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TECHNICAL AND ECONOMIC PERFORMANCE OF ANIMAL-DRAWN IMPLEMENTS FOR MINIMUM TILLAGE: EXPERIENCE ON VERTISOLS IN ETHIOPIA

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SUMMARY

Land degradation is one of the major problems related to low productivity in Ethiopia. Vertisols are potential agricultural lands but are underutilized due to waterlogging during the rainy season and are prone to soil erosion due to the traditional practices of planting crops at the end of the rainy season exposing bare land to heavy rains. An animal-drawn implement, the broadbed maker (BBM), was tested to facilitate drainage of the Vertisols. Improved drainage enables earlier planting of crops to use the resultant prolonged growing period for attaining higher yields. In order to further improve the BBM package, the frame of the BBM was used for attachment of other implements to minimize tillage practices and reduce seed and fertilizer rates, labour and animal power requirements and soil erosion. The attachments were tested both on-station and on-farm with positive results.

INTRODUCTION

In most crop-livestock mixed farming systems in developing countries, different kinds of animal-drawn simple and mouldboard ploughs are used for tillage. The number of cultivations or passes needed to achieve a good tilth depends on soil type, moisture level, crop to be grown and adequacy of draught animals. On some kinds of soils extensive tillage damages soil structure and contributes to soil erosion. Zero- and minimum-tillage practices are often recommended to avoid such problems.

In Ethiopia, 90% of land preparation for crop production by smallholder farmers is done with the traditional 'maresha' plough pulled by a pair of local zebu oxen. Three to five cultivation passes, each pass perpendicular to the previous one, with the maresha are required for all types of soils before a field is ready for planting. The first pass reaches a soil depth of 8 cm while with the last pass up to 20 cm depth can be attained (Astatke and Ferew, 1993). Land is usually

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prepared before the main rainy season and some crops, for example the principal cereal tef (*Eragrostis tef*), are sown during the main rains. Others, for example local wheat and pulses, are sown towards the end of the rainy reason. This is done because tef seeds can stand some waterlogging but wheat and pulses cannot. Due to lack of adequate vegetative cover, however, tilled soils remain exposed to heavy rain for most of the rainy period resulting in high erosion. The rate of erosion is generally higher on sloping plots and on tef fields. Five to seven cultivation passes are required to make the soil fine enough to allow good germination of the tiny tef seeds but this makes the soil extremely vulnerable to erosion.

About 12.6×10^6 ha of Vertisols (30% of Vertisols in Africa), are located in Ethiopia. Vertisols cover 10.3% of the total area of Ethiopia, two-thirds of which are in the highlands above 1500 m asl (Wakeel and Astatke, 1996). Despite the fact that they have high agricultural potential, they are generally regarded as marginal soils due to their hydro-physical properties. Due to waterlogging in the main the rainy season (June to September), crops are planted at the end of the rainy season thus subjecting the already cultivated area to water erosion during the main part of rainy season. On the other hand, crops grow on residual moisture so yields are low. Improving the utilization and productivity of Vertisols therefore can contribute immensely to counteracting Ethiopia's food security and nutrition problems.

In order to solve the waterlogging problem on Vertisols, a research consortium developed the broadbed maker (BBM), an animal-drawn tool based on a modified local maresha. The BBM creates 80-cm-wide beds separated by 40-cm-wide furrows that allow excess water during heavy rains to run off to a main drain or other outlet at the bottom end of a plot. This allows early planting to take advantage of a longer growing period, resulting in higher yield and less erosion because of the more adequate vegetative cover during the rainy season (Astatke and Gebresenbet, 1998; Astatke and Mohamed Saleem, 1998; Mohamed Saleem, 1995; Tedla *et al.*, 1992). The crops from the BBM-treated plots are harvested about two months earlier than traditional cereal crops, and at a time when there is a severe food deficit and food prices are high.

Broadcasting is the usual method for sowing most crops, including wheat, in the BBM system. This method of broadcasting has no depth-control mechanism and has been shown to mix 15.3% of the broadcast wheat seed to a depth of 10–20 cm yet leaving 25.3% within the top layer (Tinker, 1989). Due to this depth variation of wheat seeds at planting, emergence is low, so farmers need to use very high seeding rates to achieve a large enough plant population (Astatke and Kelemu, 1993).

Currently the broadbed and furrows (BBFs) are ploughed up during general land preparation and reconstructed if the BBM package is used for the next season. The possibility of retaining the furrows for repeated use with minimum tillage could be an option. This would save on animal and human labour. Along with this, the possibility of row seeding (drilling) rather than broadcasting may be considered. Row planting may reduce the required seed rate by improving the

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crop emergence with the placement of seeds uniformly at optimum soil depth and also reduce required fertilizer rate by improving nutrient uptake by these plants. Further advantages would be better control of weeds (making weeding easier and less labour demanding) and stubble incorporation into the soil (thereby partially filling ground cracks thus reducing moisture loss and helping the next crop).

Several multi-functional wheeled tool-carrier frames for tillage, planting and weeding tested in Africa have been found unsuitable for smallholder farmers. The Nolle-designed, wheeled tool-carrier was promoted in Senegal and several hundred were sold at a subsidized price to farmers. Soon, however, it became clear that the farmers wanted cheaper, lighter and simpler implements (Starkey, 1988). Small numbers of Poly-cultures and Tropi-cultures (multi-purpose tool carriers pulled by animals) were tested in several African countries but again farmers opted for simpler implements when the subsidies were reduced. The National Institute of Agricultural Engineering (NIAE) tool-carrier was tested in at least eight African countries but was found to have very low adoption rates; it was concluded that simpler implements were more appropriate (Starkey, 1988).

Given this experience, the possibility of converting the BBM frame into a low-cost tool-bar for attaching tine cultivators for minimum tillage, and planters for seed drilling was considered. Several design options were tested on-station in 1997 and 1998 at the International Livestock Research Institute (ILRI) Debre Zeit Research Station. After two years of on-station trials investigating the technical performance of the new attachments, an on-farm test was conducted at Chefe Donsa, a village in the central highlands of Ethiopia. This paper reports the testing of the BBM attachments, both on-station and on-farm.

MATERIALS AND METHODS

On-station trials

The trials were conducted at ILRI Debre Zeit Research Station (50 km south of Addis Ababa, 1850 m asl). The soil type at the experimental site is a chromic Vertisol with 59% clay, 22% silt and 19% sand. The area has a bimodal rainfall distribution. A short rainy season between February and April contributes 30% of the annual precipitation that averages 850 mm, while the main rainy season is between mid-June and mid-September.

Eight treatments incorporating different combinations of tillage, seeding method and seed and fertilizer rates were used in the 1997 cropping season and were repeated on the same plots in 1998. The treatment characteristics are shown in Table 1. Each plot measured 50 × 6m, separated by a 1-m path and laid out in a randomized complete block design with four replications. Treatment 1 represented traditional tillage, treatments 2–5 included BBF systems constructed using a BBM, and treatments 6–8 included minimum tillage on BBF. A separate experiment on zero tillage was conducted by the Ethiopian Agricultural Research Organisation (EARO). For the zero tillage trials, seed was broadcast on plots

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Table 1. Composition of treatments for on-station trial, 1997 and 1998.

Treatment number	Tillage and agronomic features	Seed rate, (kg ha^{-1})	Fertilizer rate (kg ha^{-1})	
			Urea	DAP
1	Wheat and DAP broadcast and covered with the maresha (traditional practice)	150	50	100
2	Wheat and DAP broadcast on traditionally prepared surface and covered with the BBM to form BBFs at the same time	150	50	100
3	Use of BBM to form BBFs followed by the row placement of wheat seeds mixed with DAP with the planter at 5–7 cm depth	100	50	100 (70)
4	Use of BBM to form BBFs, row placement of wheat seed at depth of 5–7 cm and followed by DAP at depth of 3–5 cm on the previous rows with the planter	115	50	100 (70)
5	Use of BBM to form BBFs and DAP broadcast on the BBFs followed by row placement of wheat at 5–7 cm depth with the planter	115	50	100(70)
6	Row placement of DAP mixed with wheat, at a depth of 5–7 cm using the planter on reshaped BBFs.	100	50(25)	80(70)
7	Row placement of wheat seed at a depth of 5-7cm followed with the placement of DAP at 3–5 cm depth on the previous rows using the planter on reshaped BBFs.	115	50(25)	100(70)
8	First broadcasting DAP on the BBFs followed by row placement of wheat seed at a depth of 5–7 cm using the planter on reshaped BBFs.	115	50(25)	100(70)

Note: Figures in parentheses are fertilizer rates for 1998. See text for reason for change.

treated with a broad-spectrum herbicide and covered by one pass of the traditional maresha implement.

For traditional tillage, the maresha was used for both land preparations and seed covering. The BBF system involved several passes with the maresha and making new BBFs with the last pass. The minimum tillage with BBF practice required a single pass of the maresha in the already existing furrows to clean the sediment of the previous year, followed by the use of the tine and blade harrow attachments to the BBM to disturb the top 5–7 cm of broadbed soil, and then reshaping the beds with the BBM. Each broadbed was 0.2 m high and 0.8 m wide, separated by 0.4-m furrows. Planting of all minimum tillage plots was done with the double-layered cone-funnel planter. Durum wheat (*Triticum durum*), variety Foka was used in both seasons.

Due to high incidences of crop lodging of wheat planted in rows during the 1997 cropping season, the amount of added di-ammonium superphosphate (DAP) was reduced from 100 to 70 kg ha^{-1} in 1998 (Table 1). Recommended rates of 150 kg ha^{-1} of wheat seed and 100 kg ha^{-1} of DAP were applied in both 1997 and 1998 to broadcast plots. In both years, urea was applied to all plots, at a rate of 50 kg ha^{-1} split and applied in two equal doses, one each at three and six

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weeks after crop emergence, except for the BBF with minimum tillage plots where urea was applied only once in the third week at a rate of 25 kg ha^{-1} in the second year due to the very high lodging incidence in the previous year. The seed rates were lower on plots where the seed and DAP were mixed and applied through the funnel planter.

The time required for seedbed preparation and planting, and data on lodging, height at harvest, grain and straw yields, and 1000-seed weight were measured for all the treatments. Analysis of variance was used to compare the various parameters of the different treatments of tillage systems by year and combination of the two years.

On-farm trials

Of the eight on-station trials, only three (numbers 1, 3 and 6 in Table 1) were selected with minor modification for on-farm trial. These were considered to be the easiest for first-time use by farmers, given that yield differences among the treatments were not significantly different. The following hypotheses were postulated about possible farmer attitude and behaviour before farmer volunteers were sought for the on-farm testing:

(a) Although zero tillage and minimum tillage performed on-station similarly to traditional tillage but with significant benefits of labour savings, some farmers may not like to test them alongside each other. There may be a need to test these options separately and in a stepwise manner.
(b) Farmers who adopted the BBM package are more likely to volunteer for testing the minimum tillage equipment and the planter, or both, than farmers who are yet to adopt the BBM package, because adopters being confident about the benefits of the BBM package may like to test the possibility of enhancing that gain.
(c) Farmers, with or without BBM experience, may be reluctant initially to test zero tillage as this is not consistent with traditional practice.
(d) If the on-farm tests with minimum tillage and/or planter show promising results, farmers are more likely to volunteer for testing zero tillage as a logical sequence. Farmers experiencing good results from participating in minimum tillage and/or planter trial are more likely to volunteer for zero tillage tests than are those who are yet to test minimum tillage and/or planter.

The on farm trial was conducted in 1999 at Chefe Donsa which is above 2500 m asl and located 35 km northeast of ILRI Debre Zeit Research Station and has a similar rainfall pattern and amount as the station. Farmers at Chefe Donsa are currently using the BBM package and so are familiar with the functional mechanism and advantages of the package. Before the field tests, consultation meetings were held with farmers in the village to share the findings of the on-station trials on zero tillage, minimum tillage and planter attachment to the BBM.

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Of those farmers who participated in these discussions, 12 expressed willingness to know more about the trial and to see the equipment and the way it functions. These farmers were then taken to Debre Zeit Research Station where the equipment was explained and demonstrated, though the trial plots could not be shown, as this was an off-season period. All 12 farmers expressed interest in participating in the on-farm trial with minimum tillage and funnel planter use, but none was willing to include zero tillage in the trial. These responses were quite in line with the expectation as expressed in the hypotheses.

Eventually nine farmers participated in the on-farm trial, of whom three did not participate in the on-station consultations regarding the different tillage packages. One farmer conducted the trial on two plots, raising the number of plots to ten. On each plot only one tillage system (treatment) was followed. Four farmers used traditionally prepared and planted wheat plots (treatment 1) and these were used as the control for comparison with the new tillage practices. Five farmers prepared land with the traditional maresha implement, then constructed BBFs with the BBM and used the funnel planter for planting wheat on six plots (treatment 3). Four other farmers retained previously constructed BBFs and applied minimum tillage and funnel planter (treatment 6). The area of the plots varied from 0.25 to 0.60 ha.

Except for the newly developed attachments for minimum tillage and the funnel planter, all other inputs for the trial were supplied by the farmers. Farmers used their preferred wheat varieties for planting. Wheat seed was mixed with DAP and, using the funnel planter, the treated seed was planted in four rows on the beds of the BBF system. The recommended amount of seed and DAP per hectare mixed for drill application with the funnel planter were 110 and 80 kg respectively. Split urea top-dressings of 50 kg on the third and sixth weeks after emergence were also recommended for the system using the funnel planter. Planting of the minimum tillage plots was done with the funnel planter at the onset of the main rains in late June. The newly constructed BBFs were planted in the first two weeks of July. The traditionally prepared wheat plots were planted at the end of the main rainy season from late August to early September, by broadcasting the seeds and covering them with one pass of the maresha.

For the different tillage systems, the seed and fertilizer rates used, the time required for seedbed preparation and planting, and the time spent weeding were monitored. Grain and fodder yields were also quantified. Due to the unbalanced number of the tillage treatments, the GLM procedure for SAS (1988) was used for analysis.

RESULTS AND DISCUSSION

On-station trials

The time required for the seed preparation and planting of the minimum tillage systems averaged 21 h ha^{-1} for the two years and was significantly lower

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Table 2. Wheat grain and straw yields in on-station trial with minimum tillage at Debre Zeit; 1997 and 1998.

Treatment	Grain (t ha^{-1})			Straw (t ha^{-1})		
	1997	1998	Mean	1997	1998	Mean
1	1.72	0.90	1.31	3.63	2.34	2.99
2	1.67	0.96	1.31	3.84	2.48	3.17
3	1.70	1.01	1.38	4.13	2.61	3.32
4	1.57	1.03	1.30	3.50	2.52	3.00
5	1.67	0.64	1.15	3.74	1.83	2.79
6	1.83	1.35	1.59	4.36	3.09	3.78
7	1.81	1.53	1.67	4.07	3.42	3.74
8	1.94	1.41	1.68	4.14	3.31	3.71
s.e.	0.10	0.16	0.07	0.37	0.41	0.15

than for both the traditional and BBF systems which took 78 and 64 h ha^{-1} respectively. Vigorous crop growth on plots where minimum tillage was practised in the 1997 cropping season led to significantly higher crop lodging of 62% while during the same period the crop lodging in the traditional and conventional BBF systems were 5 and 19% respectively. Grain and straw yields of wheat for the different treatments for the two cropping seasons (1997 and 1998) are shown in Table 2. In 1998, rains extended into early October and coincided with the crop flowering period thus lowering the grain produced compared with 1997 production. On average, there were no significant yield differences among the treatments except in one case (treatment 5), which had a lower yield than other treatments.

During wet soil conditions and when there was considerable stubble in the field, problems were encountered with the funnel planter, which got clogged at the seed outlet. As it was easy for the oxen operators to see the seed flow, the blockage was cleared whenever this happened.

On-farm trial

The short rains expected from February to April failed in 1999, so cultivation had to be started at the onset of the main rains at the end of June. The five passes with the animal-drawn implements, which included planting for the minimum tillage practice, took an average of 26 h ha^{-1}. This was significantly lower than the time for the newly constructed BBFs after several maresha passes and the traditionally prepared plots which took 61 and 72 h ha^{-1} respectively. This allowed early planting of the minimum tillage plots even with the failure of the short rains. The seed rate of wheat for the minimum tillage plots averaged 110 kg ha^{-1} with the funnel planter while on the late-planted BBF plots, in mid-July, a lower seed rate of 88 kg ha^{-1} was attained with the same implement due to wet soil conditions. The seed rate of wheat for the traditional system ranged from 150 to 250 kg ha^{-1} with an average of 200 kg ha^{-1} and was significantly higher than the system where the funnel planter was used for planting. A significantly higher

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fertilizer rate of 100 kg ha^{-1} each of DAP and urea was also applied in the traditional system while the other treatments with the funnel planter were given 73 and 55 kg ha^{-1} of DAP and urea respectively.

Due to the 15-cm-row spacing adjustment made on the funnel planter, the four lines of wheat crop took up a total of 60 of the 80-cm wide beds of the BBFs. This left 60-cm spaces (including the 40-cm furrow widths) between the beds with no crop cover. The substantial amount of weed that resulted was used as highly valuable animal feed at the end of the main rainy season. The dry matter produced from both tillage systems that used the funnel planter averaged 1 t ha^{-1} and was significantly higher than what was obtained from the traditional plots (0.3 t ha^{-1}). The time for weeding for the minimum tillage plots, which involved mainly harvesting of the weeds with a sickle, took 10 man-days ha^{-1} and was not significantly higher than the weeding time for the traditional plots which averaged 8 man-days ha^{-1}. The newly constructed BBFs that were planted in mid-July took a significantly higher weeding time (32 man-days ha^{-1}) than the other two systems. The higher weed density in the crop space may be due to the date of planting. For the traditionally prepared plots, the last pass late in the rainy season, could uproot and kill the fully germinated annual weeds. In the minimum tillage plots, however, as the wheat is planted in a fertilizer mix only at the onset of the rains the crop surpasses weed growth later. More studies on weed dynamics in relation with date of planting are needed to draw concrete conclusions.

Farmers in the Vertisol areas like Chefe Donsa generally experience food shortage and high food prices around the end of the main rainy season as the different traditional cereal crops are harvested at the end of January or early February. All the minimum tillage plots were harvested by the first week of November, followed by the harvest from the newly constructed BBFs, which extended to mid-December. Therefore, early harvests from minimum tillage and related technology interventions contributed to food security.

The rainfall in the 1999 main rainy season (June-September) at Chefe Donsa was more erosive and slightly above 800 mm which was higher than the 20-year average precipitation of 650 mm. As the Chefe Donsa landscape is undulating, 70 mm rain on 11 August 1999 resulted in considerable soil erosion from the traditionally cultivated plots, which were not covered with vegetation during that period. Temperatures were low during mid-October, a time when the early planted plots of both the minimum tillage and the newly constructed BBF plots were at the seed-filling stage. This low temperature caused seeds to shrivel, adversely affecting grain yields. The average grain and straw yields from the minimum tillage were 1.5 and 3.1 t ha^{-1} respectively and not significantly higher than grain and straw yields from the newly constructed BBF plots which were 1.4 and 2.6 t ha^{-1} respectively. The mean grain yield from the traditional wheat plots was 2.2 t ha^{-1} and was significantly higher than the mean grain yields from the minimum tillage and newly constructed BBFs even though the average straw yield produced (3.4 t ha^{-1}) was not significantly different from that of the other two treatments. In earlier on-station trials, yield differences between these treatments

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Table 3. Returns to minimum tillage and row planting per hectare in on-farm trial; 1999.

Costs and benefits	Treatment 1		Treatment 3		Treatment 6	
	Quantity	Value (Birr)	Quantity	Value (Birr)	Quantity	Value (Birr)
Tillage:						
Oxen labour (pair-days)	11.9	321	10.1	273	4.3	116
Human labour (person-days)	15.0	135	12.6	113	9.2	83
Seed (kg)	200	320	88	141	110	176
Fertilizer (kg)						
Urea	96	149	57	88	55	85
DAP	96	230	72	173	73	175
Labour (person-days)						
Weeding	8.4	76	32.5	293	10	90
Harvesting and threshing	66	594				
Total costs		1825		1486		1130
Returns						
Grain (t)	2.2	2640	1.5	2400	1.5	2400
Straw (t)	3.5	193	2.6	143	3.1	171
Weeds (t)	0.3	17	0.9	51	1.1	61
Total		2850		2594		2632
Gross margin (GM)		1025		1108		1502
Gross margin 2		1025		2038		2432
Gross margin 3		325		1108		1502

Treatment 1 is traditional (control), treatment 3 is BBF system using BBM and row planting, treatment 6 is minimum tillage with BBF and row planting.

Value US\$1 = 8 Birr approximately in 1999.

Prices prevailing in the village in 1999 and used in the estimation: oxen power, 27 Birr pair-day^{-1}; human labour, 9 Birr person-day^{-1}; wheat seed, 1.60 Birr kg^{-1}; urea, 1.55 Birr kg^{-1}; DAP, 2.40 Birr kg^{-1}; wheat grain for November harvest (treatment 3 and 6), 1600 Birr t^{-1}; for January harvest (treatment 1), 1200 Birr t^{-1}; wheat straw and weed dry weight, 55 Birr t^{-1}.

Gross margin 2 assumes that treatments 3 and 6 achieved the same higher yield as treatment 1. Gross margin 3 assumes that treatment 1 has the same lower yield as treatments 3 and 6.

were not highly significant. It was argued that even if yield differences were not significant, minimum tillage and drilling with the funnel planter could still be more profitable because of savings in labour, seeds and fertilizer.

Economic benefits of minimum tillage and row planting

The benefits of minimum tillage and row planting compared with traditional tillage and broadcasting treatments are summarized in Table 3. Although traditional tillage gave higher yields due to favourable weather for late planting in 1999, because of input savings and higher prices for early harvests, row planting with BBF and minimum tillage with BBF plus row planting respectively gave 8 and 46% higher gross margins.

If the weather had not unfavourably affected the early planted wheat and the interventions had given as high a yield level as the control, the gross margin for row planting with BBF would be twice as much as that for minimum tillage and 2.3 times as much as the control (gross margin 2 in the table). In calculating the

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gross margin 2, adjustment was made for assumed yield differences as well as differences in labour for harvesting and threshing. On the other hand, if the weather had affected all treatments equally and the control had achieved the same lower yield as the interventions, the control treatment would be financially in a worse situation than the row planting with BBF which then would give 3.4 times the gross margin, while minimum tillage would give 4.6 times. Given the original assumption that the primary differences among these treatments would be more in terms of input use rather than yield, both the 1999 actual result and the assumed scenario changes due to weather effect indicate that row planting and minimum tillage are financially rewarding innovations, particularly for farmers with severe draft power shortages and shortage of cash to buy seeds and fertilizers. If the benefits of significantly reduced soil erosion with early planting and minimum tillage can be valued and added to the benefit stream, minimum tillage and row planting would be even more rewarding.

The potential of minimum tillage use on Vertisols in Ethiopia and elsewhere

In the Ethiopian context, land degradation, defined as a reduction in long-term productivity, is caused by severe soil erosion, which results from intensive cultivations and overuse of land resources. According to Constable and Belshaw (1989), by 1984–85 about half of the Ethiopian highlands were reported to be eroded, of which 14 000 km^2 were seriously eroded. During the same period, some 20 000 km^2 of agricultural land were rendered irreversibly eroded and could not sustain further cropping. If this trend continues, it has been calculated that one-third to a half of the total area of the Ethiopian highlands would be totally unsuitable for crop production within the next two decades.

The most important aspect of soil conservation that has the greatest effect is to have plant cover during the rainy season (Hudson, 1975). The importance of a plant cover in reducing erosion is demonstrated by several experiments. At Henderson Research Station in Zimbabwe, mean annual soil loss in three years from bare ground averaged 46.3 t ha^{-1} compared with 0.4 t ha^{-1} from ground with dense vegetative cover (Morgan, 1980). In Ethiopia, soil erosion from Vertisol plots were found to be very high as traditionally they are planted late during the main rainy season, leaving the ploughed soil exposed to rain. A fall of 70.8 mm rain on 11 August 1999 (in the middle of the main rainy season) at Chefe Donsa, resulted in 18 t ha^{-1} of soil loss from the bare land prepared for planting in just a day (EARO, 2000). Long term studies in Anjeni, Amhara Region (central highlands) where planting is practised late during the main rainy season demonstrated that soil sediment loss from farmers' fields was high, approximating to 60-97 t ha^{-1} annually from a 100-ha catchment or an equivalent soil depth loss of about 1cm a^{-1} (Hurni and Perich, 1992). The role of vegetation is in interception of the raindrops so that the kinetic energy is dissipated by the plants rather than imparted to the soil.

Minimum tillage practice, which can be regarded as conservation tillage, causes less soil disturbance and allows early planting of crops and has both the physical

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and biological soil conservation potentials to lower soil losses substantially. Early planting on Vertisols allows the use of high-yielding wheat varieties which enables utilization of a longer growing period, giving higher yields in most years with normal climatic conditions. Early planting of short-duration crops on the same soils allows early harvesting, making it possible to grow a second crop on the residual moisture (Astatke and Mohamed Saleem, 1998). If water can be conserved in ponds or reservoirs, a sequential crop would be feasible in the same cropping season through minimal supplementary irrigation at planting time to secure germination. The same furrows of the BBFs that evacuated the excess water during the rainy season could be used as furrows for irrigation. This could be intensified and natural resources sustained with the use of minimum tillage practices. Minimum tillage practice on a wider scale in the country would improve the soil organic matter content and reduce the amount of carbon dioxide released from the soil thereby minimizing the greenhouse gas emissions which are not adequately understood (Dalal and So, 1998).

Furthermore, minimum tillage should be attractive because of its potential to save seeds, fertilizers and human and animal labour in a situation where all these are expensive and many farmers do not have adequate cash for such purchases. The early harvesting of crops during the severe food deficit period with the minimum tillage package will improve the food security for most rural people in Ethiopia. Technically, the adoption of the minimum tillage practices should be attractive to farmers on Vertisol soils even though a long period of time will be required for disseminating the knowledge to the wider community.

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