{ns}	223.5^{ns}	226.5^{ns}	2,263^{ns}	4467^{ns}
Slash-and-burn reduced tillage	66^{ns}	18.6^{ns}	84.0	151.4^{ns}	210.0^{ns}	217.6^{ns}	2,330^{ns}	4667^{ns}
Ploughing and harrowing	71^{ns}	19.9^{ns}	83.7	151.9^{ns}	218.7^{ns}	223.5^{ns}	2,330^{ns}	4617^{ns}
Ploughing, harrowing and ridging	76^{ns}	21.5^{ns}	85.7	149.1^{ns}	220.7^{ns}	225.2^{ns}	2,313^{ns}	4630^{ns}
Manual ridging (check)	73	21.0	95.5	165.9	224.3	226.4	2,393	4863

WAP = weeks after planting, ns = not significantly different from the check.

Table 4: Maize response to ten conservation and conventional farming practices compared with that of manual ridging (check) in 2009, using the LSD test.

Conservation and conventional farming practices	Seedling emergence (%)	Plant height (cm)					Grain yield (kg ha^{-1})	Stover + grain yield (kg ha^{-1})
		2WAP	4WAP	6WAP	8WAP	10WAP		
Conservation								
Slash-and-mulch zero tillage	69 ^{ns}	23.0 ^{ns}	60.0 ^{ns}	121.4 ^{ns}	163.7 ^{ns}	177.5 ^{ns}	1,997 ^{ns}	3,683 ^{ns}
Herbicide-based zero tillage	74 ^{ns}	22.5 ^{ns}	60.7 ^{ns}	113.3 ^{ns}	137.6 ^{ns}	156.0 ^{ns}	1,843 ^{ns}	3,730 ^{ns}
Slash-and-mulch reduced tillage	57 ^{ns}	23.2 ^{ns}	63.0 ^{ns}	125.4 ^{ns}	168.9 ^{ns}	184.0 ^{ns}	2,107 ^{ns}	3,957 ^{ns}
Herbicide-based reduced tillage	72 ^{ns}	24.3 ^{ns}	63.4 ^{ns}	114.3 ^{ns}	142.7 ^{ns}	159.1 ^{ns}	1,957 ^{ns}	3,723 ^{ns}
Conventional								
Slash-and-clear zero tillage	69 ^{ns}	21.8 ^{ns}	68.2 ^{ns}	127.4 ^{ns}	170.8 ^{ns}	174.2 ^{ns}	2,130 ^{ns}	3,990 ^{ns}
Slash-and-burn zero tillage	68 ^{ns}	26.7 ^{ns}	75.7 ^{ns}	141.1 ^{ns}	172.9 ^{ns}	181.4 ^{ns}	1,827 ^{ns}	3,450 ^{ns}
Slash-and-clear reduced tillage	78 ^{ns}	24.6 ^{ns}	73.6 ^{ns}	141.4 ^{ns}	177.5 ^{ns}	184.4 ^{ns}	1,817 ^{ns}	3,503 ^{ns}
Slash-and-burn reduced tillage	74 ^{ns}	25.1 ^{ns}	74.8 ^{ns}	143.4 ^{ns}	178.6 ^{ns}	184.2 ^{ns}	2,157 ^{ns}	3,973 ^{ns}
Ploughing and harrowing	76 ^{ns}	26.3 ^{ns}	75.9 ^{ns}	151.4 ^{ns}	186.2 ^{ns}	191.9 ^{ns}	2,530 ^{ns}	4,850 ^{ns}
Ploughing, harrowing and ridging	69 ^{ns}	24.1 ^{ns}	73.6 ^{ns}	153.2 ^{ns}	195.9 ^{ns}	205.6 ^{ns}	2,443 ^{ns}	4,790 ^{ns}
Manual ridging (check)	67	25.2	87.5	169.5	205.8	210.9	2,377	4,497

WAP = weeks after planting, ns = not significantly different from the check.

Table 5: Pooled grain yield (2008 and 2009) and yield-cost ratio of ten conservation and conventional farming practices compared with those of manual ridging (check).

Conservation and conventional farming practices	Pooled grain yield (kg ha^{-1}) across 2008 and 2009	Average cost of treatments (₦ ha^{-1})	Yield-cost ratio
Conservation			
Slash-and-mulch zero tillage	2,150 ^{ns}	9,000	0.24 *
Herbicide-based zero tillage	2,120 ^{ns}	13,600	0.16 *
Slash-and-mulch reduced tillage	2,163 ^{ns}	17,000	0.13 ^{ns}
Herbicide-based reduced tillage	2,057 ^{ns}	21,600	0.10 ^{ns}
Conventional			
Slash-and-clear zero tillage	2,163 ^{ns}	11,000	0.20 *
Slash-and-burn zero tillage	2,183 ^{ns}	15,500	0.14 ^{ns}
Slash-and-clear reduced tillage	2,043 ^{ns}	19,000	0.11 ^{ns}
Slash-and-burn reduced tillage	2,247 ^{ns}	23,500	0.10 ^{ns}
Ploughing and harrowing	2,433 ^{ns}	37,300	0.07 ^{ns}
Ploughing, harrowing and ridging	2,380 ^{ns}	55,100	0.04 ^{ns}
Manual ridging (check)	2,387	27,000	0.09

a. Least significant difference (LSD) test was used for comparing the pooled grain yield of each treatment with that of the check.

b. For yield-cost ratio, treatments with values higher or lower than that of the check ± standard deviation were rated as being significantly different from the check. Yield-cost ratio (check) ± Sd = 0.09 ± 0.06 = 0.03 to 0.15.

c. ns = not significantly different from the check, * = significantly different from the check. conservation practices are required before soil properties improve through continuous no-till and full stubble and residue retention.

Adoption Potential

In terms of cost, a lot of variation was observed among the treatments as shown in Table 5 and this gave rise to significant differences in yield-cost ratio, with slash-and-mulch, slash-and- clear and herbicide-based zero tillage treatments proving to be significantly more economical than the check. Among these three, only slash-and-mulch and herbicide-based zero tillage treatments are recommended for promotion among Nigerian farmers. The third treatment, namely slash-and-clear zero tillage, is not recommended because it violates the principle of keeping the soil covered. Slash-and-mulch and herbicide-based reduced tillage treatments which recorded insignificantly higher yield-cost ratio than the check are recommended, in addition to the earlier two, for promotion among farmers. Peasant farmers cleaedr or burnt surface residues because their presence interfered with manual field operations such as planting, fertilizer application and weeding, thereby making them more difficult to carry out. Switching to slash-and-mulch and herbicide-based reduced tillage practices may be more acceptable to peasant farmers than switching to slash-and-mulch and herbicide-based zero tillage practices because the planting lines or crop rows are clean in the former and manual operations such as planting and fertilizer application can be carried out with little interference.

Many indigenous practices in Africa have elements of what we now call conservation

agriculture (IIRR and ACT, 2005). For Nigerian peasant farmers, zero and reduced tillage practices are age-long practices and they conform to Principle 1 of conservation agriculture: disturbing the soil as little as possible. Cereal and legume seeds are often planted in untilled soil by making holes with cutlass for seed placement or the seeds are planted in small mounds made with hoe. Secondly, the dominant cropping system in Nigeria is intercropping which conforms to Principle 3 of conservation agriculture: mixing and rotating crops. Thirdly, manual application of agrochemicals generally favours precision placement and promotes use efficiency (Principle 4). Peasant farmers commonly apply fertilizers manually by side placement and not by broadcasting or banding. Regrettably, however, the planting of most fields is preceded with slashing and clearing, or more often, slashing and burning of weeds and litter to produce a clean field, thereby violating Principle 2: maintaining soil cover. Within the context of conservation agriculture, plant residues are regarded as important organic sources and burning them is anathema. Burning is an inefficient shortcut to accelerated nutrient availability but when plant residues are preserved and left in the field as mulch, nutrient recycling is promoted.

In spite of the high adoption potential, with farmers already practicing three out of the four principles of conservation agriculture, why then are Nigerian farmers not embracing conservation agriculture? Rumley and Ong (2007), rightly identified the greatest obstacle toward African smallholder compliance to conservation agriculture as the requirement for continuous soil cover with crop residues and mulch. Annual bush fires and household dependence upon crop residues for other purposes such as livestock feed, fuel and shelter constitute serious challenges. Switching to conservation agriculture can also be a challenge because farmers have to learn new skills such as chemical weed control and acquire new equipment such as jab-planter, ripper, knapsack sprayer and direct seeder.

It is concluded that slash-and-mulch and herbicide-based zero and reduced tillage practices could be substituted for conventional farming practices without significant reduction in soil productivity and maize yield and at higher or comparable economic efficiency in the short term. Government involvement in promoting conservation agriculture through various extension approaches and providing support infrastructure is essential before farmers can begin practicing conservation agriculture and this is currently lacking in Nigeria.

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