Animal Power in Farming Systems

Research on Animal Power at International Centres

Title photograph (over)
Tropicultor wheeled toolcarrier in use at ICRISAT Centre at Patanacheru, India
(Photo: Paul Starkey)

Low-cost modifications of the traditional Ethiopian tine-plow for land-shaping and surface drainage of heavy clay soils: preliminary results from on-farm verification

by

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Abstract

The traditional ox-drawn Ethiopian ard plow ("maresha" in Amharic) has been modified at the International Livestock Centre for Africa (ILCA) (1) for use in the construction of terraces for soil conservation and (2) for the construction of raised beds and furrows to facilitate surface drainage on heavy clay soils. These two modifications are described in this paper and results from on-station and on-farm tests are reported.

The plow for terrace making has slightly lower power requirements than the traditional plow, while the plow for making raised beds requires about 50% more power than the traditional implement. Both implements can be drawn by a pair of the light (250 kg) East African Short-horned Zebu. Level terraces, four metres wide, can be established by three cultivating passes on an 8% slope. Raised beds 20 cm high and 120 cm wide can be established at a rate of 0.4 to 1.2 ha per day (7 hours' work) per oxen-pair, depending on the required uniformity of the raised beds and on the moisture status of the soil.

The surface drainage facilitated by the furrows between the beds increased bread wheat yields on farmers' fields by about 80% as compared with the traditional method of land cultivation on flat land. These beds also facilitate weed control.

In a cereal-pulse area of the Ethiopian highlands where raised beds are traditionally made by hand, the human labour input required was reduced from 60 hours/ha to 16 hours/ha when using the new ox-drawn implement.

Incremental costs of the two modifications are US$5 for the terrace-plow and US$25 for the raised-bed-maker. Both modifications can be made by village craftsmen.

Introduction

In the Ethiopian highlands land cultivation is almost exclusively done using animal power. The traditional wooden plow ("maresha") has a sharply pointed metal tine and a metal hook tied to the handle of the plow. Two flat wooden wings are fitted by the hook to the handle and by a steel pin to the beam on either side of the implement. This simple implement is owned by almost all farmers. However only about one third of all highland farmers own two oxen (Ethiopian Ministry of Agriculture, unpublished data), and the majority have to enter some of the many forms of traditional renting and exchange agreements for draught oxen in order to plow their land.

To help relieve this ox-power constraint, ILCA developed a yoke and harness, and a modified version of the local plow suitable for use by a single ox. This modification has been described elsewhere (Gryseels *et al.*, 1984). A report on its on-farm performance was prepared by Gryseels and Jutzi (1986).

This paper reports on two further modifications which allow controlled soil movement. The traditional plow basically only scratches the soil, lifts and slightly turns it equally on either side of the plow and leaves a furrow and two small ridges behind. The first modification (henceforth called "terrace-plow") is a device to shift soil to one side when plowing. As it can turn soil in either direction, depending on its setting, it acts as a reversible plow. The second modification (henceforth called "Broad-Bed-Maker" or "BBM") is devised to shape the topsoil into broad beds and furrows (BBF), i.e. raised beds with furrows in between, for the drainage of excessive surface water on heavy clay soils. Both modifications have been developed within ILCA's Highlands Programme, based at Addis Ababa, Ethiopia.

Detailed descriptions of both modifications are given. Their potential use and their impact on soil and water conservation, crop yields and farm-level labour economy are discussed on the basis of the first on-station and on-farm verification trials.

The terrace-plow

Description and operation

The terrace-plow modification is made by removing the two flat wings of the "maresha" and by replacing them with a wooden mouldboard-shaped wing which is reversible, i.e. can be shifted from one side of the beam to the other without being detached from the implement. The wing has a steel sheet reinforcement at its tip through which two metal rings pass to loosely fasten the wing to the handle of the plow. The metal rings are made of reinforcing rods designed for concrete. The wing is fixed to the beam using the same metal pin used to fasten the two traditional flat wings to the beam (Figure 1).

When the wing is to be changed to the other side of the beam, the fixing pin is pulled out and the wing is swung around underneath the beam to the other side, where it is fixed again with the same pin. Thus the frame of the traditional plow does not need any modification for its use as a terrace-plow. The mounting of the reversible wing to the plow takes about 3 minutes.

The cost of the wing, including a 40 cm long and 5 cm wide metal sheet of about 4 mm thickness, two bolts of 7 cm, about 80 cm of 10 mm iron reinforcing rod with two welding points, and about 3 kg of hardwood (preferably *Acacia*) shaped as a mouldboard, is of the order of US$5.

The operation of the terrace-plow does not substantially differ from the traditional plow, except that the reversal of the wing is needed at the end of each pass in order to shift soil in one way only.

Performance

Animal power consumption by the implement was measured using the method described by A. Astatke *et al.* (1986). The force exerted by each pair of oxen was measured with a portable, battery-powered dynamometer (Novatech Measurements Ltd., UK) consisting of a loadcell inserted between yoke and drawbar of the plow and a digital indicator connected to the load cell by a cable. The minimum and maximum force (kN) over a 20 m distance and the time taken to travel the 20 m were recorded. The working heights of both the yoke and the implement hitch and the length of the draft chain were measured, and the force parallel to the ground was calculated. Power consumption was established by multiplication of actual force exerted (kN) by speed (m/sec).

Power consumption for the third pass of plowing with the traditional plow is about 660 W (SD 112) (A. Astatke and Matthews, 1982). Power consumption of the terrace-plow used at the same stage of land cultivation (after second plowing) is 534 W (SD 110), about 80% of the power requirements of the local plow (Jutzi, unpublished data). The decrease in power requirement is explained by the fact that the terrace-plow penetrates less deeply into the soil in shifting loose soil to one side.

On a field of 8% slope with clay-loam soil, an average of 3.3 passes was sufficient to establish level terraces of 4 m width. The borders of the terraces (about 30 cm high) were stabilized with rows of *Sesbania sesban.*

In a seven-hour day, an ox-pair prepared 1911 m^2 (SD 298) of finished terraces on this slope. Twenty-two terraces of 420 m length were monitored. With one pair of oxen, it is therefore possible to cover about 1 ha in 5 days, which is roughly the time input for land cultivation using the traditional plow.

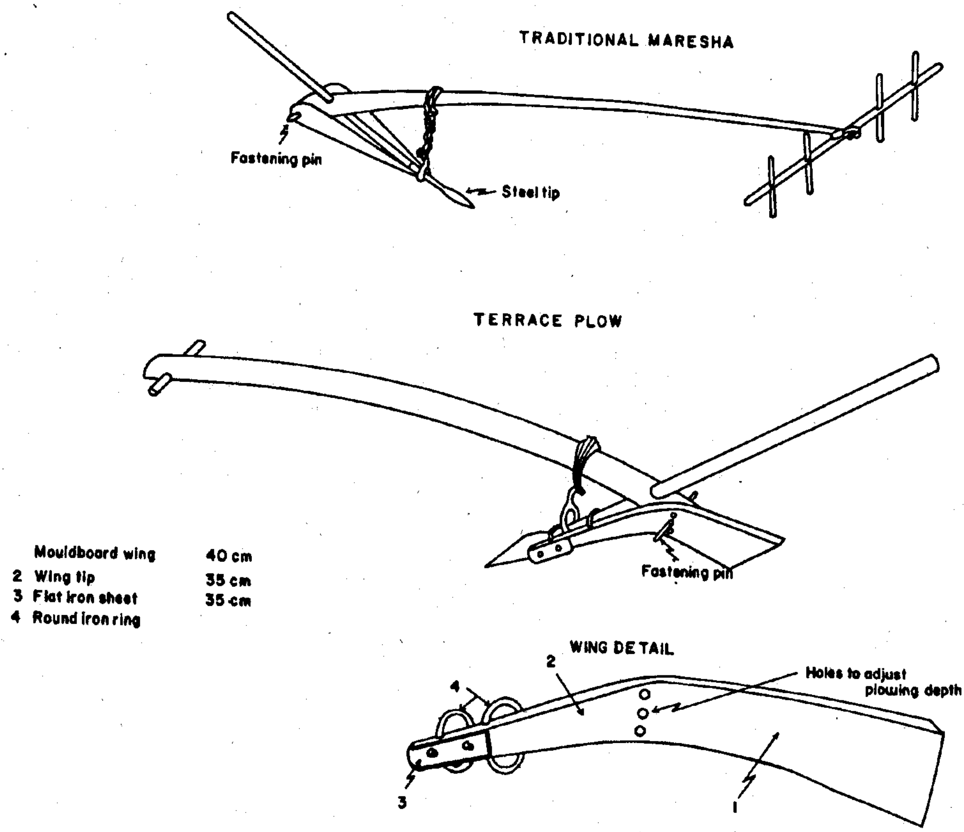
There is therefore no incremental time input required over normal cultivation for the establishment of terraces. The terraces reduce soil loss and conserve water through the reduction and slow down of run-off. More stable crop yields can be expected immediately, through the water conservation effect of terracing. In the longer term improvements can be anticipated through the effects of terracing on soil conservation.

The broad-bed-maker (BBM)

Description and operation

Much evidence indicates that waterlogging is a strong constraint to plant growth on deep black clay soils, also known as Vertisols or

Figure 1. Traditional maresha plow, new terrace-plow and detail of terrace plow wing



"black cotton soils" (Kanwar *et al.*, 1982; Ryan and von Oppen, 1983; Haque and Jutzi, 1984). This waterlogging is especially serious in high rainfall areas.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics) began experimenting in the mid 1970's with different systems of surface soil drainage to overcome this constraint (ICRISAT, 1986), and developed an animal-drawn toolcarrier with a number of attachments. The ICRISAT implement is effective but expensive. Lower-cost devices are essential for successful application of improved land management practices in the prevailing subsistence farming systems of sub-Saharan Vertisol areas. These account for 97 million ha of Africa. ILCA therefore developed a broad-bed-maker based on the local plow with attention given to low external inputs.

The BBM is made from two local plows. There main beams are shortened to about 90 cm, and they are connected with a simple wooden frame (Figure 2). The two flat wings of the traditional plow are replaced by mouldboard-shaped wooden wings, two bigger ones throwing to the centre and two smaller ones to the outside. The two handles are connected for ease of operation. Total weight of the implement is about 30 kg depending on the wood used. The weight of the traditional "maresha" is about 20 kg. The incremental cost of the BBM (additional to the two local plows needed) is about US$25 (8 bolts, 8 m wooden poles, 8 kg hardwood for wings).

Performance and effects on crop yields and labour use

Power requirements for the BBM are higher than those for the traditional plow (O'Neil and Howell, 1986). The power consumption for both implements was established in a comparative study by measuring the force in the draft chain (using a standard Novatech load cell), the angle of pull (using a "Ferranti" potentiometric clinometer) and the forward

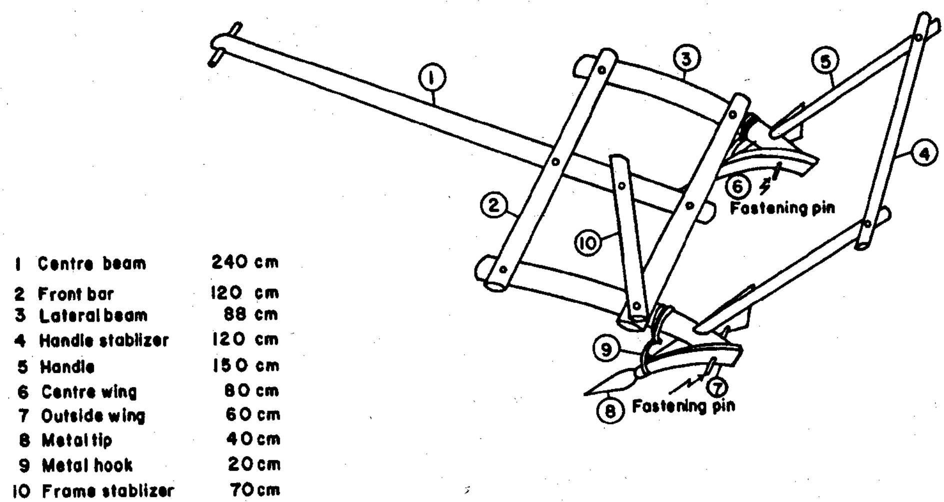


Figure 2. Broad Bed Maker (BBM), with dimensions

speed (using a "Dickey-John" radar velocity sensor).

Average power consumption of the traditional plow in a well-worked field was 398 W (SD 61, 17 observations), while the BBM consumed 634 W (SD 81, 13 observations). This power development is considerably lower than the potential power developed by the rather small (250 kg LW) local zebu (about 800 W) when hitched to the implement by a ridged neck yoke. The BBM can cover between 0.4 and 1.2 ha per day with one pair of oxen depending on the number of passes applied on each BBF and on the moisture or tilth status of the top-soil. Normally 2 passes are required on any one BBF in order to provide a uniform shape of both furrow and seedbed. A chain, connected to both centre wings, acts as a simple harrow and provides uniformity in surface cultivation.

The effects of the enhanced drainage on crop growth, achieved by the BBF, are substantial. In a series of on-farm verification tests, bread wheat yields were 78% (grain) and 56% (straw DM) higher than on the traditionally managed plots (1985, 8 participating farmers). Interestingly teff (*Eragrostis abyssinica*), the Ethiopian cereal which is an important traditional Vertisol crop and supposed to be tolerant of waterlogging, reacted with a 25% (grain) and 23% (straw) increase to improved drainage (1985, 15 participating farmers). The potential impact of this low-external-inputs technology on food production in Ethiopia, which has 8 million ha of Vertisols in high-rainfall highland areas, is considerable.

In a Vertisol area with extensive traditional hand-making of broad beds and furrows (average width 1.2 m; Inewari-plateau, North Shewa, central Ethiopia), the human labour required for this operation is about 60 hours/ha. When using the BBM for this activity, the human labour input is reduced to 16 hours/ha with one implement handler only.

Thus labour productivity for crop production can be dramatically improved using BBF technology. Total labour inputs for land preparation, seeding and drainage-making in the traditional system of BB-making are about 120 hours/ha. This figure drops to 75 hours/ha with the use of the BBM. This results in a 40% increase in labour productivity on the assumption that crop yields will be the same for both systems. The implement is currently in a large on-farm verification test in this and three other areas of Ethiopia. Early indications in the mid-season 1986 are that the BBM-treated plots will outyield the traditional system because of greater uniformity of the BBFs.

Further developments

The broad-bed-maker, as described above, can be used as a toolbar.

Two prototypes of attachments to this BBM or toolbar are currently in tests:

- *A blade-harrow.*
  This attachment consists of a metal blade fixed on the tines on either side of the implement and supported by an extended bolt at the rear centre of the frame. This blade harrow uniformly cuts the soil on a BBF at about 5 to 10 cm below the surface, thus uprooting most weeds. This implement contributes to a drastic reduction in power and time inputs for Vertisol cultivation, enabling the permanence of the BBF with only surface cultivation for weed management. The cost of the blade attachment is about US$7.

- *A row-planter.*
  The rear end of the BBM can also be used to support the seed hopper and agitator of a planter attachment. The rotary agitator is driven by a star-wheel running on one side of the BBM. The prototype has a double-hopper, one for seed (compartmentalized for simultaneous planting of intercrops) and one for fertilizer (for band application). This implement can plant 1 to 6 rows on the 70 cm top width of the BBF. Metering discs under the rotary agi-

tator allow planting of any conventional crop seed at desired rates. During planting, the planter attachment is simply run over the BBF. A chain attached to the two centre wings covers the seed in the planting rows. The rows are opened by metal row-makers fixed in front of the rear bar of the BBM. The cost of the planter attachment is about US$40.

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