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Sustaining Crop Production Through Conservation Tillage in Ghana

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Abstract: No-till demonstrations were carried out on farmers' fields in the forest, transition and coastal savannah zones of Ghana from 1997 to 2003. The purpose was to create awareness among farmers of the benefits of intensifying crop production on a piece of land by (i) eliminating burning (ii) increasing organic matter on the soil surface (iii) reducing or eliminating cultivation that destroys the soil structure and (iv) using herbicides to help reduce hand labour and save time for other operations. The no-till plots recorded greater maize yield (58-82%) than the farmers' practice in all cases. Maize yield in the forest and transition zones was greatest for PRE application of alachlor+atrazine. Post application of alachlor+atrazine resulted in smaller maize yield. Economic analysis of the yield gave marginal rate of return of 733% for the forest, 301% for the transition and 112% for the coastal savannah for PRE applied alachlor+atrazine. The corresponding values for Post applied alachlor+atrazine were 287% for the forest and 124% for the transition. The no-till demonstrations have shown that (i) there is nothing to be gained by continually relying on the traditional slash and burn systems and (ii) the time of applying alachlor+atrazine is critical to maximise yield. The results indicate that farmers can get better returns to the money invested in herbicides for producing maize under no-till than with their traditional practice.

Key words: Conservation tillage, crop production, herbicide, Ghana

Introduction

Tillage is the manipulation of the soil to grow crops and conservation tillage connotes minimum disturbance of the soil for crop production. The long term goal of conservation tillage with residue is to minimise erosion and compaction and increase crop yields via the addition of organic matter, water conservation, as well as savings in fossil energy and preventing human drudgery (Triplett and van Doren, 1977; Wall and Stobbe, 1984; Dick *et al*., 1991; Wagger and Denton, 1992; Lithourgidis *et al*., 2005, 2006).

There is a big move from crop production using soil preparation techniques that invert the soil and destroy soil structure, to that of reducing tillage to give a minimum soil disturbance and build up the soil structure with organic matter in and on the soil. As a result, there are about 72 million hectares under no-tillage worldwide (Beyaert *et al*., 2002). Soil that has a high organic matter content and is covered by some form of vegetation is considerably less likely to erode than soil that has no organic matter content nor cover (i.e., bare soil). Ploughing is an age-old technology for preparing a seedbed

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and controlling weeds. However, if the soil condition is improved with organic material to produce an acceptable seedbed and weeds are controlled with herbicides, the reasons for ploughing are drastically reduced. Removal of all vegetation or crop residue from the soil surface reduces the penetration of moisture and its retention, resulting in dehydration and deterioration of the soil to a stage of poor fertility and thus poor crop production. Crop residue management associated with conservation tillage has been shown to minimise fuel costs, soil water evaporation, erosion and temperature fluctuations (Triplett and van Doren, 1977; Wall and Stobbe, 1984; Dick *et al*., 1991; Wagger and Denton, 1992; Lithourgidis *et al*., 2005, 2006).

The unavoidable negative effects of intensive and repeated soil tillage in the tropics and subtropics on organic matter content, soil erosion, soil structure, soil temperature, soil moisture, water infiltration, soil flora and fauna (soil biological processes) and loss of nutrients, result in chemical, physical and biological soil degradation (Ofori, 1995; Kladivko, 2001; Kay and van den Bygaart, 2002; Carpenter-Boggs *et al*., 2003). This results in diminishing yields over time and in productivity losses of the soil and leads to poor soils and farmers.

As a consequence of the laws of diminishing productivity of tropical soils, sustainability of agricultural or livestock production can not be achieved as long as repeated and intensive soil tillage is performed in the tropics and subtropics. Sustainability also can not be achieved as long as the soil is exploited without reposition of nutrient losses through leaching and/or extractions that occur with harvests and as long as frequent burning of fields is performed (Giovaninni and Lucchesi, 1997).

Farmers in Ghana, especially those in the forest and transition zones, practice no-tillage as a traditional method in association with shifting cultivation. The vegetation is slashed and burnt and the crops are established by making holes to place the seed and planting materials without disturbing the soil. This traditional system can be improved by discouraging burning among farmers to obtain the full benefit of stubble mulch, which would result in improved infiltration of moisture, reduce or minimise erosion (Wagger and Denton, 1992) and increase crop yield. The practice of burning can be replaced by manual operations for early and effective weed control or by the use of herbicides. The current pressure on arable land lends itself to intensifying production on a given piece of land since the practice of using shifting cultivation and natural fallows to help regenerate the fertility of lands can no longer be sustained. In other areas, farmers prepare the land by using hoes or by ploughing with tractors. Ploughing with tractors is normally not well done because most of the tractor operators are not well trained. As a result, gullies are left after a ploughing operation which results in serious soil erosion. In addition, the cost of ploughing is increasing daily, making it out of the reach of most small and medium scale farmers.

The earliest research on no-till in Ghana started in the late 1960s (Ofori, 1973) and was boosted by Mensah-Bonsu and Obeng (1979) who reported the beneficial effects of no-till on soil and water conservation. These first researchers controlled weeds with paraquat. In the 1990s the no-till research effort was concentrated in the Crops Research Institute (CRI) through the Ghana Grains Development Project (GGDP). Later, Sasakawa Global 2000 (SG2000), Monsanto and the Ministry of Food and Agriculture (MoFA) teamed up with GGDP/CRI to promote no-till in the forest, transition and coastal savannah zones.

The purpose of the demonstrations is to create awareness among farmers of the benefits of intensifying crop production on a piece of land by (i) eliminating burning (ii) increasing organic matter on the soil surface (iii) reducing or eliminating cultivation that destroys the soil structure and (iv) using herbicides to help reduce hand labour and save time for other operations.

The aim of this study is to present results of the field demonstrations that assessed the yield of maize grown under no-till using herbicides compared to the farmers' practice of slash and burn in Ghana. A subsidiary aim is to find out how the timing of application of alachlor + atrazine affects maize yield.

Materials and Methods

Demonstrations were carried out at 10 sites or more in the forest, transition and coastal savannah zones of Ghana from 1997 to 2003. Two options were established at each site, the no-till with herbicides and the farmers' traditional practice, mainly slash and burn or ploughing in a few cases. The plot size was 50×20 m and maize was planted at 80×40 cm, 2 seeds per hill. The variety used was 'Obatanpa' an open pollinated Quality Protein Maize (QPM). The no-till plots were treated with glyphosate (360 g a.i. L^{-1}) at 5 L ha^{-1} as a pre-plant vegetation control and the maize planted through the resulting mulch. A combination of alachlor 300 g a.i. L^{-1} + atrazine 180 g a.i. L^{-1} was applied immediately after planting at 5 L ha^{-1} to control pre-emergence weeds. Farmers were allowed to apply the alachlor + atrazine in an attempt to satisfy the subsidiary aim. The herbicides were applied using knapsack sprayers calibrated to deliver 150 L ha^{-1} of spray solution using low volume nozzles. Compound fertilizer (N-P-K, 15-15-15) was applied as a starter at planting or immediately after germination and urea or sulphate of ammonia side dressed at 4 weeks after planting to give a total of 90:38:38 N : P_2O_5: K_2O kg ha^{-1} for the transition and coastal savannah zones and 45:19:19 N: P_2O_5: K_2O kg ha^{-1} for the forest (GGDP, 1992). Ears were harvested from a representative portion of size 10×10 m per plot and the yield was calculated for 15% moisture from the moisture content at harvest and assuming 80% shelling. The yield data were analyzed using analysis of variance (ANOVA) and the means were separated by single degree of freedom contrasts. Data presented are from 1999 to 2003. Economic analysis was performed using the partial budget analysis (CIMMYT, 1988) based on the following costs (US $) per hectare: glyphosate, 13.5; alachlor+atrazine, 18.3; spraying glyphosate, 6.17; spraying alachlor+atrazine, 6.17; renting of sprayer, 6.67; hauling of water, 3.33; hand weeding, 16.67; compound fertilizer, 22.5; urea, 11.25, seed maize, 11.25; labour (5 man days) of applying fertilizer per ha, 13.5; harvested maize, 83.33 per Mg. The marginal rate of return (MRR), which is the increased benefit of an option as a percentage of the increased cost, was used to determine the benefits to farmers (CIMMYT, 1988).

Results and Discussion

The effect of the tillage practices on maize yield across the agro-ecological zones are shown in Tables 1-3. Maize yield was greatest in the forest and transition zones for PRE applied alachlor+atrazine. Post application of alachlor + atrazine resulted in smaller maize yield; 55% for the forest, 67% for the transition. The no-till plots recorded greater maize yield than the farmers' practice in all cases. Maize yield was largest in the forest followed by the transition and the coastal savannah. The greater yield in no-till plots compared with the traditional practice (even for Post applied alachlor+atrazine) is consistent with previous results (Aflakpui *et al*., 1993; Lal and Ragland, 1993; Sayre, 1998).

The observed trend in yield across the agro-ecological zones may be attributed to greater amount of rainfall coupled with the amount of mulch which was greatest in the forest followed by the transition and the coastal savannah. Additionally, weeds were better controlled in the plots treated with herbicides at all sites compared with the farmers' practice. The other benefits associated with no-till such as greater alkaline phosphatase activity and readily mineralisable carbon (Carpenter-Boggs *et al*., 2003), greater concentration and storage of soil organic carbon (Deen and Kataki, 2003) and greater abundance or biomass of soil organisms (Kladivko, 2001) may also have contributed to greater yield. In addition, farmers in the forest and transition zones seem to be more conversant with the practice of no-till because the technology transfer activities started earlier in the forest and transition zones than in the coastal savannah. The level of acceptance is exemplified by the observation that some farmers in the forest zone always carry mulch from adjacent fallow lands to their maize fields anytime the level of mulch reduces due to decomposition.

Table 1: Maize yield (Mg ha^{-1}) from tillage demonstrations, forest zone, Ghana, 1999- 2003

	Year					
Option	1999	2000	2001	2002	2003	Mean
Farmers' practice	1.12	1.34	1.58	1.14	1.22	1.28
NT (Post)	3.78	4.13	4.21	4.37	4.11	4.12
NT (PRE)	6.96	7.07	8.12	7.45	7.39	7.39
SE	1.20	1.33	0.99	0.39	0.26	
Contrasts						
Farmers' vs (Post)	**	**	**	**	**	
Farmers' vs (PRE)	***	***	***	***	***	

NT (Post) = No-till with Post applied alachlor+atrazine; NT (PRE) = No-till with PRE applied alachlor+atrazine, Means in a column differ at **p<0.01, ***p<0.001

Table 2: Maize yield (Mg ha^{-1}) from tillage demonstrations, transition zone, Ghana, 1999- 2003

	Year					
Option	1999	2000	2001	2002	2003	Mean
Farmers' practice	1.23	NA	1.28	1.63	1.70	1.46
NT (Post)	3.46	3.45	3.48	3.12	4.18	3.53
NT (PRE)	5.05	5.30	5.95	4.28	5.86	5.23
SE	0.54	0.39	0.67	0.12	1.07	
Contrasts						
Farmers' vs (Post)	**	**	**	**	**	
Farmers' vs (PRE)	***	***	***	***	***	

NT (Post) = No-till with Post applied alachlor+atrazine; NT (PRE) = No-till with PRE applied alachlor+atrazine, Means in a column differ at **p<0.01, ***p<0.001

Table 3: Maize yield (Mg ha^{-1}) from tillage demonstrations, coastal savannah zone, Ghana 1999- 2003

	Year					
Option	1999	2000	2001	2002	2003	Mean
Farmers' practice	1.09	1.26	0.90	1.50	1.07	1.16
NT (Post)	NA	NA	NA	NA	NA	NA
NT (PRE)	2.71	3.5	2.90	3.70	3.80	3.32
SE	0.34	0.18	0.41	0.19	0.39	
Contrasts						
Farmers' vs (Post)	NA	NA	NA	NA	NA	
Farmers' vs (PRE)	**	**	**	***	***	

NT (Post) = No-till with Post applied alachlor+atrazine; NT (PRE) = No-till with PRE applied alachlor+atrazine, NA = data not available, Means in a column differ at **p<0.01, ***p<0.001

Farmers in the forest zone have been using atrazine in their maize fields for some time now because of earlier recommendations (GGDP, 1992). In almost all cases farmers have used atrazine to kill broadleaf weeds by spraying it in their maize field anytime from 2 to 6 weeks after planting. This practice may have been extended to the use of alachlor+atrazine with very little or no benefit. In all years, the yield results emphasize the need to PRE apply alachlor+atrazine. This emphasis is necessary because of the persistent delay by farmers to apply alachlor+atrazine. The demonstrations on no-till have been emphasizing the need to PRE apply alachlor+atrazine to cooperating farmers but it appears more time is needed to educate farmers to accept and adopt this practice. In these demonstrations, the delay in applying alachlor+atrazine varied from 2 to 8 weeks after planting. The yield figures indicate that farmers who do not PRE apply alachlor+atrazine are likely to have their maize yield reduced by about 44% in the forest and 33% in the transition zone. The reduction in yield could be due to ineffective weed control as well as phytotoxicity to maize thereby reducing photosynthesis.

Some cooperating farmers have attributed their inability to PRE apply alachlor+atrazine to the unavailability of knapsack sprayers. They argue that the time interval from planting to the application of alachlor+atrazine is so short that the critical period elapses before the farmers get the sprayer.

Table 4: Economic analysis of tillage demonstrations, forest zone, 1999-2003 (costs in US \$ ha^{-1})

Tillage	Farmers' practice	NT (PRE)	NT (Post)
Average yield (Mg ha^{-1})	1.28	7.39	4.12
Gross benefit	106.70	615.80	343.30
Costs that vary			
Glyphosate	0.00	13.50	13.50
Alachlor + atrazine	0.00	18.30	18.30
Spraying glyphosate	0.00	6.17	6.17
Spraying alachlor + atrazine	0.00	6.17	6.17
Renting of sprayer (2X)	0.00	6.67	6.67
Hauling of water (2X)	0.00	3.33	3.33
Hand weeding	33.33	0.00	0.00
Compound fertilizer (NPK)	0.00	11.25	11.25
Ammonia	0.00	5.63	5.63
Application of fertilizer	0.00	16.67	16.67
Transporting fertilizer	0.00	6.75	6.75
Total	33.33	94.44	94.44
Net benefit	73.37	521.36	248.86
Marginal rate of return (%)		733.00	287.00

NT (post) = No-till with Post applied alachlor+atrazine; NT (PRE) = No-till with PRE applied alachlor + atrazine

Table 5: Economic analysis of tillage demonstrations, transition zone, 1999-2003 (costs in US \$ ha^{-1})

Tillage	Farmers' practice	NT (PRE)	NT (Post)
Average yield (Mg ha^{-1})	1.30	5.30	3.54
Gross benefit	108.30	441.60	287.50
Costs that vary			
Glyphosate	0.00	13.50	13.50
Alachlor+atrazine	0.00	18.30	18.30
Spraying glyphosate	0.00	6.17	6.17
Spraying alachlor+atrazine	0.00	6.17	6.17
Renting of sprayer (2X)	0.00	6.67	6.67
Hauling of water (2X)	0.00	3.33	3.33
Hand weeding	33.33	0.00	0.00
Compound fertilizer (NPK)	0.00	22.50	22.50
Ammonia	0.00	11.25	11.25
Application of fertilizer	0.00	16.67	16.67
Transporting fertilizer	0.00	13.50	13.50
Total	33.33	118.06	118.06
Net benefit	88.37	343.80	193.74
Marginal rate of return (%)		301.00	124.00

NT (Post) = No-till with Post applied alachlor + atrazine; NT (PRE) = No-till with PRE applied alachlor + atrazine

Table 6: Economic analysis of tillage demonstrations, coastal savannah zone, 1999-2003 (costs in US \$ ha^{-1})

Tillage	Farmers' practice	NT (PRE)	NT (Post)
Average yield (Mg ha^{-1})	1.26	3.50	NA
Gross benefit	104.90	291.70	NA
Costs that vary			
Glyphosate	0.00	13.50	13.50
Alachlor+atrazine	0.00	18.30	18.30
Spraying glyphosate	0.00	6.17	6.17
Spraying alachlor+atrazine	0.00	6.17	6.17
Renting of sprayer (2X)	0.00	6.67	6.67
Hauling of water (2X)	0.00	3.33	3.33
Hand weeding	33.33	0.00	0.00
Compound fertilizer (NPK)	0.00	22.50	22.50
Ammonia	0.00	11.25	11.25
Application of fertilizer	0.00	16.67	16.67
Transporting fertilizer	0.00	13.50	13.50
Total	33.33	118.06	118.06
Net benefit	63.37	158.64	NA
Marginal rate of return (%)	112.00	NA	

NT (Post) = No-till with Post applied alachlor+atrazine; NT (PRE) = No-till with PRE applied alachlor+atrazine; NA = data not available

Irrespective of this, the yield of the no-till demonstrations have shown that there is nothing to be gained by continually relying on the traditional slash and burn systems. This is further emphasised by the economic analysis (Tables 4-6) that gave a marginal rate of return of between 287 and 733% for the forest, 124 and 301% for the transition and 112% for the coastal savannah.

Despite these good results from the demonstrations, there are some constraints that need to be addressed to enhance adoption of no-till by many more farmers. These include: 1). Lack of appropriate equipment for slashing and planting. Farmers who are changing from the traditional slash and burn still use their old equipment which are not always appropriate for the no-till fields that are covered with mulch. 2). The promotion of the no-till programme has concentrated on the small-scale farmers for some time now. There is an emerging group of medium to large scale farmers who must be targeted to broaden the scope of the programme. This definitely re-emphasizes the need for simple and appropriate equipment. 3). Inadequate integration of cover crops and crop rotation in no-till. More research and extension efforts are needed on crop rotation to help reduce pest and disease pressures. 4). The lack of well organized and coordinated farmer groups makes it difficult to implement policies not only on no-till but all other agricultural related policies.

Conclusions

The results indicate that farmers can get better returns to the money invested in herbicides for producing maize under no-till than with their traditional practice of slash and burn. Timely application of alachlor+atrazine is critical since farmers who did not PRE apply alachlor+atrazine had their maize yield reduced by about 44% in the forest and 33% in the transition zone.

To enhance the adoption of no-till, there is the need to develop appropriate farm tools or adapt existing ones, use cover crops and crop rotation to sustain soil cover and to focus on medium to large scale farmers through dynamic and well organized groups.

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