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Combining Organic and In-organic Fertilizers for Sustainable Maize Production under Two Tillage Systems in the Northern Savanna Zone of Ghana

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Abstract Soils in the northern savanna zone of Ghana are poor in plant nutrients and are prone to compaction. Some amount of tillage and the application of fertilizers to enhance crop yields are necessary. To assess the performance of maize (cv: *Obatanpa*) on two tillage systems (Manual and bullock plough) by the application of different fertilizers on the same plots for two years, a field experiment was laid in a split-plot design with four replicates. The main plots were the tillage systems and the sub-plots were different fertilizers made up of recommended rates of in-organic fertilizers (64 kg N/ha, 15 kg $P_20_{5/}$ha and 15kg K_20/ha), 6 tons/ha of animal manure, half the rate of in-organic (32 kg N/ha, 7.5 kg $P_20_{5/}$ha and 7.5kg K_20/ha), and half the rate of animal manure (3 tons/ha) and no fertilizer as the control in 2008 and 2009 at Nyankpala, Ghana. Tillage loosened the soil and thus reduced soil bulk density, increased porosity and could have enhanced the availability of water and nutrients for better crop growth. The application of animal manure alone increased maize yields in the second year by 57% as compared to 25% and 35% for the recommended fertilizer rates and half the rates, respectively. However, maize yields from the recommended fertilizer rates and the half rates of both in-organic fertilizers and animal manure in each year were similar but significantly ($p<0.05$) higher than yields from the manure and the control treatments. For sustainability, the application of half rates of the in-organic and animal manure could be recommended. Bullock plough with higher benefit-cost ratios and benefits than the manual system was a better tillage method in terms of economic returns to investment.

Keywords Tillage Systems, In-organic Fertilizers, Organic Fertilizers, Yield, Economic Returns

Introduction

Low grain yields of cereals especially maize in Northern Ghana have been attributed to poor soils. For the past decade, low fertility status of soils has been ranked first among the constraints collated from all the districts of northern region of Ghana at the regional planning sessions [1]. In the Northern region of the country, land preparation for crop production is carried out manually by hand hoe, bullock plough, tractor and to some extent, the slash and burn method (zero tillage) with or without the use of herbicides [2]. Among these tillage systems, the hoe farming method is the most common tillage practice in Northern Ghana [3].

Of late however, due to the intervention by several Non-Governmental Organizations (NGOs) to enhance the food security situation in this part of the country, many more farmers have been acquiring bullocks for land preparation [4]. The hand hoe tillage practice which has been described [5], as mainly for weed control probably because it is not deep enough as in bullock and tractor tillage systems suggests that the latter tillage practices can be beneficial in storing soil water for crop production in Northern Ghana.

The effect of the application of organic and in-organic fertilizers separately and in combination of both to enrich the soil of its nutrients for high grain yields of cereals have been for the past years compared and results are available [6]. Similarly, the application of Farm yard manure and in-organic fertilizers separately and in combination of both to maize, showed a significant high fodder yield in the combined treatments over the organic or in-organic fertilizers alone [7]. Results from experiments in this direction indicate that the best yields of maize were obtained when half the recommended dose of in-organic fertilizer was combined with three tons (3 tons) of animal manure (organic fertilizer) and applied to the soil [8]. Also, on the effect of different sources of N on the yield of maize, [9] found increasing maize yields with increasing tillage depth and increasing N irrespective of its source.

There is therefore enough information on the role of integrated soil fertility management (ISFM), i.e combined application of organic and mineral fertilizers on the yield of crops in Northern Ghana. However, information on the effect of ISFM on the yield of maize on different tillage systems and the economic returns of maize produced on these tillage systems in the northern region of Ghana is scanty.

The objectives of this study were therefore (i) to assess the yield and yield components of maize on the two commonly practiced tillage methods as affected by the application of both organic and in-organic fertilizers and (ii) to assess and compare the economic returns of maize produced under the two systems with the application of organic and in-organic fertilizers.

Materials and Methods

Location and period of study

The trial was carried out during 2008 and 2009 on the experimental field of the Savanna Agricultural Research Institute (SARI) at Nyankpala located in northern Ghana (Lat 9^0 25"N, Long 1^0 00"W and at 183 m above sea level). The annual rainfall in this area is between 800 and 1200 mm. Maize (*cv Obatanpa*) which was obtained from the Crop Breeding Section of SARI was used as the test crop in the trial.

Experimental design and treatments

The experiment was laid out in a split-plot design with four replications. The main plots were tillage systems which were made up of manual (hand hoe) and bullock plough while the sub-plots were four: Recommended fertilizer rates of in-organic fertilizers (NPK & SA) as 64 kg N/ha, 15 kg P_20_5/ha and 15kg K_20/ha, 6 tons/ha of animal manure, Half-rates of Recommended in-organic fertilizers (32 kg N/ha, 7.5 kg P_20_5/ha and 7.5kg K_20/ha) and half rate of animal manure (3 tons/ha) and a Control (No in-organic fertilizer and no animal manure applied). Each replicate had four plots measuring 5 m by 4 m, representing the four treatments, giving a total of 16 experimental units.

Soil and crop management

The experimental site was ploughed and harrowed twice on the same set of plots as per the tillage treatments in 2008 and 2009. The maize crop was sown on 15 July 2008 and on 10 July 2009. The maize was sown on flat in rows (80 cm x 40 cm) with 2 plants/hill. A net plot from the middle of each plot measuring 5 m x 2.25 m was used for grain-yield assessment. Before the planting of the maize crop, a composite sample of both the soil and the animal manure were analysed for NPK and pH.

To ensure proper seed germination, plots in the hand hoe treatments were loosened up with a hoe before maize seeds were planted. Plots were kept weed-free by hoeing manually three times before harvest. In order to meet the various nutrient requirements as treatments for the experiment, the following were adhered to: (1) 5 bags/ha of compound fertilizer (15-15-15) representing the recommended in-organic fertilizer rates applied at planting as basal and top-dressed with 2.5 bags of sulphate of Ammonia at 8 weeks after planting. The second plot received only 6 tons/ha of the animal manure at planting while the third plot had half rates of both the in-organic fertilizer and the animal manure i.e. 2.5 bag/ha of compound fertilizer (15-15-15) and 1.75 bags/ha of Sulphate of Ammonia combined with 3 tons/ha of the animal manure while the last plot never received any type of fertilizer at all as the control.

Soil and crop data collection

Soil Properties: Tillage depth, soil bulk density and soil porosity

Tillage depth of both bullock plough and manual systems were measured by gently pressing a metre rule into the soil in each plot and in each of the tillage system until the rule was no more penetrating. The graduation (mark) at the surface of the soil on the rule in each of the tillage practices was recorded as the depth of tillage of that system. Soil bulk density was measured by the core method up to a depth of 30 cm. A core with known dimensions was used in collecting soil samples by pressing it down into the soil at 0-15 cm and 15-30 cm randomly in each plot. These were each weighed and oven dried and weighed again. The bulk density was calculated by dividing the total weight of oven dried soil by the volume of the core. The porosity of the soil was then calculated as follows:

$f = (1 - P_b / P_s) \times 100$

Where, f is porosity, P_b is bulk density of the soil and P_s is particle density (2.65 g cm^{-3}).

Crop Parameters: Plant height, stover weight and yields of Maize

Plant height of maize was determined by randomly selecting four plants per plot. These plants were tagged and their heights taken bi-weekly throughout the growth period and average determined each time. Plant height measurement started at 2 weeks after planting (2 WAP) up to 8 weeks after planting (8 WAP). Before harvesting, the number of lodged maize plants was also counted in each plot to assess the effect of both tillage and fertilizer application on maize lodging. After harvesting, the weight of maize straw (stover) was obtained from each net plot by placing in a sack and weighing it with a spring balance and the values expressed on a per hectare basis. The shelling percent of maize was calculated as the weight of maize grains (xg) divided by the weight of the selected ears or cobs (zg) and expressed as a percentage: xg/zg x 100. In each plot, Cob length and number of grains/ cob were determined. This was done by randomly selecting ten (10) ears or cobs and their lengths measured and an average found per cob. These ears were then shelled and the number of grains/cob determined. To obtain the one-hundred seed weight of maize after shelling, 100 grains were randomly picked and weighed using an electronic scale. The ears (cobs) of maize from each net plot were sun-dried after harvesting. The dried maize cobs were shelled to obtain grain yield (weight) per plot. Grains of maize were sun-dried to a moisture content of 10% after shelling. The grain yield per plot was determined and expressed on a hectare basis.

Economic Analyses

Economic analysis was carried out to compare the profitability of producing maize on both tillage systems using the same inputs. The crop enterprise budget technique developed by [10] where the benefit cost ratio of the two tillage systems was used to assess the economic returns on investment. The cost of all recommended variable inputs used in the study were considered. Crop prices and all input prices were surveyed in the study area using seasonal averages that prevailed in the study area during the cropping seasons. The value of the maize crop was taken at harvesting periods and therefore there was no cost borne for storage. Variable costs were the actual prices paid by farmers each year which included the different types of fertilizers. Net returns per hectare were then calculated as the difference between the gross income and total variables costs. The net benefit-cost ratio was therefore calculated by dividing the benefits by the total variable costs as:

$$B/C = \frac{NB}{TVC}$$

Where, B/C is benefit cost ratio, NB is net benefit and TVC is total variable cost.

Data analysis

Data were subjected to an analysis of variance for a split-plot design using GENSTAT to determine treatment effects. Treatments were considered fixed effects, years and replication were treated as random variables. Main effects and all the interactions were considered significant at $P<0.05$. Means were separated with Least Significant Difference (LSD) at 5% level of probability.

Results and Discussion

Initial soil and animal manure properties

Results of the soil analysis at the start of the experiment in 2008 showed that the soil was made up of 75% sand, 12.6% silt and 12.2% clay. The soil identified as *Tingoli series or Ferric Luvisol* [11] is formed in-situ over weathered products of Voltaian sandstone on middle slope site of gentle sloping topography. It is deep, well drained, red in colour with a thin (<10cm) brown granular and humus-stained top-soil overlying a thick red, clayey, gravely sub-soil. It was further revealed that the top 0-15 cm of the soil is slightly acidic (pH 6.2) with generally low level of total nitrogen (0.042%), available P (11.0 mg/kg), organic carbon (0.43%) and exchangeable cations. The analysis of the manure used also showed N to be an average of 1.4 %, P (230 mg/kg) and K (1370 mg/kg).

Effect of tillage and fertilizer on some soil properties

In each year, tillage × fertilizer type interactions were statistically significant for all parameters measured, indicative of fertilizer difference in the response of the two different tillage systems to the four fertilizer treatments. Additionally, there were differences between years and for this reason data were presented for each fertilizer type on each tillage system separately for each year

Tillage depth

Tillage systems in 2008 and 2009 significantly ($p<0.05$) influenced the depth of tillage in the study (Table 1). The average depth of tillage recorded for the manual was 6 cm while the Bullock plough went as deep as 12 cm. It was therefore realized that using manual tillage system reduced the depth of tillage by more than 50 %. The greatest working depth recorded by bullock plough compared to the manual system in this study could be linked to the findings of [12] that the depth at which a tillage implement reaches in the soil depends on the size, angle of attachment and the force applied to it.

Soil bulk density

Both tillage systems significantly ($p<0.05$) affected the bulk density of the soil in both years (Table 1). Bulk density values for 0-15 cm depth were generally lower than those of 15-30 cm in the two years. Within the 0-15 cm depth, the bulk density values of the bullock plough treatment were significantly ($p<0.05$) lower than the manual treatment. The bulk density values within the 15-30 cm depth for both tillage systems were higher than within 0-15 cm but no significant difference was found between the bullock and manual systems. The low soil bulk density values on the soil surface were due to the fact that the loosening of the soil in both systems was within the 5 cm soil depth. Deep tillage system has been found to be very important on easily compactable soils of the arid and semi-arid regions [13]. Loosening the soil also implies more water can be stored in deeper layers of the soil. Thus, more water is always conserved for plants use because the pore discontinuity caused by tillage does not permit the water to move to the surface to be evaporated.

Table 1: **Tillage depth, soil bulk density and porosity as affected by tillage systems**

Tillage System	Tillage Depth (cm)		Soil Bulk Density g cm^{-3}				Soil porosity (%)			
			0-15		15-30		0-15		15-30	
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
Bullock Plough	12.3	11.5	1.26	1.38	1.64	1.62	52.45	47.90	38.11	38.87
Manual	5.8	6.3	1.45	1.50	1.62	1.64	45.30	43.40	38.86	38.11
LSD $_{(0.05)}$	1.2	1.1	0.16	0.11	NS	NS	2.92	2.56	NS	NS

Soil porosity

Both the bullock plough and the manual systems had significant ($p<0.05$) influence on the soil porosity (Table 1). Soil porosity values were significantly ($p<0.05$) higher within the depth of the 0-15 cm for bullock plough than the manual in both years because loosening effects were within that depth of soil. However, within the 15-30 cm depth in both years, both tillage systems produced lower porosity values which were not significantly different. Higher porosity values also indicate lower bulk densities within the various tillage depths of both tillage systems implying that tillage tools enhanced total porosity of the soil. Observations made by [14] and [15] which are similar to the findings of this study, showed that tillage practices lowered bulk densities and increased soil porosities which could have also led to the increase in water storage.

Effect of tillage and fertilizer on maize growth and yield attributes of maize

Plant height

Maize plant height recorded bi-weekly showed that there were significant differences in maize plant height between the bullock plough and the manual but up to the 6 WAP (Table 2). The plant height of maize on the bullock plough plots were significantly ($p<0.05$) higher than those on the manual but only up to the 6th week after planting (WAP). However, at the 8th week, the height of maize plants on both tillage practices did not show any significant difference. The depressed maize plant height in the early growth stage of maize on the manual tillage plots could be due to a reduction in rooting depth as a result of high bulk density of the soil. High bulk density of the soil in the manual treatment compared to the bullock plough could have affected the efficient absorption of water and nutrients since the manual tillage depth was just down to 5 cm. The result of this study is similar to the findings of [16] where high bulk density significantly reduced plant height compared to low density soils. However, as the maize crop developed to maturity with many more rains, the soil got moister and the differences in height disappeared.

Similarly, the application of the recommended fertilizer rates and the combined organic and in-organic fertilizers significantly ($p<0.05$) increased maize plant height over the control and manure only plots (Table 2). Nitrogen has been found to be very important in the growth and development of maize plant [17]. The readily available high amounts of N and P in the recommended fertilizer rate and the combined organic and in-organic fertilizer treatments as compared to the low contents of these nutrient elements in the other treatments could have been responsible for these differences.

Shelling percentage

Shelling percentage of maize is one of the components of yield of maize but the analysed data showed that both the tillage methods and the fertilizers applied had no influence on the variable (Table 3). The no influence of the various fertilizers on the shelling percentage of maize in this study agrees with the findings of [18] that the application of N and P has no effect on shelling percentage of maize. However, it disagrees with [19] who reported that lower rates of N increases shelling percentage but decreases with increasing rates. These differences on the effects of the application of the various fertilizers on shelling percentage of maize were observed by [20] to be due to the method of application, location, crop cultivar and cultural practices. The results of this study therefore suggest that the shelling percentage may be similar on all the plots both in the manual and Bullock plough and on all the sub-experimental units at this particular location of the study.

Table 2: Maize plant height (cm) as affected by tillage and different fertilizers

Tillage System	2 WAP		4 WAP		6 WAP		8 WAP	
	2008	2009	2008	2009	2008	2009	2008	2009
Manual	16.3	19.6	39.9	34.1	91.3	87.7	177.7	136.9
Bullock Plough	19.2	14.2	46.8	36.2	91.3	96.1	180.3	140.9
LSD $_{(0.05)}$	1.5	2.2	2.4	1.5	9.1	9.2	NS	NS
Fertilizer								
Recommended NPK +SA	18.6	17.2	41.9	36.1	80.9	95.3	179.2	137.5
Animal Manure	16.2	15.6	33.6	32.2	78.2	90.2	176.4	136.2
Half rates of NPK+SA +AM	18.4	19.0	42.0	39.4	82.3	96.1	182.1	140.3
Control-No NPK/SA No AM	14.1	12.9	30.2	32.5	75.2	89.2	179.3	138.7
LSD$_{(0.05)}$	1.5	1.9	2.0	2.7	NS	NS	NS	NS

NPK= Nitrogen, Phosphorus, Potassium, SA=Sulphate of Ammonia, AM=Animal manure

Cob length

There was significant difference in maize cob length between the two tillage methods (manual and bullock plough) in the study (Table 3). In both years maize cob lengths on the bullock plough treatments were significantly ($p<0.05$) longer than those from the manual tillage systems. For the effects of different fertilizers on the length of cobs of maize, it was found that cobs were significantly ($p<0.05$) shorter on the control which were similar to those on the manure plots.

Table 3: Effect of tillage method and different fertilizers on the shelling percentage (%), lodged plants/plot, cob length (cm) and number of grains/cob of maize.

Tillage System	Shelling %		Lodged plants/plot		Cob length		Grains/cob	
	2008	2009	2008	2009	2008	2009	2008	2009
Manual	78.9	73.0	15	18	10.7	10.5	351.7	361.4
Bullock Plough	75.6	71.6	10	13	11.0	11.7	470.2	365.2
LSD $_{(0.05)}$	NS	NS	4	4	0.25	0.68	60.28	45.60
Fertilizer								
Recommended NPK +SA	76.3	71.3	18	17	12.2	11.7	380.2	482.5
Animal Manure	77.1	74.2	16	16	10.0	9.8	278.9	414.2
Half rates of NPK+SA +AM	79.9	78.5	15	17	13.5	12.6	375.6	524.3
Control-No NPK/SA No AM	74.2	71.2	15	14	8.9	9.3	262.4	325.2
LSD$_{(0.05)}$	NS	NS	NS	NS	1.7	1.5	124.3	120.1

NPK= Nitrogen, Phosphorus, Potassium, SA=Sulphate of Ammonia, AM=Animal manure

However, the maize plants which were applied with recommended rates of in-organic fertilizer and half rates of fertilizer and animal manure had longer cobs with no significant difference in length between the two treatments. The significantly ($p<0.05$) longer cobs of maize measured in the fertilizer treatments could be the presence of high amounts of N and P in these fertilizers as the manure contained only some small amounts of these elements which probably was not readily available to the plants. The application of N and P has been known to increase cob length with increasing rates of these nutrient elements [21, 22]. It was therefore not surprising that the shortest cobs of maize were found in the control where the available N was as low as 0.042 %.

Number of Lodged plants/plot

It was observed that lodging of the maize plants were either from the roots or the stem. Comparably, the stem lodged plants were fewer than the root-lodged maize plants. The number of lodged maize plants in both years on the bullock plough and manual tillage systems were significantly different (Table 3). The number of lodged plants counted was significantly ($p<0.05$) higher on the manual than the bullock plough. The higher number of lodged plants on the manual tillage than the bullock plough plots could be due to the differences in the depth of tillage. The shallow depth of manual plough might have caused the roots of the crop not to be firmly anchored as most of the lodging was at the rooting level. Deep tillage systems have been found to be responsible for firm anchoring the plants roots which also create favourable conditions for enhanced water storage and for good root development [23, 24]. The number of lodged maize plants was not significantly different among the fertilizer treatments (Table 3). The non-significance in the number of lodged maize plants among the treatments could be due to the availability of P. High level of P has been known to reduce lodging as it gives strength to cereals and therefore prevent them from lodging [25, 17].

Number of grains/cob

The number of grains per cob of maize was significantly (p<0.05) higher on the bullock tilled plots than the manual (Table 3). The number of grains counted in the control treatment (no fertilizer applied) was not different from the number of grains/cob of the manure treatment but these were significantly (p<0.05) lower than those on the recommended fertilizer rates and half rates of fertilizers and Manure. The higher number of grains/cob in the treatments involving in-organic fertilizers could be attributed to the higher N and P which are very essential for grain yield of maize.

100 seed weight

Analysed data on 100 seed weight of maize in Table 4 showed that there was neither significant difference between bullock plough and manure nor among the various fertilizers applied. In separate experiments, [26] and [27] found that 100 seed weight of maize has been one of the most important components of yield and has very strong correlation with grain yield but were not influenced by N and P application.

Grain and Stover yield

In general, stover weight and grain yield of maize were higher in 2008 than 2009 probably because of residual effects of both the tillage and the fertilizers applied in the previous year. However, in both years, the stover weight and grain yield of maize were significantly (p<0.05) higher in the bullock plough than the manual treatment (Table 4). The significantly (p<0.05) higher values of these variables (stover weight and yield of maize) in the bullock plough than the manual treatment could be due to the greater working depth of the former tillage system. Deep tillage system creates favourable conditions which facilitates the in-take of more water and nutrients by the maize plant. In the arid and semi-arid zones, the general observation was made [28-30] that crop dry matter and grain yield of crops increased with increasing tillage depth. This suggests that the deep tillage system such as the bullock plough in this study, made more water and nutrient available for dry matter production and the subsequent higher grain yield than the manual tillage system which was shallow. The effects of tillage on crop production have been found to be its effects on soil parameters that influence growth,

Table 4: Effect of tillage and different fertilizers on 100 seed weight, stover weight and maize grain yield

Tillage System	100 Seed weight (g)		Stover Weight (kg/ha)		Grain yield (kg/ha)	
	2008	2009	2008	2009	2008	2009
Manual	22.4	27.5	6978.5	7375.2	1925.4	2446.3
Bullock Plough	22.5	28.2	7852.4	8400.4	2317.6	2862.5
LSD $_{(0.05)}$	NS	NS	806.3	875.2	306.4	375.2
Fertilizer						
Recommended NPK +SA	23.3	27.8	6862.5	7537.1	1895.4	2324.3
Animal Manure	22.1	27.3	5381.4	6425.8	1278.4	2019.1
Half rates of NPK+SA +AM	23.2	27.6	7215.3	7854.2	1989.5	2700.4
Control-No NPK/SA No AM	22.0	27.0	42561.3	4892.4	795.6	1008.2
$LSD_{(0.05)}$	NS	NS	210.6	271.6	947.7	1017.4

NPK= Nitrogen, Phosphorus, Potassium, SA=Sulphate of Ammonia, AM=Animal manure

development and yield [30]. From the above, the deep tillage as performed by the bullock plough reduced soil bulk density, and enhanced surface roughness which might have led to increased surface water storage, enhanced water distribution and provided easy access of plant roots to water and nutrients to the crop plants.

There were general increases in the yield and some components of yield of maize in 2009 as compared to 2008. It was observed that the percentage increase of maize yields on the manure plots in 2009 was as high as 57% compared to 2008. The percentage increases of maize yields for the recommended rates, half rates of fertilizers and manure and control were 25%, 35% and 14% respectively. The increase in the control plots could be due to some spill over of the various treatments on to the plot. However, the increases in the yield and yield components of maize on the same treatment plots for two years indicate the positive nature of the residual effect of these treatments. With the highest percentage increase in the yield of maize obtained on the manure plots among the treatments in 2009, might be due to the slow decomposition of the organic matter and gradual release of the nutrients to the crop plants. Additionally, the presence of organic matter helps to trap and retain the available nutrients from the soil and making it available to the crop plants with time.

Maize yield components such as cob length and number of grains per cob have been found to be the two most important characters affected by the application of N and P [19]. It could therefore be explained that the significant increase of maize grain yield with treatments containing readily available N and P was probably due to their positive effects on these variables.

Manure only and the control plots gave similar stover weights and grain yields of maize but these were significantly (p<0.05) lower than those on the recommended fertilizer rates and half rates of fertilizers and the manure plots (Table 4). Also, the stover weights and grain yields on the recommended rates and half rate treatments plots even though higher than on the control plots, there was no significant difference between them. This suggests that the higher stover weight and grain yields obtained on these plots were as a result of the availability of higher N and P in the recommended rates of fertilizers and half rates of fertilizers and the manure.

Economic Analysis

The economic analysis of maize production on both the bullock and manual tillage systems using the benefit-cost ratio is shown in Table 5. Bullock tillage system for 2008 had a benefit cost ratio (1.9) and net benefit (GHC 903.56) which were both more than on the manual tillage system's benefit- cost ratio of 1.4 and net benefit of GHC 668.30. Even though there were higher benefit-cost ratio and net befits for both tillage systems in 2009, the trend was similar. The higher net benefit-cost ratios from the production of maize on these tillage system in 2009 compared to 2008 could be due to higher yields of the crop and higher price for it. In this study, the benefit-cost ratios of both tillage systems were each more than one, indicating that the production of maize on each of them would be profitable but the bullock tillage system was a better option as it had higher benefit-cost ratios in each year than the manual system.

Table 5: Comparing the economic returns (GHC) of the two tillage systems

	manual		**Bullocks**	
	2008	2009	2008	2009
yield/ha (kg)	1925.5	2446.3	2317.6	2862.5
Price per kg	0.6	0.6	0.6	0.6
Gross Benefit	1155.3	1467.78	1390.56	1717.5
Cost				
Ploughing	62.5	62.5	62.5	62.5
NPK	200	200	200	200
Amonia	87.5	87.5	87.5	87.5
Herbicides	35	35	35	35
Labour	102	102	102	102
total var cost	487	487	487	487
net benefit	668.3	980.78	903.56	1230.5
B/C ratio	**1.4**	**2.0**	**1.9**	**2.5**

Conclusion

Based on this study, it can be concluded that tillage loosened the soil which lowered the bulk density and increased the porosity of the soil. Bullock plough significantly increased the yield components of maize such as cob length and number of grains per cob which translated into higher maize yield than the manual tillage system. Comparatively, Bullock plough with a higher tillage depth than the manual was better in improving these soil properties. Similarly, the combination of organic (3 tons/ha) and half the recommended rate of in-organic fertilizer gave maize yields which were comparable to the full recommended rates of in-organic fertilizer but higher than the organic alone. However, for increase in maize yields in the subsequent years, the combination of both the in-organic fertilizer and the animal manure was found to be more appropriate. It was also found that producing maize on both bullock and manual tillage systems were profitable since the benefit-cost ratio was more than one (1). However, the bullock plough was more profitable as it had higher benefit-cost ratios and benefits than the manual tillage system.

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