CONSTRUCTION OF CAMBER BEDS FOR SURFACE DRAINAGE OF VERTISOLS

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December 1989

Institute of Agricultural Research
Library
Addis Ababa
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PREFACE

This handbook is to acquaint the farm manager and the agricultural extension officer with the equipment required for and the steps to be followed in the construction of camber beds for the drainage of Vertisols.

To maintain continued effectiveness of camber beds and associated structures, the appropriate seedbed preparation methods and the techniques to be employed in bed maintenance are also discussed.

Results of trials with camber beds and other surface drainage methods based on my experience in settlements and state farms are shown in tables; bed construction and maintenance techniques are illustrated with figures.

Under conclusions and recommendations, an effort is made to persuade agricultural policy makers how simple and inexpensive such drainage work can be once farm equipment is provided and development work is started in a given area or an agricultural enterprise.

Measures that should be taken to alleviate drainage problems on lands already under cultivation by state farms and small farmers and expertise that should be incorporated in any drainage venture, at least at the initial stage of development, are also recommended.

This handbook will be revised as and when new information becomes available or when existing data can be updated.

Lemma Kassaye
Introduction

According to the International Livestock Center for Africa (ILCA), Vertisols constitute an estimated 12.7 million hectares of land in Ethiopia, out of which 2.045 million hectares are cropped in both the highlands and the lowlands. Vertisols, which are 60%-70% montmorillonite, are self-mulching and are characterized by swelling, shrinking and cracking. Because of waterlogging during the rains, no crop can be economically grown on such soils without proper drainage.

The bedding system of plowing, which is used to construct comber beds, is one of the oldest surface drainage methods applied on flat, poorly drained soils with a gradient between 0 and 1.5%. The application of the system in Ethiopia dates back to 1935-1945, during the Italian occupation. Traces of such beds, which vary between 8 and 10 m in width, still exist under natural pastures north of Holetta, 44 km west of Addis Ababa. The system is applied worldwide. Different countries give it different names; 'ridge and furrow plowing' in England, 'bawla' in Yugoslavia, 'cumber bed' in East Africa, etc.

The system provides surface drainage via furrow ditches and the side slopes of the beds. Its main advantage over the parallel field drain system is that the root zone is raised above the waterlogged layer; thus plant roots are suffocated only minimally and consequently biotic activity and breakdown of organic matter are facilitated. The crown, formed at a height of about 30 cm above the bottom of the furrow ditches, gives the bedding system its advantage; otherwise the parallel field drain system would be preferable owing to ease and economy of construction.
If in practice the results are found uneconomical and of little effect, subsurface drainage methods should be considered. It must nevertheless be borne in mind that subsurface drainage is not only costly but also requires a considerable amount of engineering know-how when compared to the construction of comb bed or any other surface drainage method.

There are, however, certain disadvantages in the bedding system, so that some drainage engineers recommend it only for pasture and hay crops:

- the top soil is removed from the side of the beds to the middle, which may cause a reduction in crop yields near the furrows
- the system hampers mechanized farming
- the furrows require regular maintenance to prevent the growth of weeds and to ensure efficient drainage.

Be that as it may, in view of the prevailing grain shortage that is likely to occur for many years to come in most parts of Ethiopia, it is deemed necessary to reclaim waterlogged areas in selected parts of the country for crop and livestock production purposes.

In this regard, concerted effort must be exerted by relevant government institutions such as the Relief and Rehabilitation Commission, the Ministry of State Farms Development, the Ministry of Agriculture, and the Institute of Agricultural Research to find ways and means to alleviate drainage problems and operate on a nationwide scale in agriculturally potential areas.

The search for well-drained soils in remote parts of the country for production of crops, as is the trend nowadays, is neither practical nor economically justifiable.
Technological assistance and material inputs cannot readily reach such locations, aside from marketing difficulties, which are encountered as a natural course.

2. **Bed Construction**

To construct the beds the land is plowed repeatedly in one year or in the course of a number of years until the desired crown height is obtained with the crowns separated by dead furrows, which run in the direction of the prevailing slope.

The bed width depends on the land use, the slope of the field and that of the dead furrow, the soil permeability, the forming operation, and the width of the farm machinery. The recommended bed width according to the International Institute for Land Reclamation is:

- very slow internal drainage, 8 - 12m
- slow internal drainage, 15 - 17m
- fair internal drainage, 20 - 30m

As the beds get wider the area lost to the furrow ditches becomes proportionally smaller, and correspondingly the net productive area becomes larger. The cost of bed construction and subsequent field preparation is also lower for wider beds than for narrow ones.

On the other hand the effectiveness of drainage is better on narrow beds. This is attributable mainly to the crown, which is higher in relation to the bed width, and the greater number of the furrow ditches per unit area. Consequently per hectare yields of crops are normally higher on narrow beds despite the fact that the net productive area is smaller.
The decision regarding the optimum bed width should nevertheless be left to the judgment of the agricultural engineer and the concerned farm manager. Such decisions must be made with great caution inasmuch as once beds are constructed it is costly and cumbersome to make structural changes.

The length of the beds varies from 100 to 300 m while the width is variable. For effectiveness in drainage, fields under camber should not exceed 30 ha. Larger fields tend to be cumbersome and inaccurate. The crown height (the difference in height between the bottom of the furrow and the top of the bed) should be about 30 cm.

The side slopes of beds should be between 1.5% and 4% while the furrow ditches (dead furrows) and the field drains should not exceed a slope of 1.5% and 1.0% respectively.

The following steps should be followed in the construction process using conventional farm machinery.

2.1 Equipment

Although earth-moving machines like graders can be used if large areas have to be covered in one season, integral disk plows are more practical and are relatively cheap.

Another useful implement is the one-way disk tiller of 10-12 disks. This minimum tillage implement can be effectively used for disking plowed beds and simultaneously gathering the soil towards the crown. If this implements is available, only one plowing and two diskings will suffice to obtain the required height.

If a disk tiller is used after plowing it is not necessary to carry out subsequent operations with a disk harrow. Using a spring tine harrow is recommended, preferably with a leveller attachment,
Just before planting to produce smooth and uniform beds. In this manner a seedbed that facilitates accurate seed placement in the soil can be prepared. For agrochemical applications Knapsack or tractor-mounted sprayers can be used, depending on the field and crop condition at the time of spraying.

Planters and seed drills can be used depending on the type of crops to be grown. In row planting, the formation of ridges and furrows longitudinal to the beds should be avoided or minimized as they may impede drainage. Fertilizers can be applied using tractor-mounted spreaders alone or in combination with planters and drills.

Interrow cultivation is not advisable as ridges are bound to be created by the tines or duckfeet of the cultivator, which would inevitably prevent overland flow of surface water to the furrows. As long as weeds can be controlled by herbicides or manually, mechanical cultivation should be avoided.

Harvesting can be performed manually or with combine harvesters depending on the type of crop and the size of the field.

To mark the field before constructing the beds, a 50 m tape measure and a good number of 1.5 m pegs are required.

Field marking

Before constructing beds it is essential to lay out the field and establish the direction of beds, the position of field drains, field laterals, the main outlet drain and roadside ditches as shown in figure 1. Beds should maintain regular side slopes and uniform configuration throughout their total length (figure 1b)
If the field lies at the foot of a hill, a cut-off drain of 0.5%-1.0% slope must be constructed at the bottom of the hill to collect the runoff and convey it to an outlet drain so as to prevent excess water from entering the field and aggravating the drainage problem.

- Headlands or turn strips are marked out to avoid having to turn the tractor on farm roads or cross over roadside ditches.

- The prevailing slope of the field site should be identified. A line of pegs is placed and then the centerline of the beds is marked out in a downward direction on a 0.1% - 1.5% slope starting from one side of the field. An 8m bed is marked shallow, with a plow running 4m from the border and then every 8m until the opposite side of the field is reached.

### 2.3 Bed formation

- Plowing is started by back-furrowing at the center of the bed, throwing the first two furrows together.

- Driving speed should be higher than in normal plowing so that the furrow slices can be effectively thrown towards the center of the bed. Extreme care must be exercised to develop beds of uniform width and to avoid forming ridges and furrows on the beds while plowing.

- Furrows are thrown towards the back furrow until the required width of bed is attained. Thus a dead furrow, which becomes the furrow ditch, is formed.
Fig 1  Field layout for construction of beds.  
cross-section of B-B is given in 1b.
The desired crown height is reached by plowing two to three times as necessary during the first year. Each bed is plowed sequentially in the initial year to ensure construction of beds of uniform width and crown height (figures 1b and 2).

Furrow ditches should be straight, regular and free of weeds at all times to convey superfluous water effectively into field drains constructed at the lower ends of fields. The field drains should be fairly wide, with gently sloping sides of 8:1 minimum slope; bed width should be 1 m and depth of 20-30 cm. The drains should also be easy to cross with tractors and implements. The hedland occurs below the field drain and also serves as access to the lower field.

**Fig.2** Cross-section of bed showing construction method

Plowing starts by back-furrowing at center or bed until the required bed width is attained. Adjoining beds are plowed in like manner. Adapted from USDA-SCS, Keith Beauchamp.
2.4 Construction of field drains and collectors

Although motor graders are preferable from the standpoint of creating a continuous grade, disk plows can also be used for constructing field drains and collectors. The two disks closer to the furrow wheel are retained and the rest removed for better penetration and ease of operation. This is preferable to a ditcher as the latter tends to form lips on either side of the drain, obstructing the flow of water from the ditches into the field drain. The disk plow should be used to cut and place slices at the lower side of ditches, repeating the operation until the desired depth is attained.

Several field drains may drain into a collector (field lateral) that lies on one side of the main farm road and finally discharges into a natural outlet or the main drain. The collector drain should be 45-60 cm deep with a minimum side slope of 1:1.5 and a bed width of 1 m. To avoid soil erosion near drain outlets, all drains should grade smoothly backwards. Otherwise construction of some sort of drainage outfall would be necessary at every drain outlet.

3. Additional field operations

3.1 Disk harrowing

Although using a disk tiller of 10-12 disks is preferable on camber beds because of the added advantage mentioned earlier, an offset disk harrow can be used as a second option.

A tandem disk harrow can be used as a third option with care being taken not to form ridges on the beds. The ridges can be avoided by adjusting appropriately each gang on the implement.
3.2 Tine harrowing

Spring-tooth or spike-tooth harrows should be used to make a level seedbed just before planting, or even earlier if a flush of weeds emerge before the planting date. All the above operations are executed longitudinally to the beds.

3.3 Planting

Planting or drilling of row crops is best carried out longitudinally to the beds; broadcasting small grains and grasses can be carried out in either direction. Headlands will also have to be cropped after planting is completed on each field. If not, they may harbor insects and weeds that will eventually become a serious problem for the adjoining crops.

3.4 Spraying

Pre-emergence herbicide spraying using tractor-mounted sprayers can be carried out in either direction for all crops; postemergence spraying should be carried out longitudinally for row crops.

3.5 Cultivation

Interrow cultivation on camber beds should be avoided as much as possible for the reasons stated earlier. Weeds should be controlled by hand weeding, Hericides, or both.

3.6 Harvesting

Mechanical harvesting should preferably be carried out longitudinally to the beds. In harvesting across the beds, the combine table must be carefully controlled so that the cutter bar does not run into the ground while crossing each bed. Here again operator care, patience and perseverance are of paramount importance.
4. **Maintaining beds**

Plowing beds in the same direction year after year tends to raise bed height beyond the optimum level. The dead furrows also keep on widening as a result of the soil thrown toward the crown. This inevitably concentrates the topsoil at the crown and exposes the subsoil at the lower part of the beds. Hence plant vigor is irregular and low yields result.

It is therefore recommended to start plowing by back-furrowing at the center of each bed only during the year of construction. In subsequent years plowing should start on two adjoining beds at the dead furrows by throwing first back-furrow slices on each side only partially into the dead furrow so that the dead furrow remains at least 30 cm wide. In short, to maintain the optimum bed height and uniform bed configuration, the starting place for plowing must be staggered systematically as shown in figures 3 and 4.

It is also worth mentioning that for effective drainage and moisture, roadside ditches, field drains, furrow ditches, collectors and headlands must be maintained and kept free of weeds.
Maintaining beds

In the first year after bed construction, plowing starts between two adjacent beds around dead furrow B by partially throwing slices into the furrow until the adjoining beds are plowed up to dead furrows A and C. Adapted from USDA-SCS, Keith Beauchamp.

Fig 3

Maintaining beds

In the second year and subsequent years after bed construction plowing starts by throwing slices partially into dead furrows C and A and continues around both beds, treating them as one unit, up to dead furrow B. In the third year, the procedure in figure 3 is followed, and so on. Adapted from USDA-SCS, Keith Beauchamp.

Fig 4

5. Crop Performance observation

Crop adaptation has been very encouraging for most crops, as observed on beds constructed on Taddele Settlement Farm, the Sheno and Holetta research stations of the Institute of Agricultural Research, and Wamå State Farm (table 1).
Table 1: Crop adaptation on camber beds vs conventional plots

<table>
<thead>
<tr>
<th>Crop</th>
<th>Variety</th>
<th>Yield (ha)</th>
<th></th>
<th></th>
<th>Increase</th>
<th></th>
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<tr>
<td></td>
<td></td>
<td>Conventional</td>
<td>Camber bed</td>
<td></td>
<td>(kg)</td>
<td>(m)</td>
</tr>
<tr>
<td>Wheat</td>
<td>Enkey</td>
<td>730</td>
<td>8</td>
<td>950</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Haricot bean</td>
<td>Mex. 142</td>
<td>1350</td>
<td>8</td>
<td>1350</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Noug</td>
<td>Local</td>
<td>620</td>
<td>8</td>
<td>610</td>
<td>-2</td>
<td></td>
</tr>
<tr>
<td>Pepper</td>
<td>Mareke fana</td>
<td>550</td>
<td>8</td>
<td>1420</td>
<td>158</td>
<td></td>
</tr>
<tr>
<td>Sun flower</td>
<td>Russian Black</td>
<td>570</td>
<td>8</td>
<td>1300</td>
<td>163</td>
<td></td>
</tr>
<tr>
<td>Tef</td>
<td>DZ-01-787</td>
<td>600</td>
<td>8</td>
<td>380</td>
<td>-37</td>
<td></td>
</tr>
<tr>
<td>Maize</td>
<td>KCC</td>
<td>1770</td>
<td>6</td>
<td>2980</td>
<td>68</td>
<td></td>
</tr>
<tr>
<td>Maize</td>
<td>KCC</td>
<td>1770</td>
<td>8</td>
<td>2660</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Maize</td>
<td>KCC</td>
<td>1770</td>
<td>10</td>
<td>2760</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>Maize</td>
<td>KCC</td>
<td>1770</td>
<td>12</td>
<td>2640</td>
<td>49</td>
<td></td>
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a) Yields of maize and wheat were low under both treatments mainly because of very low plant population, about 35,000 plants/ha of maize. Yet there is a significant difference between the two treatments warranting the need for drainage.

b) Because of early planting (22 May) haricot beans matured before the soil became waterlogged. Consequently, the plants were not affected by excess water and the yield obtained was as good as that on the camber beds. Normally haricot beans are susceptible to waterlogging.

Location : Wama State Farm, 1984
Design : Single plot observation
Plot Size : 2100 m² each
Fertilizer : 100 kg DAP
Table 2: Per hectare marginal yield, cost and return, as a result of drainage (based on table 1)

<table>
<thead>
<tr>
<th>Grain</th>
<th>Marginal</th>
<th>Grain</th>
<th>Prices</th>
</tr>
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<tr>
<td></td>
<td>Yield (kg)</td>
<td>Revenue (birr)</td>
<td>Cost (birr)</td>
</tr>
<tr>
<td>Maize</td>
<td>950</td>
<td>307</td>
<td>120</td>
</tr>
<tr>
<td>Pepper</td>
<td>877</td>
<td>1453</td>
<td>120</td>
</tr>
<tr>
<td>Sunflower</td>
<td>930</td>
<td>556</td>
<td>120</td>
</tr>
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</table>

On Vertisols under comber beds, two crops may be grown in the same season. Since the water-holding capacity of such soils is relatively high, there is sufficient moisture in the soil after harvesting the main crop to grow a second crop such as chickpeas.

One disk- ing using a disk tiller will suffice to pulverize the cover weeds and plant residues from the previous crop and incorporate them with the soil. Sowing should be carried out either by broadcasting manually and covering seeds with a tine harrow or with a drill. No fertilizer may be necessary and one hand weeding generally suffices. As the planting is out of season, weeds should not be a major problem.

On 8 m-wide beds of 1550 m² each, in three sowing dates (September 10, 20 and 30) chickpeas were observed at Wama state farm. The yields per hectare obtained were 650, 1230 and 1310 kg, respectively. The variety used was Dubci with a fertilizer level of 100 kg/ha of diammonium phosphate (18:46:0). A total of 2660 kg/ha of grain yield was obtained in one season, 1350 kg/ha of haricot beans and 1310 kg/ha of chickpeas.
6. Conclusion and recommendation

Construction of camber beds is nothing but a modified plowing method. In the conventional method, forming dead furrows is avoided as much as possible; in the bedding system, dead furrows are deliberately created to serve as drainage furrows. The dead furrows occur at intervals of 6 m to 30 m depending on the bed width.

Once tractor operators develop the skill required to construct beds of uniform configuration, the whole exercise becomes routine. It is worthwhile to make operators aware of the purpose of the beds so that they will be involved in the program enthusiastically rather than just carrying out mechanical work. Particularly in using farm machinery, the services of a conscientious and skilled supervisor are also essential.

Although not absolutely essential, the guidance of an irrigation drainage engineer would also be valuable during the construction phase. Furthermore, agronomists and engineers must jointly evaluate the effectiveness of the drainage system, especially during the peak of the long rains. The performance of crops and the boost in economic return should be the ultimate interest of all concerned. Therefore, before expansion into larger areas is embarked upon, improved agronomic, structural and mechanization methods should be established.

The construction of broad camber beds can only be effectively executed by use of tractor power or earth-moving machines. In the initial stage, the use of animal power is not worth the trouble. However, once the beds are constructed field operations can be carried out either by tractors or by animal power and allied implements.
ACKNOWLEDGMENTS

My thanks are due to Mr. Tessema Wubneh, irrigation drainage engineer of the Ministry of State Farm Development and to Mr. felix pinto, FAO agronomist of the Ethiopian Seed Corporation, for their valuable suggestions and critical reading of the manuscript.

Tables and Figures

Table 1  Crop adaptation on camber beds VS conventional plots
Table 2  Marginal cost and surplus due to drainage
Figure 1a Field layout for construction of beds
        1b Cross section of field B-B
Figure 2  Cross section of bed showing construction methods
Figure 3  Maintaining beds - Year 1
Figure 4  Maintaining beds - Year 2
BACKGROUND MATERIAL


