Soil Fertility Management and Biological Soil Conservation

1. Compost Making
2. Fertilization and Manuring
3. Live Checkdams
4. Mulching and Crop Residues Management
5. Grass Strips along the Contours
6. Stabilization of physical Structures and Farm Boundaries
7. Vegetative Fencing
8. Ley Cropping
9. Integration of Food/Feed Legumes into Cereal Cropping Systems
10. Intercropping
11. Crop Rotation
12. Strip Cropping

TECHNICAL INFORMATION KIT

COMPOST MAKING (CM)

(3) Suitability, agroecology, adaptability to local knowledge

Vast experience in CM exists, traditionally and through new methods. Pit method is common in moisture stressed areas. Heap method in moist weyna dega and dega areas. CM can be scaled up in most areas, including dry areas. Can build upon traditional practices of keeping animals under shed at night and collect waste and roughage around the homesteads and fields (Kraal or Ohura traditional system for cultivation of peper, maize, etc.).

(1) Period/phases for implementation

1. Pit excavation 1-1.5 m depth x 2 m width x 4m length (Feb-Sept).
2. Collection of roughage, ashes and animal dung (around farms, foot paths, etc.) in Aug-Oct.
3. Compost preparation (end Sept-Oct) - for either pit or heap method.

(2) Objectives/remarks

- To promote compost making at household level for cost-effective soil fertility improvement and to support **local level compost entrepreneurship** linked to natural resources management activities at watershed level.
- CM will improve soil fertility, increase water storage within the soil profile and reduce surface runoff, thus reduce soil erosion. **It is one of the best "hidden" water harvesting methods** available (compost absorbs water 4-7 times its own weight).
- CM can be undertaken at very large scale and linked to area closure management and the **upgrading of terraces into "cash crop production belts".**
- CM can become a business: groups of households (landless, etc.) can decide to become compost makers and provide "fertilization" services to other farmers.

(4) Main land use

. Compost is made for the following main land uses:
1. Apply for high value crops within homesteads (horticulture).
2. To fertilize conserved fields and/or supplement artificial fertilizers in cultivated lands treated by bunds/terraces.
3. To apply around valuable trees plantations and inside

(5) Technical preparedness

. Preparation of available materials kept under shade (cow dung, ashes, etc.) until compost is done.

. Training of group of farmers in CM necessary (demonstration).

(6) Potential to increase/sustain productivity and environmental protection

. Currently, 1-2 tons of compost per homestead are prepared through pit method in several dry and moist areas. Productivity improvements recorded as high as 60-80% increased yields and 3 years average of 30-50% increased yields. Allows to reduce temporary waterlogging along bunds and creates "fertile infiltration zones" within the first 2-3 meters above bunds (where the soil is deeper and moisture is higher) that can be planted with high demanding crops along those strips.
. Offer opportunities for very poor households to serve as compost makers for others.

(7) Minimum surveying and tools requirements

. Select shaded places and availability of composting materials (link with area closure and homestead re-vegetation if necessary).
. Tools: only shovels and pick axes for excavation - other containers as required

(8) Min. technical standards, steps and work norm

(1) Pit method
The pit method is recommended in (1) moisture deficit areas with shortage of water supply, (2) in very cold areas, (3) in windy areas and (4) in nurseries. Steps for CM are:
a) Select the site for CM under a shelter (boundaries, trees, etc.).
b) Collect organic waste, animal manure and ash (from kitchens). To carry the materials use a stretcher or a basket.
c) Demarcate the pit. The size and number of pits will depend on the amount of plant material available, but in any case the pits should not be more than 2 m wide, 4 m long and 1.2-1.5 m deep. Start with digging 2 pits, one next to the other as shown in Figure 1. Make a drain to protect the pit from excess rains.
d) Prepare compost in the 1st pit by making layers of:
   1. Crop residues and waste of about 20 cm thick. Compact lightly and apply water (moist all layer).
   2. Sprinkling of ash over the layer of plant waste: 0.5 kgs/square meter/layer will be enough.
   3. Apply farmyard manure (FMY): 3-5 full spade/square meter/layer.
   4. Some soil should be also spread (1-2 cm) on top of each layer.
e) Repeat the same procedure till you reach the top of the pit.
f) To improve the aeration in the pit, bamboo or other sticks should be placed standing in the middle of the pit at every 2 m. Cover the pit with dry grasses or other dry residues.
g) The pit is now left for one month. During this period check the moisture and add some water to keep the pit moist, never dry or wet. Usually undertake this task once/week.
h) After a month turn and mix the compost into the second pit.
i) Compost ready after 3-5 months - keep under shade and covered.

WORK NORM: Pit: 10 PD/pit (4mL x 2mW x1,5mD)

(2) Heap method
. Requires less labour than pits. Not suitable in dry areas, windy areas or very cold areas. Nutrients can be leached if heap not protected.
Steps:
· Follow a) and b) as for the pit method. Then first demarcate the boundaries of the heap using wooden pegs. The size of the heap depends from the amount of organic waste but it should not be wider than 2 m and 1.5 m high, and as long as necessary. Then dig a shallow pit (30cm deep) for collection of leached nutrients and moisture.
· Then follow all the same steps from d) up to i) for the heap.
· The sides of the heap can be also covered or plastered with soil to some height to keep the heap warm and to avoid drying by wind.

WORK NORM: 1 PD/linear meter (2mW x1.5m Height)

(12) Planning and implementation arrangements

Fig 1. Dimensions of pits

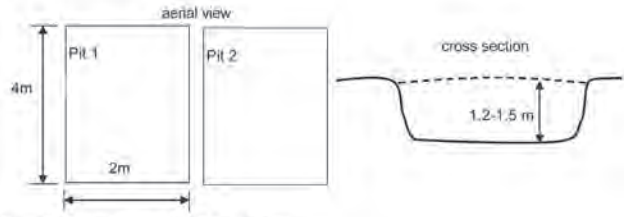


Fig 2. Cross section of pit showing layers

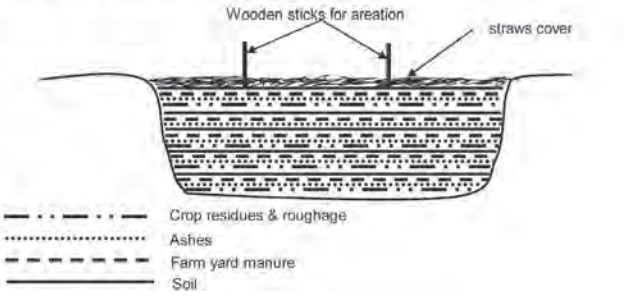
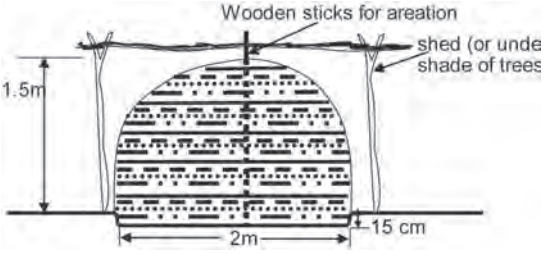


Fig 3. Cross section of a compost heap



(9) Modifications/adaptation to standard design

. A simple form of composting is to throw into a pit organic waste and manure from the cattle shed mixed with some ashes and soil without following precise layers. Watering is required every 20 cm. The compost is turned once and left maturing until the time for distribution. In this case quality of compost may not be as of good quality as if following the procedures indicated above.

(10) Management requirements

Refill the first compost pit one month before the end of the composting process taking place in the second pit and repeat the same procedure. By this system you can produce compost three times a year (see figure 80) or more if the time of decomposition is faster.

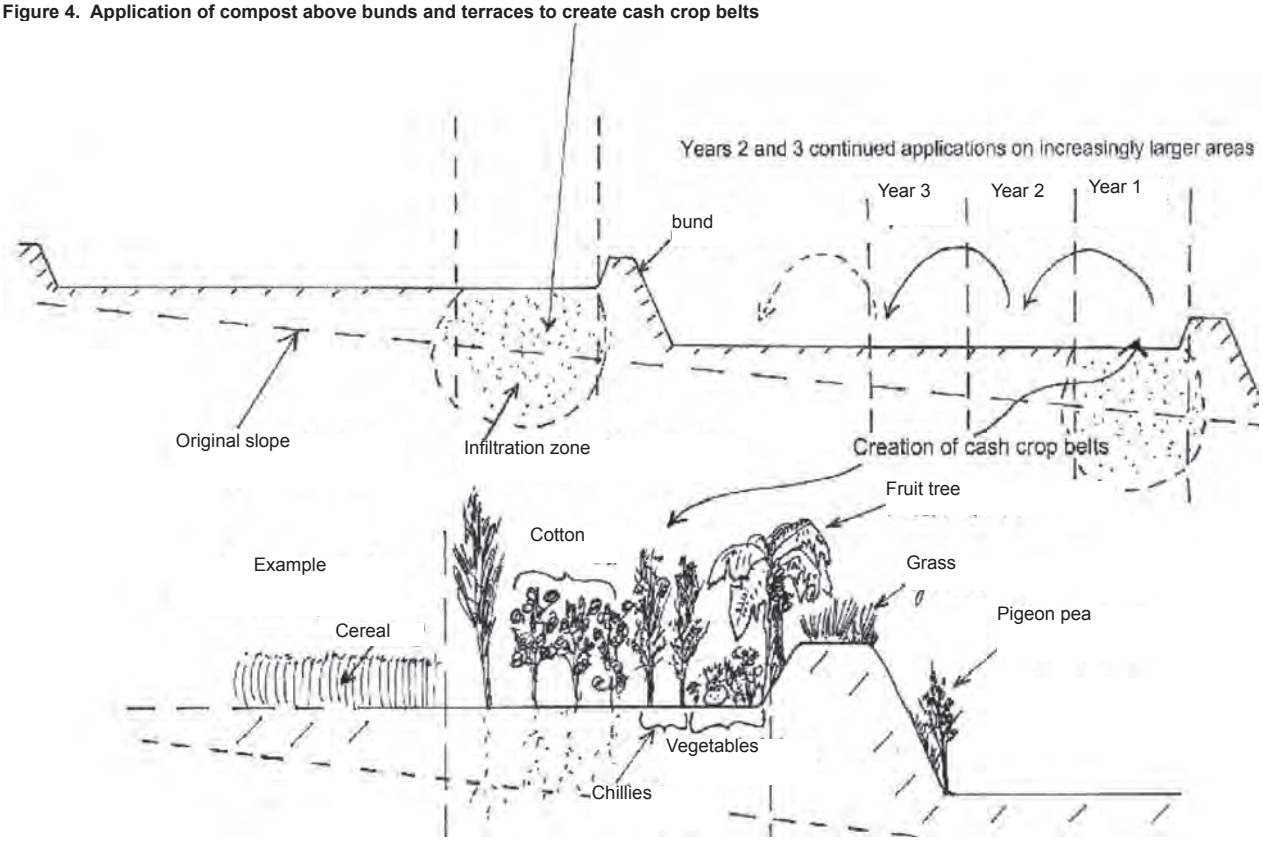
(11) Use of compost as a moisture harvesting measure in areas treated with bunds

Hundred of thousand of hectares have been treated in Ethiopia with various conservation structures. Many areas have gradually benched or are benching. Thus, compost making in Ethiopia is an excellent opportunity to support increased productivity of conserved areas. Cultivated sloping lands treated with bunds have deepest soil and higher moisture content near the terrace embankment. To take advantage of this situation:

(1) Use "selective" applications: apply significant amount of compost along the first 2-3 meters of cultivated land above bunds during the first year. This will have maximum impact in creating a re-cycling zone where the soil is deeper and moisture is the highest. Plant cash or high value crops along those strips.

(2) Apply additional compost to the same area + apply compost 2-3 meters upwards every year. In this regard, compost making or supply of compost from compost makers need to be planned (see Example below).

Figure 4. Application of compost above bunds and terraces to create cash crop belts



Examples of possible use and advantages of compost making

(1) Compost making as a business and income generation for the poor (link compost making to area closure and homesteads): Groups (5-20) of landless or poor farmers (with small plots) can be organised to prepare compost for other farmers on a contract basis. For example, two pits to be constructed as terms of contract. This activity can be closely connected with measures such as rehabilitation of closures and hillsides to access biomass. Compost makers can be grouped together and create an income generation group (IG) specialising in this kind of activity. Such groups can provide a "fertilization" service for a large number of farmers.

(2) Compost making or "local fertilizer factories" can be organized at the lower part of area closures, close to the cultivated lands (foot of the hills) to get compost close to the fields for distribution.

(3) Compost making linked to fertilizer distributions: local DAs could promote a campaign aimed to sensitize any farmers that buy fertilizers with a brief session on benefits and use of compost. The use of compost helps retaining and releasing fertilizer nutrients, increasing its efficiency as high as 50% or more in most places. In areas with conservation + compost farmers can also use small quantitites of fertilizers compared to little in untreated areas.

(12) Limitations	(13) Institutional responsibility
Not applicable in areas with very limited access to water. Can not expand to proper scale without proper watershed rehabilitation.	. Fully on community members (commitment to mgt.). . DAs and wda experts - technical support and mgt.

TECHNICAL INFORMATION KIT

Fertilization and manuring

(1) Period/phases for implementation

According to cropping seasons and crops, mulching possible throughout the year

(2) Main objective/purpose

The current cropping systems in Ethiopia are highly extractive as chemical fertilizers are expensive and not always available, manure is used in most areas as fuel or income source, due to open grazing manure not readily available as compared to tethered animals, mulching is not practiced due to use of crop residues for forage. Levels of organic matter are low leading to reduced soil stability, infiltration, water holding capacity and increasing erosion. Application of fertilizers will increase yields, while manure and mulching will improve longterm soil quality and nutrient levels

(3) Suitability and adaptability to local knowledge

If financial means and distribution allow, farmers utilize chemical fertilizers, in some cases manure is used in homegardens or on fields, application of ash (Potassium source) is frequently observed.

(4) Potential to increase/sustain productivity and environmental protection

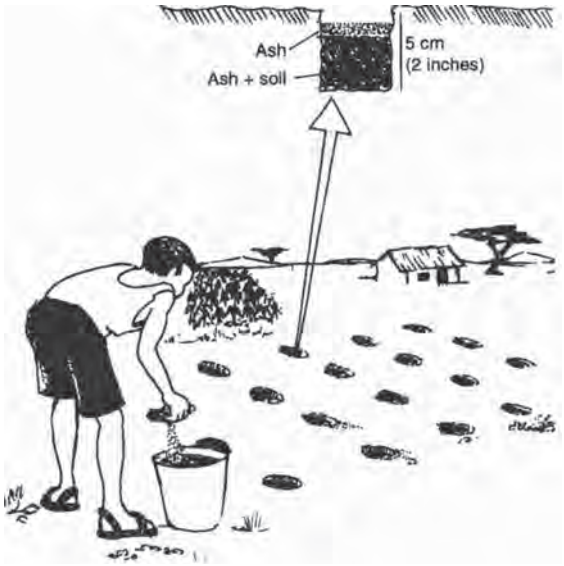
Due to long history of cultivation in Ethiopia and almost complete disapearance of fallow periods nutrient mining has led to low levels of productivity and organic matter of the croplands. If usage of manure and other types of organic fertilizers is implemented production and soil stability will be improved considerably. Nutrient mining frequent from outfields to homegardens due to ownership issues.

(5)Technology description

- Use of different fertilizer types, either chemical or organic, in cropping systems. This can be done either by broadcast application before sowing or with certain crops in band or spot application.
- For homegardens and smaller areas composting can be an effective fertilizer source, integration of manure possible.
- Mulching brings several benefits: soil cover, longterm nutrient supply, increased soil stability and health.

(6) Minimum tools/requirements

Transport mechanism (people, carts), shovels and rakes for distribution, carrying devices for DAP and Urea,



Ash application for homegardening

(8) Work norm

- Application of DAP or urea broadcast same as sowing of cereals
- Mulching labour intensive but only once per year
- Manure application labour intensive

(9) Management requirements

- Awareness about longterm effects of organic fertilizers and mulching systems has to be raised.
- Appropiate application timing and methods.
- Band application as opposed to broadcast, use of funnel planters in combination with sowing of seeds in order to minimize amounts and maximise effectivity.
- For mulching systems livestock have to be kept from fields.

(7) Integration requirements and opportunities

- Chemical fertilizers available at crucial times either through goverment or private sector facilities.
- Credit availability for farmers to purchase fertilizer.
- Availability of improved energy sources (improved stoves, etc) to allow utilization of manure for fertilization.
- Feed resources in the watershed sufficient to allow for utilization of crop residues for mulching.
- Animals tethered for more efficient manure collection.Grazing strategy allows for application of mulch.

(8) Constraints and limitations

. Cost of fertilizer
. Opportunity costs of manure
. Opportunity costs of mulch materials
. Only N and P fertilizers commercially available
. Micronutrient defficiencies cannot be adressed

TECHNICAL INFORMATION KIT	(1) Period/phases for implementation	(2) Main objective/purpose
LIVE CHECK DAMS	During the rainy season	Live check-dams are established by planting/seeding or plugging of cuttings in gully bottoms to replace or reinforce physical check-dams. The main objective of the establishment of live check-dams is to reduce the cost of establishing physical check-dams. Live check-dams can be applied by individual farmers and does not need the organization of a large group of people to undertake physical structures.

(3) Suitability and adaptability to local knowledge

Gullies and dry river beds with low to medium slopes

(4) Potential to increase/sustain productivity and environmental protection

The biomass produced is an immense contribution to animal fodder as well as fuel wood, poles and other wood products.

(5)Technology description

Woody plant boxes: Poplar, willow or other suitable species stems with a diameter of 2-4 cm and a length of 70 cm are inserted 20 cm deep next to each other across the gully floor spaced 50 cm apart. The space in between the rows is filled with stems of the same species. This works in gully floor within the soil and should be established at the beginning of the rainy season.

Reinforced Bundling/wattling

It is a technique where fresh stems of plants (e.g. elephant grass, bana grass, Spanish reed, poplars, willows) are bound together, horizontally planted and covered by soil. The use of other organic matter (e.g. straw, tree branches) may be used to economize on fresh planting material. Fresh vegetative material are placed in between two rows of reinforcing materials such as poplars and willows inserted in the soil as described above. Apply after the start of the rainy season.

Layering of vegetative material

It is the horizontal planting of fresh stems of plants (e.g. elephant grass, green gold, bana grass, poplar, willow) across the gully floor, or at the base of gully walls. This technique is applied when a satisfactory level of sediment accumulates. The shoot growth forms a dense barrier that breaks the velocity of run-off.

Gully bed plantations

The planting of water loving or tolerant species (e.g. Paraserianthes lophantha, Salix spp., Acacia melanoxylon, Phalaris aquatica, Pennisetum clandestinum, green gold) on the gully bed, adequately spaced, breaks the flow and velocity of run-off, traps sediment and protects the gully bed from erosion

(6) Minimum tools/requirements

The characteristics of species (such as tolerance to water logging, sprouting ability, etc.) should be well understood during the selection of the species and approaches. The main factor which determines success/failure is the choice of species.

(8) Management requirements

(a) Effort should be made to have a continuous vegetation strip by replanting

(b) woody plants may be coppiced, pruned, pollarded or looped depending on species and type of products required

(c) cut and carry system should be used for utilization of grasses and other fodder

(7) Integration requirements and opportunities

Very effective with loose stone or brush check-dams.

TECHNICAL INFORMATION KIT	(1) Period of implementation	(2) Main objective/purpose
MULCHING AND CROP RESIDUES MANAGEMENT	. After the harvest of crops for cultivated areas and in September for area closures.	. Mulching is the covering of the soil with crop residues such as straws, maize/sorghum stalks or standing stubble. The cover protects the soil from raindrops, drastically reduces splash erosion and velocity of runoff. It then minimises erosion, increases soil infiltration and permeability, prevents the formation of hard crusts and contribute to improve fertility. . The second major advantage of mulching/ crop residue maintenance, is its potential for sustaining productivity. . Mulching, in addition to its positive effects on soil structure also helps in reducing evaporation and maintaining soil moisture. The improved soil structure also will have an effect on moisture retention and consequently higher water budgets for the growing crop.

(3) Suitability and adaptability to local knowledge

Mulching is applied in several areas around high value cash crops such as fruit trees, coffee, etc. It is seldom used as stubble except in specific areas such as Derashe in SNNPR. This activity can expand provided sufficient biomass could be made available from closures and/or crop residues.

(4) Main land use and agro-ecology

For cultivated areas, suitable mostly on plots around homesteads and with good soils. In open cultivated fields vertical mulching is preferred as it does not require much residues. Mulching is strongly recommended for tree planting using trenches and similar structures. This technology is not suitable in areas where both excess dryness or cold slow down the breakdown of residues. In dry areas crop residues can be easily decomposed by termites. In this case planted crops should be termite resistant during growth period.

(5) Potential to increase/sustain productivity and environmental protection (impacts)

1. Potentials for increasing moisture availability and infiltration are high. Mulching is an excellent fertility improvement measure, especially when combined with moisture conservation measures and compost applications.

2. Mulching of plantation structures prior and/or after planting of trees/shrubs increases the growth of plants and induce high water conservation within the soil profile. Mulched closures become highly productive “vegetative sponges” with beneficial effects in water tables recharge and runoff control.

(6) Description of the technology and steps

(1) Surface mulching

• Different crop residues can be applied (based upon availability), especially for fallow lands. Materials from leys can be used at the end of their cycle. Another possibility is to bring such grass and roughage from hillside closures.

• It is recommended to scatter the residues over the whole surface in a 2-5 cm thick layer. At least 40% cover is recommended to reduce erosion by 60-70% based on slopes and type of soils.

(2) Vertical mulching

• This activity is useful to safe mulching materials and to increase water infiltration at regular intervals between crops.

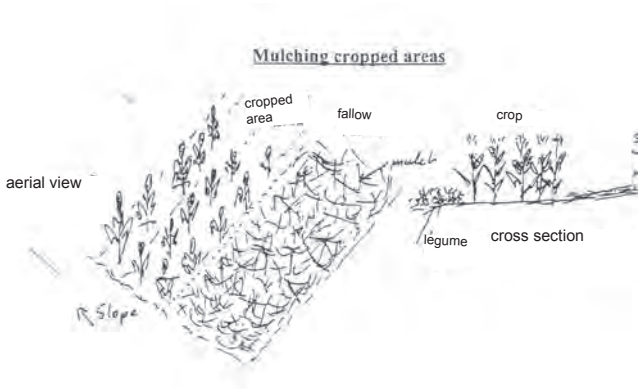
• It consists in opening shallow furrows every 2-6 m, 20 cm deep and along the contours. Then straws or mulch is buried with 20 cm of height standing over the soil surface. In addition to reducing runoff it substantially increases water intake around the mulch area and nearby crops. This operation should be done 40-50 days before sowing crops. Vertical mulch is well integrated with bunds and ripping (mulched lines along contour ripped areas).

(3) Mulching of plantation structures (trenches/eyebrows/herring bones/hillside terrace+trench)

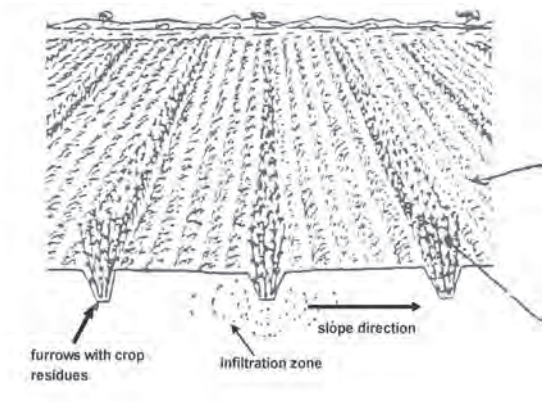
• By end of September cut and mulch the grass growing around trenches, eyebrows, etc, in a thick layer first arounf the planted pit and then if materials are sufficient inside the water collection ditches. This operations can be repeated for 2 years.

Work Norms: it includes cut and carry and transport of mulch to site (distance 300 m from site max.) and layering of mulch over the entire area. (1) For surface and vertical mulching the norm is estimated as 250PD/ha mulched. (2) For plantation structures the work norm is 50 TR/EB/HB structures mulched per day.

(1) Stubble mulching



(2) Vertical mulching



(7) Integration requirements and opportunities

1) Integration naturally occurs with different sort of contour bunds and moisture conservation systems.
2) In open fields need to be integrated with compost making and physical structures on slopes > 5%.
3) In closures, integrated with compost or manure applications to planting pits.

(8) Constraints and limitations

. A main limitation is the availability of organic materials. In this case, the rehabilitation of degraded areas and closures using water harvesting devices offers an opportunity to produce substantial amount of biomass that can be used for mulching.

TECHNICAL INFORMATION KIT

GRASS STRIPS ALONG THE CONTOURS

(1) Period/phases for implementation

Seedbed preparation before begininng of rains. Planting at beginning of rains.

(2) Main objective/purpose

. Grass strips are vegetative barriers made out of grass planted in narrow strips of 0.5 to 1.5 meters width laid out along the contour. Grass strips control erosion rather effectively in gentle slopes but above 5-8% slope their effect decreases.

. While contributing to protect soils against erosion they also provide valuable biomass meant to increase animal feed or used for different purposes (eg. roofing, etc.).

. Grass strips cause less interference than other measures as they can easily be crossed by oxen and plough. Moreover, grass strips take out little amount of arable land. Cost of construction is much lower than physical structures.

(3) Suitability and adaptability to local knowledge

. There are grass strips in various parts of the country, often in the form of buffer strips of land left uncultivated and filling up with spontaneous grass. This is done with the dual purpose of allowing some valuable grass to grow and to control runoff. This system is usually not of permanent nature. Standard grass strips technology was introduced by different projects but did not meet the expected success, mostly because of the difficulty to control free grazing.

(4) Main land use and agro-ecology

Grass strips are suitable for cultivated land, mostly in medium and high rainfall areas (moist weyna dega and dega). Within the context of moisture deficit areas grass strips can be applied in semi-arid areas and but not for arid areas.

(5) Potential to increase/sustain productivity and environmental protection (impacts)

. Potential is relevant in medium-high rainfall areas provide control grazing is ensured. This is critical during the first year of establishment. Grass strips can replace physical structures effectively usually up to 8% slopes. Exceptions are possible above those ranges but not as effective and/or combined with physical structures and or trees/shrubs hedgerows.

(6) Description of the technology and steps

. **Type of grass**: Grass species should be perennial and persistent, compete with and suppress weeds, provide good ground cover, slow down the water flow and hence conserve the soil and moisture. Besides, they should provide valuable fodder or other materials of use by the farmers.

. **Layout**: grass strips are established along the contours. Grass strips are established on a 1m vertical interval, i.e. at 3% slope the distance apart two strips is 33 m and decrease to 7 m at 15% slope. In dry areas, grass strips should not be established on slopes > 8%. For slopes up to 15% they may be planted alternatively with bunds (one grass strip/one bund). The width varies from 0.5 m to 1 m, depending on the density of the plants in the strip. For conservation purposes a width of 0.8-1 m is recommended (Figure 2). The strip is established by broadcasting or sowing/planting seeds/splits/cuttings in two or three lines. The middle row can be sown with a legume to improve the nutritive value of grasses. If the broadcasting method is used, grass seeds can be mixed with the legume seeds and broadcast in the strip.

. **Planting technique**: For direct sowing a fine seedbed preparation is required. Generally, 0.5-1.5 cm depth is the optimum for most species. When planted manually, rows are opened with a stick at the desired spacing and seed is drilled in the row. Seeds are covered with a thin layer of soil and pressed hard to the soil. Before planting, seeds should be checked for their germination. Alternatvely and for improved efficiency and rapid cover use splits and/or grass cuttings or seedlings planted in lines/rows without discontinuity. Spacing between the seedlings/splits should not be wider than 5 cm to guarantee effective grass strip.

. At the time of planting, the handling of planting materials is very important. The grass is cut at about 12 cm above the ground, then the clump is uprooted and transported to the planting site. At planting, the clump is split into pieces including 2 to 3 tillers each to ensure a good establishment (figure 1). Legume seeds planted in the middle row should be sown by using seeds.

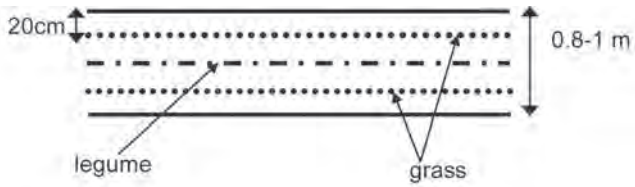
. Planting should be carried out at the onset of rainfall, when the soil is not too wet or too dry. Planting should always ensure good soil-seed/seedling contact by pressing the sides of planting material to soil.

. Harvesting of grasses depend from their use and inner characteristics. Some grass should be cut frequently and at a young stage, other at flowering or filling time etc. If used as forage usually the first harvest is after 3-4 months from establishment, before flowering and cutting grass 10-15 cm above the ground.

. **Type of species**: should not be aggressive on adjacent crops and act as weeds. There are number of grass species that can be effective in grass strips, such as Rhodes, Andropogon, Setaria, Phalaris, Vetiver, etc. But also native grass (see bund stabilization) which may be more adaptable to local conditions and tolerant to drought. Besides, the advantage of using native grass species is that land users are familiar with the purpose and management of such grasses. Regarding legumes, species such as Stylo, Sirato, Desmodium for drier areas and clovers and medicago in other areas should be tried. However some grass are aggressive with rhizoma and stolons which rapidly colonize the surroundings. Forage/livestock specialists should be consulted prior to the selection of this technique.

Figure 1. Splitting grass from clumps

Figure 2. Grass strip (aerial view)



(7) Integration requirements and opportunities

1. Grass strips can be integrated with lines of legume shrubs such as pigeon peas, Sesbania, Treelucerne and Acacia saligna planted in dense rows.

2. Integrated with physical structures alternatively in 8-15% slopes. Above such range grass strips are better replaced by physical structures stabilization (less risks of breakages and rapid benching).

3. Control grazing and cultivated land closure recommended.

(8) Constraints and limitations

. Although they retard the movement/velocity of water and encourage infiltration they do not offer much resistance against erosive rainstorms, particularly at the beginning of the rainy season because the new shoots are not yet developed. Besides, they are easily overgrazed and damaged by animals.

. In dry areas grass strips are less effective in reducing runoff as they provide little storage capacity.

TECHNICAL INFORMATION KIT

STABILIZATION OF PHYSICAL STRUCTURES AND FARM BOUNDARIES

(1) Period/phases for implementation

. Mostly at the beginning of the rainy season and/or on residual moisture for specific species.

(2) Main objective/purpose

. Stabilization refers to the planting of crops, grass, shrubs and trees in different combinations in order to strengthen the resistance and stability of physical structures such as bunds, trenches, checkdams, SS dams, etc, against rain drops splash effect, runoff and cattle trampling. At the same time, stabilization has the purpose of making productive the surface area occupied by the structure.

. Stabilized structures would need less maintenance and damages are less likely to occur, even during heavy rainstorms.

. Trees or shrubs help to demarcate farm and homestead boundaries, thus provide additional sense of ownership.

. Particular plants are also hosts for insects able to control pest incidence.

. Stabilized areas are an additional source of timber, fuelwood, fibre, food and forage, palatable grasses and legumes, fruits and other products (dyes, gum, medicinal, etc.).

(3) Suitability and adaptability to local knowledge

. Different forms of stabilization using trees, shrubs and crops exist in several parts of the country. This system is effective in areas with controlled grazing arrangements (Hararghe, etc.) or for seasonal crops (gourds, tomatoes, sweet potatoes, "noug", sunflowers, etc). Free grazing remains the major obstacle to stabilization of physical structures.

(4) Main land use and agro-ecology

. Stabilization applies in all land uses provided with physical structures for soil conservation and water harvesting. Virtually all surfaces can be stabilized. Different species will be recommended in different agroclimatic conditions (see infotechs on agroforestry and grasses). In dry areas moisture conservation measures and drought resistant species are key elements for stabilization.

(5) Potential to increase/sustain productivity and environmental protection (impacts)

.. This activity has enormous potential in Ethiopia. Stabilization of physical structures needs **to be seen as a "multiple cropping" activity within the physical structure area** and integrated with additional soil management techniques within the terraces or treated areas. Achieving proper and productive stabilization will also encourage farmers to protect conserved areas and appreciate its effects.

. Stabilization can also make physical structures integral part of the farm production system. In several countries physical structures and their immediate surrounding area constitute cash crop belts where fruits and cash crops grow.

(6) Description of the technology and steps

A) STABILIZATION WITH TREES AND SHRUBS FOR FODDER PRODUCTION (Figure 1)

--> Tree/shrubs should be planted at close spacing: 30 to 60cm apart on single or staggered double row (one on the berm and the other at the lower side of the embankment).

--> In dry weyna dega plant the trees/shrubs using seedlings instead of direct sowing. Seedlings grow faster and by the end of the rainy season have a rooting system able to explore wider and deeper portions of the soil profile and thus have a better chance to withstand the long dry season.

--> For forage production preferably select nitrogen-fixing trees/shrubs such as Leucaena leucocephala, Pigeon peas and Sesbania sesban. Acacia saligna planted in dense rows can also be introduced and used as forage mixed with crop residues.

B) TREES/SHRUBS FOR FUELWOOD AND TIMBER PRODUCTION (Figure 2)

--> Usually, single row is preferred and spacing between trees is wider (1-4m). Planting with seedlings is preferable. Nitrogen fixing trees are also preferable such as different Acacia species, Albizia Lebbeck but also Leucaena, Sesbania, and Pigeon peas planted in wider stands (1-2m). Grass can be planted between trees in single rows. Fruit trees and specific multipurpose trees (Azadiracta Indica (Neem), Cordia, Ziziphus, etc) can be also combined.

--> After 1-2 years from establishment and before the crops growing season, branches and foliage should be reduced by side pruning to avoid shade and competition for nutrients and water (depending on the type of species).

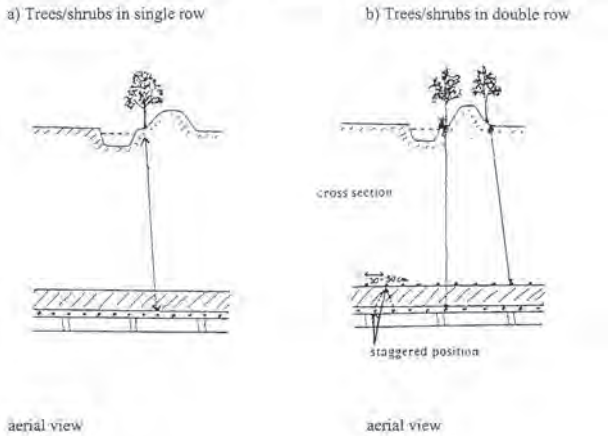
--> Root pruning may be necessary after 2 years to avoid competition with crops.

C) FRUIT TREES

--> Fruit trees can be planted along bunds, bech terraces and in collection ditches, etc. Plantation of fruit trees is very appropriate in most conditions combined with trenches behind structures. Species include mango, guava, citrus and other species. Some other drought resistant perishable and non-perishable fruit trees species should be tried from other countries (cashew nut, custard, apple, pistachios, apricots, jackfruit, tamarind, etc.). Highland fruits such as apples, plums, and peaches can grow at higher altitudes and make bench terraces an attractive and productive option.

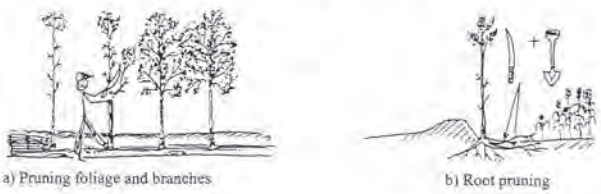
--> It is recommended to plant fruit trees in combination with other multipurpose species at various intervals (for ex: 1 fruit tree - 3 fodder trees, 1 fuelwood tree - 3 fodder trees - 1 fruit tree, etc).

Figure 1 Trees/shrubs for fodder production



Examples of Pollarding

Examples of Pruning



D) STABILIZATION WITH FORAGE GRASS AND LEGUMES (Figure 3)

. All physical structures can be stabilised with grass and legume pasture species. Amongst these, soil and stone faced soil bunds, trenches and herring bones are most suitable for grass and legume stabilisation. Fodder grass and legume can be integrated with trees/shrubs in different combinations. Therefore they close gaps between trees/shrubs and make the bund stronger.

--> In Ethiopia, several local drought resistant and palatable grass species are available (Dasho grass, “Sembelete”, etc.).

--> Choose the best type of grass species based upon type of soil, water requirements, palatability and biomass production.

--> If native grass species are to be used ask the farmers which one they suggest, prefer and have sufficient seeds for planting.

--> If new grass species are to be introduced consult forage/livestock expert. Test germination rate of seeds (50-80% is satisfactory). If germination is lower increase the number of seeds during sowing time or look for another lot of seeds.

--> Plant grass and legumes in different proportions based upon needs (2 rows of grass+1 row legume, 2 rows legumes+1 row grass, etc).

--> At the onset of the rainy season plant the seeds not deeper than 2cm, preferably 1cm depth. Use a sharp stick to open a shallow row and drill inside the grass seeds. Then press the soil back to the row so that to ensure a good contact between soil and seeds.

--> After 1 or 2 months from planting, weeding of other spontaneous aggressive vegetation may be necessary.

--> Grasses should be harvested before flowering, when their nutritional value is high. Harvested grass can be used as green fodder immediately or kept for a longer period through hay making. Hay making requires the grass to dry under the sunshine for 3-5 days, on a scattered layer not thicker than 10-20cm which is to be turned twice a day. Then bundles can be stored under shade for several months.

E) STABILIZATION WITH CROPS (Figure 4)

. Traditionally farmers plant different crops along the bunds where moisture is higher. This practice should be encouraged and improved.

--> The first year, waterlogging tolerant crops should be planted along the berm such as millet and pigeon pea. Some other crops such as pulses, oilseeds (nug, niger, etc.), beans or vegetables (pumpkins, etc.) can be planted on top of the embankment. At the end of the rainy season, the bottom of the collection trench can also be sown at late rains stage with crops such as sunflower, chick pea or vegetables.

--> At harvesting time any crop growing on the embankment should be harvested by cutting the stem and not by pulling them out so that the stability of the bund would not be affected.

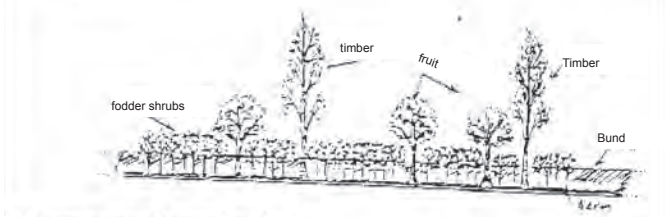
--> The second and following years only the space along the bund can be planted with crops (as above), usually the same ones planted in the whole cropped area, often long term and higher productive varieties to benefit from the increased moisture available near the bund.

F) STABILIZATION WITH A COMBINATION OF CROPS/GRASS/TREES/SHRUBS

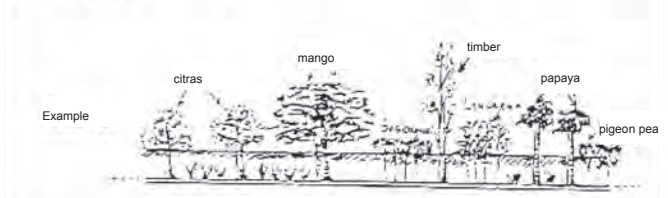
. Bunds can be stabilized using a combination of both crops, grass and trees/shrubs, particularly in stabilized areas, specific parts of closures on multipurpose trenches and similar structures.

Figure 2. Multipurpose trees/shrubs and fruit trees

i) Primary purpose fodder production



ii) Primary purpose fuelwood production



iii) Primary purpose fruit production

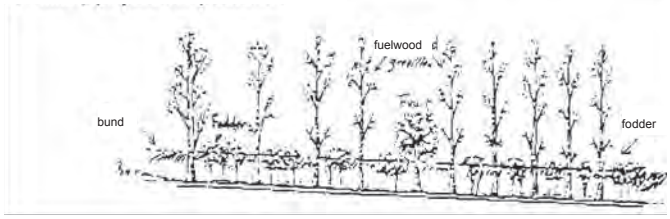


Figure 3. Stabilization with grass and legumes

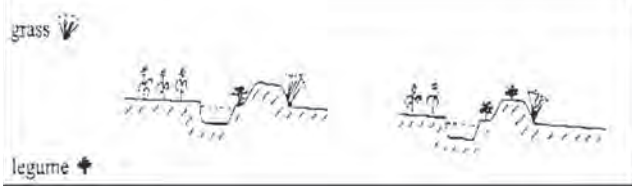
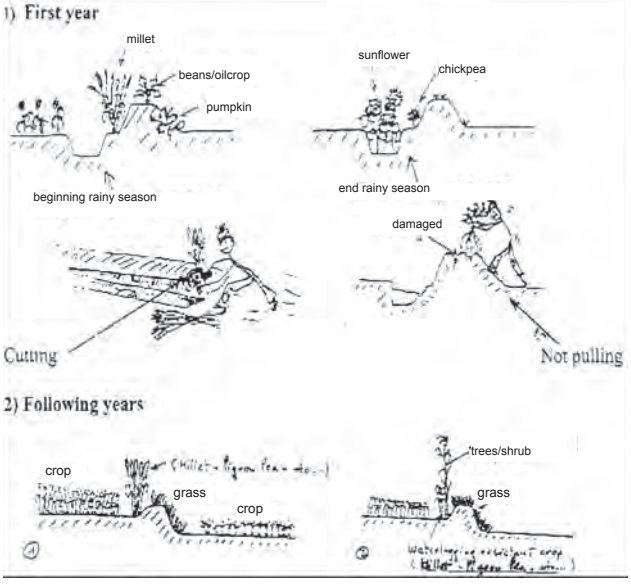


Figure 4. Example of stabilization with crops



(7) Integration requirements and opportunities	(8) Constraints and limitations
1) Apply “farmland closure activity” as a form of control grazing. In a given community specific blocks of farmland areas are closed from cattle interference - this will allow stabilization but also increase fertility and moisture availability for the next crop. Every year an additional group of farms will be closed from interference and cattle kept tethered at home. This measure needs to be applied gradually to encourage farmers based on results. 2) Integrated with compost applications and various trees/shrubs/grass/legumes/ crops management techniques.	. Stabilization requires control grazing for periods of time ranging from few months to one or several years, depending on the type and purpose of vegetation. . Regular management of vegetation is required to avoid competition with crops, improved grass or trees (pruning, pollarding and thinning of trees, weeding, mulching and cut and carry of grass, etc). . Wrong selection of species and their arrangement may increase weed infestation, shading, and competition for nutrients and moisture.

TECHNICAL INFORMATION KIT

VEGETATIVE FENCING (VF)

(1) Period/phases for implementation

. Drought resistant plants (Euphorbia, Erithrina, Aloes, Sisal, etc.) planted as main fence during the first two months of the rainy season.

. Shrubs (Sesbania, Dovalis, Pigeon pea, Trilucerne, etc) and grass species (preferably indigenous) planted at the beginning of the rainy

(2) Objectives/remarks

- Vegetative fencing (VF) is a conservation practice which consist of a combination of vegetative planting materials resistant to cattle grazing planted in rows and with grass/ legume plant species sowed behind these rows.

- Used to protect and enrich reclaimed areas like closures and gullies, farm boundaries and specific community assets like ponds. By doing so it also helps controlling runoff and erosion. It is the "first level of defence" against animal interference that allow other valuable trees to be planted after the fence is established.

- VF can be exercised as a "grid system" in closures, around reclaimed gullies, and farms, providing increased sense of ownership to users.

(3) Suitability, agroecology, adaptability to local knowledge

VF is commonly practiced in Ethiopia along farm boundaries using different local species. Although rarely used for communal and degraded areas, it can expand in such lands as land use certification will encourage farmers to protect and develop such areas. Can be used also to fence group of cultivated plots.

(4) Main land use

. In all land uses but specifically recommended for community areas shared amongst households, like closures and gullies. Also recommended along group of farm boundaries and to divide grazing land areas into controlled grazing paddocks. Suitable also around community ponds combined with planting of trees belts behind the VF.

(5) Technical preparedness

. Local knowledge on how to plant tree/ shrub species. Nurseries organized to supply rest of species.

. Caution required for species that can be irritating for the skin and eyes (Euphorbia, etc) and on new species.

(6) Potential to increase/sustain productivity and environmental protection

. Vegetative fencing is the entry point for high value trees and fodder species to be planted behind these fences, creating productive green belts. Vegetative fences implemented over a large area constitute formidable barriers agains erosion and runoff. They create a "conservation webs or nets" capable to trap sediments and moisture in various directions. They also act as windbreaks and reduce evapotranspiration of cultivated plots.

. Assist in providing psychological security regarding tenure and encourage investment for better land care. Studies in Asia demonstrated that an entire "web" of green boundaries projected over large areas had huge implications in terms of incentives for "intensive land care", water harvesting (recharge of water tables) and erosion control. Combined with land use certification it can generate high level of investments.

. This activity can be combined with many others related to the treatment of hillsides, closures, gully control, etc. A combination of self-help work on farmlands and incentives on communal lands for VF can be used to reach large scale fencing and protection efforts.

(7) Minimum surveying and tools requirements

Survey: community and groups assisted to divide closures, gullies and reclaimed plots into compartments based on agreed size and conditions of the area (soil, slopes). The horizontal part of fences should follow contours as much as possible.

Tools: farmers tools sufficient (machetes, small hatchets, axe and hooks).

(8) Min. technical standards, steps and work norm

Main Fence: made preferably of 2 rows of species planted staggered such as Euphorbia candelabra (tall Euphorbia or "Koal-koal") and finger Euphorbia ("Kincheb"), Erithrina ("Korch"), Aloe, Sisal and other plants.

Spacing of plants in main fence: 50 cm between rows and 20 cm within row, possibly using a combination of the above species. Single row also possible - plants 10 cm or very close apart based upon local knowledge (necessary to obtain a tight and continuous vegetative fence).

Plantation of grass/legumes behind main fence: this is to further support and make the fence thicker and more productive. Direct sowing of Sesbania, Pigeon peas, Acacia Saligna, Treelucerne and local grass strips is recommended. Plant one line of grass as close as possible to the fence or between the two rows. Plant one or two rows of legume shrubs by opening a furrow of 20cm behind the fence.

In areas already treated with hillside terraces place single row VF following lower part of stone raiser (see Figure 3). For measures like trenches, eyebrows and similar structures place single row VF in between series of those structures based on the size of plots. WORK NORM: 40 person days/km

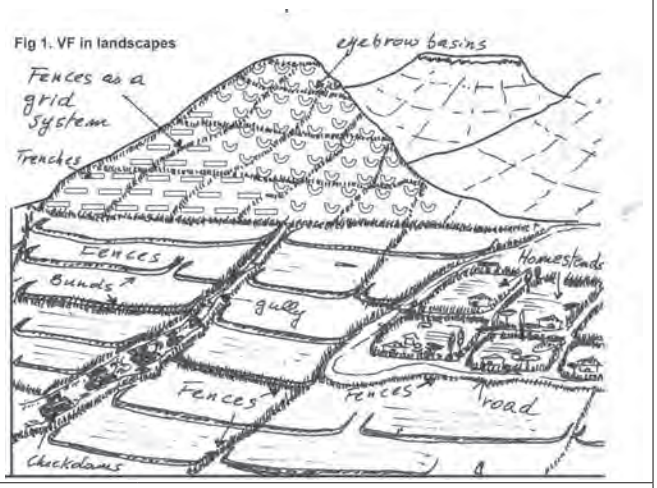


Figure 2 Example of vegetative fence

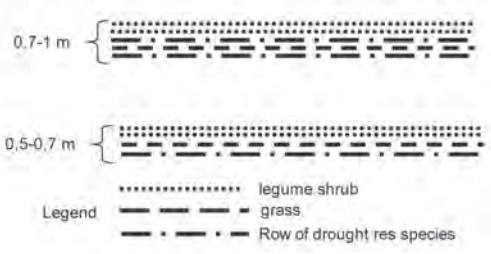
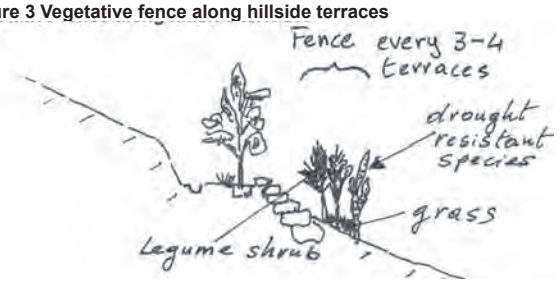


Figure 3 Vegetative fence along hillside terraces



(9) Integration

. Can be integrated with all possible watershed treatment measures on hillsides, gullies, grazing lands and farms.
. Need participatory planning for sharing/fencing areas and land use arrangements. Would strongly benefit from the land use certification strategy.
. Some of the planting material are needed to be grown in nurseries and/or part of specific seed collection strategies.

(10) Management requirements

Refill the first compost pit one month before the end of the composting process taking place in the second pit and repeat the same procedure. By this system you can produce compost three times a year (see figure 80) or more if the time of decomposition is faster.

(11) Institutional responsibility

. Fully on community members (commitment to mgt.).
. DAs and wda experts - technical support and mgt.

TECHNICAL INFORMATION KIT	(1) Period for implementation	(2) Main objective/purpose
LEY CROPPING	. Applied at the beginning of the rainy season.	. Ley cropping is a cropping system in which legume based pastures are rotated with purely grown crops. Legume based pastures are grown on fallow lands for a few years to improve fertility of the soil and thus the yields of subsequent crops (mainly cereals). . The establishment of dense, productive forage crops during the fallow period (1-3 years) provides a thick ground cover, supply forage of good quality after the rainy season, prevent soil erosion, restore soil fertility quicker than bare (and overgrazed) fallow, increase the water holding capacity of the soil and have a beneficial effect on future crop yields.

(3) Suitability and adaptability to local knowledge

. This system has been developed in Southern Australia where its value to agriculture has been enormous. The practice is expanding elsewhere and believed to be feasible under Ethiopian conditions where fallow is a common practice to restore fertility of shallow and depleted soils.

(4) Main land use and agro-ecology

. Suitable under most agro-climatic conditions and for cultivated land left under fallowing for a few years. Fallow lands are common in parts of Ethiopia above 2500 masl (Chencha, etc). In lower ranges fallow lands are also areas with shallow soils and left to rest for some time and grazed or planted with very low demanding crops.

(5) Potential to increase/sustain productivity and environmental protection (impacts)

. Leys will be very effective if combined with the closure of cultivated plots and cut and carry practice of removing fodder from leys.

. The substantial biomass produced is either harvested and fed to livestock during the dry season or maintained on the ground and incorporated into the soil to raise fertility levels (stubble mulching) before crops return. The effect on water retention and accumulation resulting from increased infiltration will benefit the cereal crops that will follow the leys.

. Erosion control in leys is excellent, particularly if lays are sown along the contours or between conservation structures.

(6) Description of the technology and steps

. A pasture legume is sown after a shallow ploughing of the bare fallow. Normally, fertilization is not necessary but 0.5-1 Qls./ha of DAP (diammonium phosphate) or triphosphate fertilizer application would help the legume seeds to establish and develop their rooting system.

. These legumes would be appropriate conserving pasture crops able to restore fertility and provide feed of good quality. They can be planted in mix stands or rows with grass such as Rhodes, Buffle, Panicum (Guinea), or improved native grass, etc. Row planting also reduces competition within and between the species. In case of mixed pasture, two-third legume seed is mixed with one-third of grass. Mixing grasses with legumes has the advantage of combining carbohydrates (energy) with proteins (nitrogen fixation of legumes), making a balanced livestock feed.

. Results from research shows that Lablab and some clovers are capable of leaving 30 to 60 kg N/ha in the top 20 cm of the soil profile through their root system only. If the aerial part is not removed and incorporated into the soil, this content increases considerably (80-100 kg N/ha). These amount will not give maximum cereal yields, but they are sufficient to meet the N requirements of cereal crops grown in a subsistence system, for instance for crops such as sorghum and millet. Yields of these two crops were reported to have increase by 30 to 100% based upon soils and rainfall conditions.

. The introduction of ley pastures into fallow lands can be either with annuals or perennials species, depending on the length of the fallow period.

In moisture deficit areas, the following legume crops are recommended (*):	In other areas (*):
- Siratro (Macroptilium uncinatum), - Lablab purpureous (Lablab), - Stylosanthes hamata (Varano Sylo), - Desmodium uncinatum, - Fenugreek (Trigonella),	- Lupins (lupinus album) - Vetch - Clovers (Trifolium sp.) - Alfa-alfa (Medicago sativa)

NOTE (*): there are many other legumes possible to plant in all agroclimatic conditions

(7) Integration requirements and opportunities	(8) Constraints and limitations
1. This measure can be integrated with rainfall multiplier systems for crop or grassland improvement, various forms of bunds and other agronomic measures such as stubble mulching before the return of the main crop. A very effective supplementary measure is ripping of fallow land and sowing of mixture of grass/legume along the ripped lines. 2. Legume shrubs can also be planted in rows along ley lines (pigeon peas and sesbania in moisture stressed areas and Treelucerne in high rainfall/altitude areas). 3. Cut and carry and control grazing of the area.	. Except for additional labour and some seeds, in most circumstances ley cropping is effective and cheap.

TECHNICAL INFORMATION KIT

Integration of food/feed legumes into cereal cropping systems

(1) Period for implementation

Planting of most crops/forages at the start of the main rains except for sequential crop to be planted at the end of rains after harvest of first crop.

(2) Main objective/purpose

1) Better and full use of production resources such as water, radiation, nutrients, space and time.

2) Integration of cropping optimises productivity by producing higher combined yields from the crops and greater economic returns from a given area of land than the same crop grown in monoculture.

3) Lower risk in intercropping than with mono cropping.

4) Better distribution pattern of labour demand. For example, land preparation is done only once for all crops and therefore the labour situation is less constrained.

5) Control pests, diseases and weeds in the absence of biocides.

6) Better control of soil erosion realised.

(3) Suitability and adaptability to local knowledge

Intercropping of food legumes with maize/sorghum is extensively practiced in the most densely populated areas of Southern Nations and Nationalities Peoples Regional State. In the Afar Region, farmers using irrigation in the lower Awash intercrop haricot beans between maize or sorghum rows(Fig. 1). The haricot straw, high in protein level, improves quality of animal feed.

(4) Main land use and agro-ecology

Two food crops can sequentially be fitted within a year accompanied by complementary forage crop to raise both the quality and quantity of fodder, which are harvested at different times during the year from a unit land area. For this technology kit, the following typology of the main multiple cropping systems have been adopted (a)sequential cropping using food crops (b)sequential cropping using forage crops followed by food crops and (c) Intercropping (mixed cropping).

(5)Technology description

Integration of food/feed legumes into the cereal cropping systems is defined as the growing of more than one crop in the same piece of land during one calendar year.

a. Sequential cropping using food crops: Possible in areas where conditions for plant growth exist beyond the duration of one early maturing crop. Two short duration food crops can be fitted sequentially within a growing season. The second crop matures using the residual moisture in the soil or one or two supplemental irrigation when rain is not sufficient for the latter crop.

b. Sequential cropping using forage crops followed by food crops: Short duration forage and food crop can be fitted sequentially within the same year. Fast growing forage can be planted and harvested early to derive good quality feed. This is especially in areas where land is a constraint and high cropping intensity limits natural pasture during the cropping period. Fodder from the subsequent food crop will then be available after harvest for the dry season.

c. Intercropping (Mixed cropping): Intercropping is when two or more crops are grown in mixture as companion crops, in the same area of land at the same time. The crops may be grown in separate rows or in a more mixture, but the important feature of this system is that there is inter-crop competition and; indeed scope for several interactions between crops. Selection of appropriate crops should be made which will result in a minimum competition effect between the inter-crops and one or both crops should have a complementary effect to the other.

(6) Minimum tools/requirements

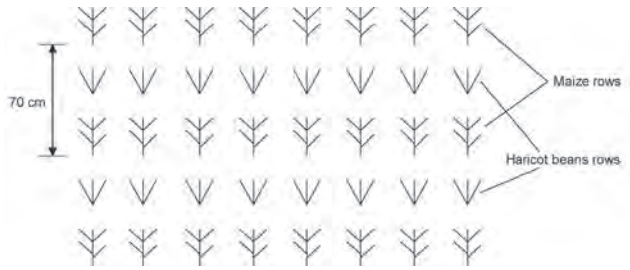
Time of sowing different crops may be very critical in establishing crop forage mixture and the right conditions will need to be determined if new crops are to be considered for intercropping.

(7) Integration requirements and opportunities

As labour and land become constraints in the Ethiopian highlands, it is unlikely that smallholder farmers will grow monoculture stands of forage crops for the foreseeable future. But if forage legumes can be grown in association with food crops, without adversely affecting grain yields, farmers may adopt them. This is the most practical way of growing good quality fodder in situations where farmers depend on the same piece of land for sustaining people and livestock. As the legumes in the mixture have nitrogen-fixing capabilities, there could be some benefits in the long-term to the maintenance of soil fertility of the fields

An example of intercropping in the highlands involves growing wheat in association with clovers to increase both the quantity and quality of livestock feed available without affecting the wheat grain yield. Because of the complementary nature of the associated crops, overall productivity can be significantly higher than when they are planted separately

(Fig 1.) Intercroping of maize with haricot beans or other legumes



(8) Work norm

a) Time of sowing of the different crops/forages should be established. In most areas where the main rains start in June it could be assumed safely that most crops and forages could be planted in June.

b)Harvesting of the different crops/forages should be done separately. This would increase the labour input of harvesting.

(9) Management requirements

1) The harvesting for grain and fodder from the same area will be different. This will need an adoption of a new practices and management different than the traditional just one harvest for the collection of grain and straw.

2) The cultural practice of planting crops late in the rainy season, especially on Vertisols, should be changed. With improved drainage, Vertisols could be used from the beginning of the rainy season. It is anticipated that under sowing the early sown wheat with clover / maize with lablab or other creeping legumes would improve the quality and quantity of crop residues.

(10) Constraints/limitations

1) Very limited supply of legume forage seeds, which could be used in intercrops systems. This would be one of the major constraints in adopting integration of crop – legume mixtures.

2) Due to the vegetative cover of the planted legume after the harvest of the main crop, the bylaws of grazing harvested fields should be revised if individual farmers that adopted this technology are going to benefit.

TECHNICAL INFORMATION KIT	(1) Period for implementation	(2) Main objective/purpose
INTERCROPPING	. Crops are sown at the beginning up to the middle of the rainy season.	. Intercropping is a practice of growing two or more crops along the contour simultaneously in the same plot in a fixed pattern in one season. The aim of intercropping is to increase crop production and provide protection to the soil against erosive forces. . Different planting times and different length of growing periods spreads the labour requirement of planting and harvesting, but also allows mid-season change of plan according to the rain in the early part of the season. . The various leaf arrangements of different plants allow light to be better intercepted over time. The contrasting patterns of root growth, which utilize different soil layers, optimize the use of available soil moisture and nutrients. Mixed stands protect the soil surface more effectively than pure stands. Overall output per unit area can be much greater from intercrops than single crops and chances of total crop losses are lower than in pure stands.

(3) Suitability and adaptability to local knowledge

Intercropping is a widely applied traditional technique (with pigeon peas, cotton, etc.) in many parts of Ethiopia, particualrly in Hararghe zones and in SNNPR.

(4) Main land use and agro-ecology

. Applicable in all agroclimatic conditions and mostly suitable between 1800 and 2300 masl and rainfall 700-1200 mm. In low rainfall areas need to be integrated with soil and moisture conservation (tie ridging, etc.) measures. In areas above 2500 masl the range of crops and possible combinations is reduced.

(5) Potential to increase/sustain productivity and environmental protection (impacts)

. Intercropping needs to be seen as a flexible system and as a system of mutually-reinforcing crops. Intercropping allows different rooting systems to explore various soil depth and recycle nutrients better. The presence of legumes is enriching the soil, especially if part of the legume plants are mulched. Crops can rotate within the plot and between plots. Intercropping also integrates well with a number of soil fertility management practices (compost, etc) and moisture conservation measures. It contributes to control soil erosion, particualrly if applied together with conservation measures and stabilization. Positive effects are also observed inpest control as mixed cropping systems are more resistant to pests than monocultures.

(6) Description of the technology and steps

. In moisture deficit areas, the practice seems to be more feasible for row crops such as maize and sorghum, or cotton. These crops do not form a good ground cover at an early stage from establishment. At a later stage, when crops begin to form a denser cover, the canopy is high above the ground level and runoff is free to move in between plants and erode the soil.

. At the same time, these crops have bulky biomass which is not often returned to soil. The big stalks are often removed for various purposes, thus there is very little return of nutrients to the soil. To contrast this nutrient mining system, suitable legume species (chick peas, cowpeas, beans, green gram, soyabeans, forage legumes, etc.) or conserving row crops (pigeon peas) should be planted in the spaces left between rows.

. Fodder legumes tend to produce more biomass than food legumes and the amount of nitrogen fixed is proportional to the biomass produced by the crop. The effect of N-fixation is not much felt by the current crop but rather by the crop planted next season and often for more than one year.

. There should be attention paid to maximize the benefits from intercropping depending on the interest of farmers. In most cases farmers want to minimize the reduction of yield of the main crop. Then, adjustment to the sowing dates should be made to minimize competition between the main crop and the legume (companion crop). In this regard, companion crops should be sown 2 to 3 weeks after the main crop. With such planting calendar, the reduction of the main crop is minimal and the total yield from both crops is much higher than the yield of purely grown main crop. Some intercropping would also be advantageous to control incidence of pests because of crop diversity (host of different predators).

Example of combination:

--> Every 3-5 cereal row crops (maize, sorghum, millet) one or two legume row crops such as Pigeon peas or Sesbania should be densely planted.

--> Short legume crops as indicated above are planted between rows of cereal crops.

Note: Plant legume trees/shrubs also around the farm boundaries and on bunds if any. Leucaena, Pigeon peas, Gliricidia and Sesbania can be planted.

• Other possible combinations:

--> Cereal crops with treelucerne rows;
--> Pigeon pea with sunflowers;
--> Three rows combinations (cereal, legume and oilseeds);
--> Double legumes intercropped (pigeon pea + chick peas/beans/peas, etc or Treelucerne + faba bean/peas);
--> Legume shrub + cash crops + short legume:

a) cotton + pigeon peas + beans/chick peas/etc
b) sesame + pigeon pea + cotton
c) sunflower + pigeon peas + sorghum
d) Other combinations.

(7) Integration requirements and opportunities

• The system should be integrated with bunds, ripping and/or rainfall multiplier systems to increase water availability and thus reduce competition, organic and inorganic fertilization to compensate for some competition.

(8) Constraints and limitations

. Possible competition for water and nutrients between crops. Test new combinations first.

TECHNICAL INFORMATION KIT	(1) Period for implementation	(2) Main objective/purpose
CROP ROTATION	. NA	. Crop rotation is one of the oldest practices known to man for fertility restoration and pest/ disease control and it consists of growing different crops one after the other on the same piece of land. . Plants of the same crop develop their roots at the same depth of soil profile and thus the proliferation of the root systems in the same depth results in a strong competition for moisture and nutrients. Therefore, if the same crop is grown on the same land year after year, the soil nutrient in that layer decreases sharply and the crop yield consequently declines. . On the other hand, if different crops are rotated, the depletion of soil nutrients and decline of crop yields are not as serious as when the same crop is grown year after year. Different crops have different characteristics that enable them to exploit the soil at different depths. . Crops also differ in terms of their effect to the soil. Some crops restore or build fertility while others deplete fertility.

(3) Suitability and adaptability to local knowledge

. Rotations are integral part of Ethiopian farming systems. To a various extent they have been affected by factors related to food insecurity and the need to increase staple cereals. However, improved solutions for sound rotations are possible and can be integrated into extension and conservation packages.

(4) Potential to increase/sustain productivity and environmental protection (impacts)

. The improvement of plant cover and soil structure through sound crop rotations substantially influences the effect of runoff and levels of soil loss. Benefits of crop rotation in soil conservation can be illustrated by the results obtained in Kenya (see table below), at 20% slope, with loamy soils and rainfall of about 960 mm/year

The effect of crop rotation with pasture ley (legume and grass) on runoff and soil loss

Practice	Runoff %	Soil loss ton/ha
Continuous maize	40	242,21
Maize in rotation	24	103,81
Wheat in rotation	25	14,83
First year ley	18	1,48
Second year ley	13	0,49
Permanet pasture	4	0,0049

. Crop rotation in addition to fertility restoration and soil and water conservation is a popular traditional practice of controlling diseases, pests, rodents and weeds infestation. It is well known that different crops are not equally susceptible to the same kind of pests or diseases. Growing the same crop year after year will provide an opportunity for pests to multiply and outbreak virulently after two or three years of continuous cultivation, eventually leading to serious loss of crop yield. The same problem holds true for weed infestation.

(5) Description of the technology and steps

. The specifications are left to farmers and agronomists who have to decide the best alternance between crops and their effect on soil loss and fertility based upon local conditions.

. A rotation is a practice strongly influenced by economic factors. Generally, sound rotations have been shortened or changed to accommodate other crops more beneficial in monetary terms or required for food. Technicians are often facing problems to recommend a change in rotation, not because farmers do not like it but because they can not afford the change. It is then suggested that improved rotations should be proposed to the land user **together with an entire set of additional measures able to improve yields of the main crops so that the rotation becomes acceptable**. For instance conservation measures for additional moisture retention, fertility management, fertilizer application, manuring, etc. Besides, wherever possible, existing rotations should be improved by avoiding the removal of part of crop residues, green manuring, mulching and various other techniques described in other infotechs.

. In Ethiopia the rotation should be seen within a dual perspective, i.e. within the year and between successive years of cropping. Within the year refers to the possibility to intercrop different species (see above) or double cropping based upon the available moisture and the crop water requirements. Between years refers to the alternance of conserving and depleting crops or pastures (leys) in a sound manner.

. In Ethiopian moisture deficit areas, crop rotations should also be moisture based within the plot (see Konso experience) – i.e. a spatial as well as temporal moisture based rotations. Besides, the possibility to introduce improved varieties of legumes and other crops, existing cropping patterns offer ample scope for improvement in terms of optimizing the sequence of crops, their arrangement and sowing dates. In this respect, **accessibility to improved varieties of legumes (locally improved), possibly inoculated with highly efficient strains of rizhobia** would significantly improve fertility and yield of crops. In all circumstances legumes need to be rotated with cereals and compost applications need to become a regular feature of the farming systems in all agroclimatic zones. Under Ethiopian dryland conditions, an important aspect to consider is that crop rotations are also livestock based. Therefore, crop rotations should view forage legumes (crops, shrubs and trees) as part of the rotation to compensate from constant removal of other residues and improvement of animals diet.

(6) Integration opportunities/requirements	(7) Constraints and limitations
1. Sound rotation can be easily introduced when fields are properly conserved and fertility restored (compost, etc). 2. Ley and intercropping are also best practices to encourage rotation.	. Improved rotations may be difficult to apply with low value crops or in situations where food insecurity push farmers to plant mostly cereals. In this case an integrated approach and multiple packages, which includes rotation, will be required.

TECHNICAL INFORMATION KIT	(1) Period for implementation	(2) Main objective/purpose
STRIP CROPPING	. Different crops planted at the beginning of the rainy season. Timely planting important.	. Strip cropping is a cropping practice where strips of two or more crops are alternately established on the contour or, it is a system of establishing more than one crop in alternate strips following a contour pattern for the purpose of erosion control, crop diversification, and decrease the risks associated to the use of single crops only. . This cropping system is designed as a defence mechanism against soil erosion in areas where the cropping system is dominated by row/sparsely growing crops that exposes the ground to erosive forces. For instance, crops like sorghum and maize are susceptible to erosion and need to be grown alternately with soil conserving crops.

(3) Suitability and adaptability to local knowledge

. Different forms of strip cropping exists in some areas but rarely done in an organized way. This technique can be adapted if strips are developed using flexible modalities and do not follow rigid patterns of distances.

(4) Main land use and agro-ecology

Applicable on cultivated lands. Below 500mm it can be practiced using runoff-runon system between terraces (see figure 2). Above 500-700 mm soil and moisture conservation measures are required above 5% slope.

(5) Potential to increase/sustain productivity and environmental protection (impacts)

. The potential to increase productivity results from the combined effect of conserving fertility and reducing erosion as well as from the value of the crops chosen for strip cropping.

. Of high potential is the combination of strip cropping with the improvement of the areas around benched portion of terraces using compost. Such strips closer to the terrace can be planted with cash crop and create “cash crop belts” along conserved areas (see also compost making infotech).

. This practice is useful for conservation <5% slopes without additional conservation structures and needs to be combined with conservation measures above such range.

(6) Description of the technology and steps

a) Description: Crops are sown in strips and following row planting, one being a soil depleting crop and the following a soil conserving/fertility restoring crop. If the main crop is maize or sorghum, the second crop can be a legume (e.g. beans, cow pea, chick pea, etc.) that forms good ground cover; in this case maize is regarded as soil depleting/degrading crop while the legume is the soil conserving crop. Erosion is largely limited to the row-crop of cereals and the soil removed from those strips is trapped in the next strip down slope planted with the legume-row soil conserving crop.

. This measure is effective against soil erosion on slopes < 5% (if well designed) and is best suited to well drained soils. The strips can be rotated to optimize the benefits of crop rotations. Above 5% slope strip cropping is applied in between physical measures.

b) Design and establishment: strip width vary with the degree of erosion hazard but are generally between 5, 10, 15 and 20m with narrower strips on steep slopes and wider strips on gentle slopes. Planting technique is traditional except that it is along the contour. To increase their effectiveness, the density of the legume crop should be higher than normal cultivation. However, on steeper slopes it may be necessary to add grass buffer strips of 2 to 4 m wide, placed at 10 to 20 m interval. The width of permanent buffer strips, however, should be negotiated with farmers and determined based upon not only technical considerations but also according to their land holdings (space, tenure issue). Otherwise place bunds following standard vertical intervals based on slopes.

Fig. 1 Alternate strips of soil conserving (A) and erosion prone crop (B)

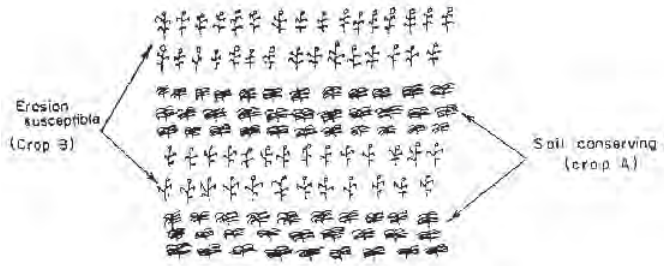
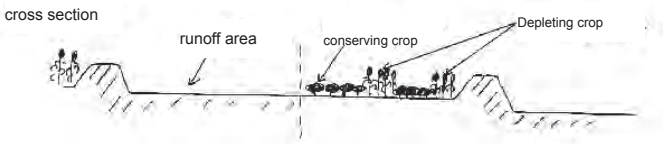


Fig. 2 Strip cropping with rainfall multiplier systems



(7) Integration requirements and opportunities

1) Integration with bunds, grass strips, etc, able to reduce runoff and increase storage is recommended.

2) When legumes are harvested, residues and roots should be not pulled out but left as stubble.

3) Improved fast covering varieties can be tried.

(8) Constraints and limitations

. The following constraints are usually observed:

a) Farmers may be reluctant to leave space for crops of lower monetary value

b)The residues from legumes may not be used for mulching or compost.

c) Lack of land pushes farmers to use all plots for staples.

d) In areas with rainfall lower than 500 mm the range of crops that can be grown using these patterns is limited.

Agro-forestry, Forage Development and Forestry

1. Area Closure
2. Microbasins (MBs)
3. Eyebrow Basins (EBs)
4. Herring bones (HBs)
5. Micro-trenches (MTRs)
6. Trenches
7. Improved Pits (IP)
8. Multistorey Gardening
9. Seed Collection

TECHNICAL INFORMATION KIT

AREA CLOSURE (AC)

(1) Period for implementation

. Area is closed before the rainy season. Other supplementary measures as per their specific requirements.

(2) Main objective/purpose

. Strip cropping is a cropping practice where strips of two or more crops are alternately established on the contour or, it is a system of establishing more than one crop in alternate strips following a contour pattern for the purpose of erosion control, crop diversification, and decrease the risks associated to the use of single crops only.

. This cropping system is designed as a defence mechanism against soil erosion in areas where the cropping system is dominated by row/sparsely growing crops that exposes the ground to erosive forces. For instance, crops like sorghum and maize are susceptible to erosion and need to be grown alternately with soil conserving crops.

(3) Suitability and adaptability to local knowledge

. Area closure suitable for degraded areas in most agro-climatic parts of the country. Commonly practiced in Ethiopia with different levels of performance. Best closed areas found when directly managed by the community and groups of interested farmers.

(4) Main land use and agro-ecology

Area closure increases the productivity of degraded and moisture stressed areas. Combined with different soil and moisture conservation measures AC restores sufficient productivity for the growth of multipurpose trees, grass and specific cash crops. AC protects downstream fertile fields from flood and erosion and contribute to recharge acquifers. When properly managed AC can provide significant income to poorest households.

(5) Potential to increase/sustain productivity and environmental protection (impacts)

Main land use: Mostly degraded hillsides and large gully networks

Main Core Measures:

. Guarding: No livestock is allowed to graze for 3-5 years, and no or limited human interference is tolerated until 80% grass cover is obtained,]

. Hillside terraces + trenches or

. Multipurpose trenches (trees, fodder, cash crops) or

. Eyebrow basins for multipurpose plantation or

. Improved pits for fodder and tree plantation or

. Combinations of the above.

Other possible measures:

. Checkdams and brushwoods in gullies dissecting the closure;

. Vegetative fencing and dry fencing if encroachment is difficult to control;

. Cutoff drains and waterways for excess runoff control in sensitive parts of closure;

. Mulching of planting pits/trenches/etc by cutting grass & weeds around each structure;

. Manuring of planting pits;

. Firebreaks;

. Land sharing and certification.

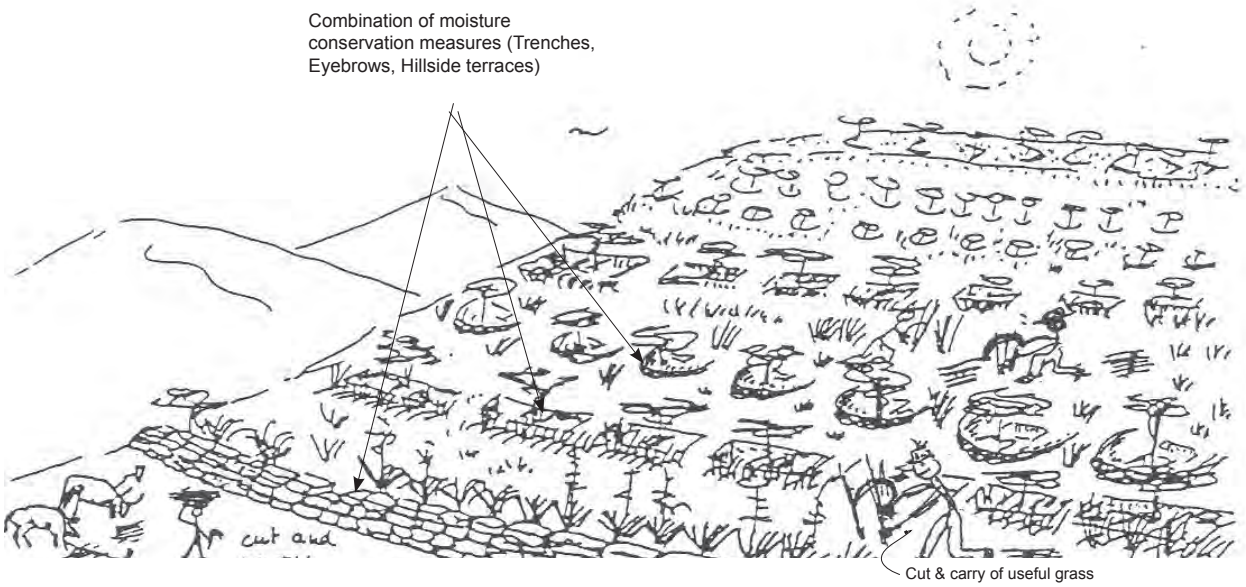
(6) Technical preparedness

. Requires combination of skills and techniques based upon the range of measures to be established.
. Trainining on area closure management to groups of farmers required.
. Training on various SWC measures
. Others based on type of works.

(6) Work Norms

Work norm for site guards only if strictly necessary: **4 person days/ha/year**.
For SC and water harvesting activities see other infotechs.

Figure 1 Example of Area Closure



(7) Planning and implementation arrangements

. Preparation for sharing of AC required (certification, informal sharing, group formation, etc).

. Planning and design of core and supplementary measures agreed and phased.

. Management and utilization plan prepared and agreed.

(8) Limitations

Area closure alone (without support measures) is a slow recovery process and may not be seen a very beneficial. However, AC combined with various conservation and management measures could become an attractive investment. This is possible provided assistance is available to undertake the various works.

. Some farmers may see their access to grazing land reduced in the short term.

Example on steps for implementation

STEPS:

(1) Group of farmers should select an area suitable for closure and negotiate use rights with the community and Kabele/woreda, possibly agree on certification.

(2) Various SWC activities discussed & agreed. Implementation undertaken based upon technical requirements and resources availability.

(3) Manuring and soil mixing of planting pits required 1-2 months before planting.

(4) Planting trenches with trees in the middle of the tie or in front of the trench; pigeon peas or cash crops on berm (8-10plants per structure) and legume pulses + grass rows on soil embankment.

(5) Plant vegetables (tomatoes, gourds, etc.) at the bottom of trenches by the end of rainy season to use residual moisture (plant if soil is deep enough or by making small mounds in the middle of each ditch) .

(6) Establish vegetative fences using drought resistant species like Euphorbia, Sisal, Erythrina, Aloes, etc (see vegetative fencing infotech) based upon shared plots within closure.

(7) Grass & weeds and residues cut and mulched the first year on planted structures after the harvest of crops.

(8) Palatable grass growing on residual moisture harvested in January – February.

(9) Compost making undertaken as a form of service contract for interested land holders – to start in Sept-October by digging pits 4mL x 2 mW x 1,2-1,5m D (Length, Width, Depth). Collection of roughage from closure and other sources (gullies, footpaths, etc.) undertaken and compost moisturised every week by the group.

(10) Turning of compost pits (1-2 times) and distribution of compost to fields before Belg or kept under shade for Meher season.

(11) Beekeeping introduced after 1 year (only if water is within 1 km radius from site).

(12) Trees pruned and cut following proper rotations.

(13) Establish cutoff drains at the foot of hillsides to check possible excess runoff in sensitive parts.

(14) Explore possibility to dig hand-dug wells at the foot of the hillsides and on bottom of stabilized gullies.

(15) Store excess runoff from closure using series of microponds at the foot of hillsides (see infotech on microponds).

How to make an area closure more productive

Type of trees to plant and planting arrangements:

. Trees planted in one closure should be at least of three different species to allow for undergrowth and rooting system to explore different soil depths. For example a mixture of Grevillea robusta, Acacia Saligna and Acacia Melanoxilon is can be tried in middle altitudes. In addition and according to each agroecological zone, tree species such as Acacia Senegal (for gums), Cordia africana, Croton macrostachis, Albizia lebbek, and countless other species may be planted in different combinations.

. In each site medicinal species (for example Haegyna abyssinica) and other valuable trees for Integrated Pest Management (such as Azadiracta indica or Neem, etc.) or valuable indigenous species (Olea africana, etc.) can also be introduced and sparsely planted within a given site (every 25-50 trees). Bee-keeping is also supported through diversification of species and flowering periods.

Type of crops to grow on trenches, eyebrows or on hillside terraces

Various crops can be planted in section of closure where soil is more fertile (usually at lower parts) together or after composting and mulching. Some examples as follows:

. Cash crops planted along the berm use & exploit increased moisture near the embankment.

. Cash crops planted in the middle of the ditch at the end of the rainy season benefit from the residual moisture of the trench. Crops that do not perish easily such as pigeon peas, hoops (gesho), chillies (“caria”), and other pulses and oilseeds are preferably planted along berm. Perishable crops (tomatoes, etc.) better planted on mounds within trenches/ditches.

. Legume crops such as chick peas and other pulses have to be planted at the top of the embankment at the beginning of the rainy season (at harvest time do not pull but cut).

. The top of embankments can also be stabilised with dense rows of Acacia saligna that can be used as fodder or mulch belt. Hyphernia grass for roofing also recommended together with legume rows on stabilised embankments.

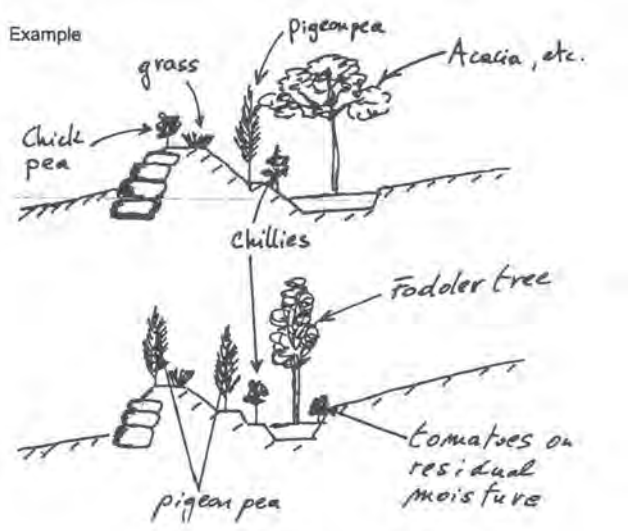
How to manage an area closure

. Each month the group/community undertakes a review of the overall work conducted in the closure. Meetings are held to discuss improvements and explore new opportunities. New plans are developed and submitted for approval (for example a compost making activity following a year of regeneration of grass, bee-keeping, etc.), then steps and responsibilities decided and agreed on how and when to proceed.

. Briefings by the group (s) at general community assembly meetings are held to inform the community about the experience gained and progress made. New ideas can be shared and encouraged. More area for closure may be agreed.

. Profits and benefits need to be shared by the group or amongst individuals according to agreements and sharing rights.

. Review of overall initiative undertaken once a year before next rainy season.



TECHNICAL INFORMATION KIT

MICROBASINS (MBs)

(1) Period/phases for implementation

Mostly during the dry season or after short rainy season for hard soils.

(2) Objectives/remarks

• MBs are small circular & stone faced (occasionally sodded) structures for tree planting • Are suitable for medium and slightly low rainfall areas, stony areas and shallow soils •. Based upon experience they are not very effective in low rainfall areas (where trenches, eyebrows, etc. are preferred).

(3) Suitability, agroecology, adaptability to local knowledge

VF is commonly practiced in Ethiopia along farm boundaries using different local species. Although rarely used for communal and degraded areas, it can expand in such lands as land use certification will encourage farmers to protect and develop such areas. Can be used also to fence group of cultivated plots.

(4) Main land use

• Applicable in steep and degraded hillsides (max slope 50%) and for community closures • MBs need to be often combined with other measures such as hillside terraces, stone bunds, trenches, etc.

• Can also be applied inside large gully areas for tree planting

(5) Technical preparedness

• Depth of soil and slope assessed (5-50% max). Discuss and agree with farmers on species, spacing and integration with other measures as required
• Training on layout and construction needed
• Preparation of follow-up plan for management of planted

(6) Potential to increase/sustain productivity and environmental protection

• Good potential to improve degraded and steep hillsides - mostly for area closure and multipurpose trees and fodder trees plantations

• When combined with sound moisture conservation (trenches,etc.) and proper management it will contribute to watershed rehabilitation, biomass production and recharging of water tables.

(7) Minimum surveying and tools requirements

Layout: One A-frame or line level (with 5 meters string and two range poles).

Work: crow bars, sledge hammers, shovels, and pick axes.

(8) Min. technical standards (fig 1)

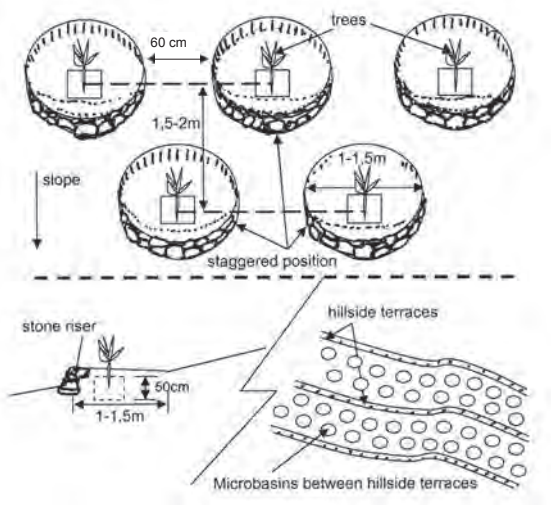
• Diameter: Min 1 m and max 1.5 m.
• Stone riser: 0.2 m foundation and height 0.2-0.4 cm above ground based on slopes,
• Plantation pit: 40 cm diameter x 50 cm depth,
• Soil sealing: sealed with soil from cut area,
• MBs are constructed in staggered position between rows and in rather close spacing within row in case of 1 m diameter basins (some overlapping required between rows)

(9) Work norm elements

• Layout in staggered position;
• Foundation;
• Placement of stone raiser;
• Cut and fill & seal;
• Plantation pit construction.

WORK NORM: 1 person day/5 microbasins

Figure 1. Microbasin along the contours



(10) Integration opportunities/requirements (see also WHSC guideline)

1. Few series of staggered lines of MBs can be constructed in between hillside terraces (say every 10-15 meters) on slopes up to 30% - rows of MBs decrease as distance between hillsides decreases, especially > 30% slope.

2. Controlled grazing and area closure necessary.

3. Fodder legumes, shrubs can be planted along the filled area (pigeon peas, treelucerne, etc.) in smaller planting pits instead of a tree.

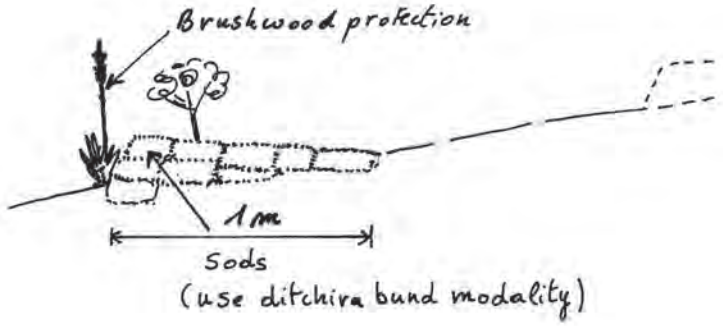
4. Manuring of plantation pits and mulching (decrease evaporation and enhance growth).

5. Integration with strong checkdams along depresssion points and in small gullies.

(11) Modifications/adaptation to standard design

a) MBs constructed using sods and stabilized with plants (figure 2).
b) Large microbasins or eyebrow basins (see related infotech)

Figure 1. Microbasin constructed with sods in areas without stones (max 20% slope)



(12) Planning and implementation arrangements

• Agreements for use rights and management of treated areas (areas shared amongst individuals, groups or managed by community or mixed)
• See opportunities for land use certificates
• Arrange working groups for regular maintenance

(13) Management requirements

• Control grazing is a precondition for microbasins as even light trampling will compromise their function
• Fodder growing on MBs should not be uprooted but cut and carried

(14) Limitations

• MBs can be easly overtopped - need integration with hillside tcs.
• Require maintenance if not well constructed and stabilized.

(15) Institutional responsibility

• Fully on individuals/groups +/- community (commitment to mgt.)
•DAs and wda experts - technical support and follow-up/mgt.

TECHNICAL INFORMATION KIT

EYEBROW BASINS (EBs)

(1) Period/phases for implementation

Mostly during the dry season or after short rainy season for hard soils

(2) Objectives/remarks

• EB are larger circular and stone faced (occasionally sodded) structures for tree and other species planting • Based upon experience they are effective in low rainfall areas to grow trees and harvest moisture. • Can be constructed in slopes above 50% for spot planting.

• Controls runoff and contribute to recharge of water tables.

(3) Suitability, agroecology, adaptability to local knowledge

• Suitable in degraded areas, mostly in semi-arid and medium rainfall areas with shallow soils
• Commonly practiced in dry and moist weyna dega areas for the growth of trees and support to plantations in area closure

(4) Main land use

Applicable in steep and degraded hillsides (max slope 100%) and for community closures. Can be combined with other measures such as hillside terraces, stone bunds, and trenches based upon soil, slope and stoniness. Can also be applied inside large gully areas for tree planting.

(5) Technical preparedness

• Depth of soil (min 25 cm) and slope range (5-100%). Discuss and agree with farmers on species, spacing and integration with other measures as required.
• Training on layout and construction.
• Preparation of follow-up plan.

(6) Potential to increase/sustain productivity and environmental protection

• Good potential to improve degraded and steep hillsides - mostly for area closure and multipurpose tree and fodder tree plantations • Can also be planted with a mix of trees, shrubs and cash crops • Together with other measures EBs can significantly improve watershed rehabilitation, biomass production and recharging of water tables.

(7) Minimum surveying and tools requirements

Layout: One A-frame or line level (with 5 meters string and two range poles).

Work: crow bars, sledge hammers, shovels, and pick axes.

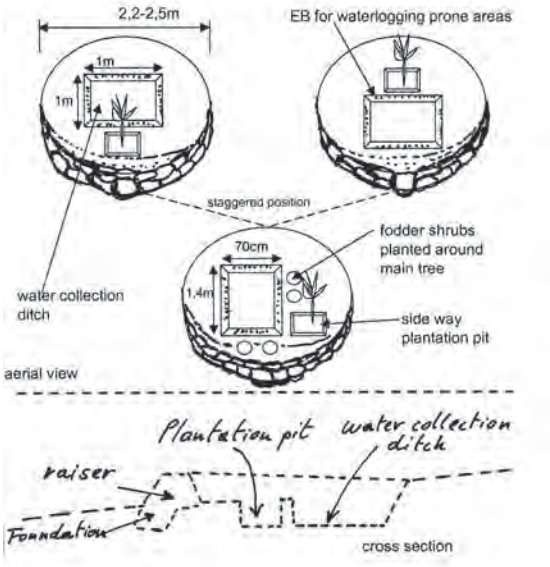
(8) Min. technical standards (fig 1)

• Size: 2.2-2.5 m diameter
• Stone riser (or stabilized by brushwood or life fence): with 0.2 m depth of the foundation, height 0.4-0.6 m;
• Stone riser sealed with soil excavated from water collection area;
• Water collection area: dug behind the plantation pit: 1 m width x 1 m length x 20-25 cm depth (lower side);
• Plantation pit (s) of 50cm depth x 40cm diameter dug between riser and water collection area. Water collection ditch can be placed sideways or in front of plantation pits depending on soil type.

(9) Work norm elements

• Precise layout using A-frame or other level;
• Collection of stones from working site;
• Excavation of foundation and construction of stone riser;
• Excavation of water collection area, cut and fill, plantation pit and sealing of stone riser.

WORK NORM: 2 EB/person day

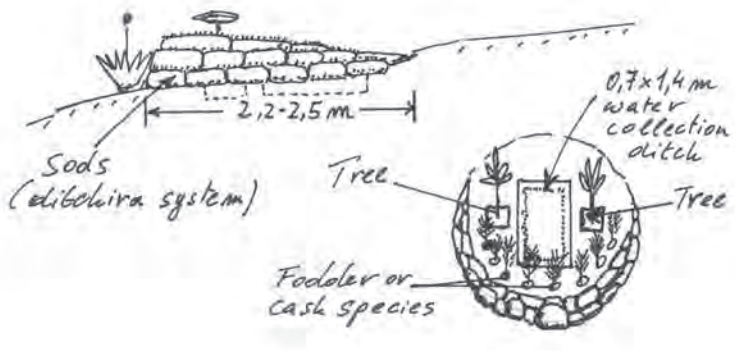


(10) Integration opportunities/requirements (see also WHSC guideline)

1. Few series of staggered lines of EBs can be constructed in between hillside terraces (say every 10-15 meters) on slopes up to 50% - rows of EBs decrease as distance between hillsides decreases > 50% slope (for example one line of HTs and one of EBs).
2. Control grazing and closure of areas treated with EBs is necessary.
3. Fodder legumes shrubs and cash crops (on better soils) can be planted along the filled area (Pigeon peas, Sesbania, etc.) in addition to the tree.
4. Manuring of plantation pits and mulching required (decrease evaporation and enhance growth).
5. Integration with strong check dams along depresssion points and small gullies.

(11) Modifications/adaptation to standard design

a) EBs constructed using sods and stabilized with plants up to 20% slope (fig. 2)
b) Multipurpose EBs (tree+fodder+cash crop) (figure 3)



(12) Planning and implementation arrangements

• Agreements on use rights and management of treated areas (areas shared amongst individuals, groups or managed by community or mixed)
• See opportunities for land use certificates in protected areas
• Arrange working groups for maintenance.

(13) Management requirements

• Control grazing is a precondition for EBs as even light trampling will compromise their function.
• Fodder/cash crops growing on EBs should not be uprooted but cut and carried.

(14) Limitations

• EBs are labour intensive.
• Require maintenance if not well constructed and stabilized.

(15) Institutional responsibility

• Fully on individuals/groups +/- community (commitment to mgt.)
• DAs and wda experts - technical support and follow-up/mgt.

TECHNICAL INFORMATION KIT

HERRING BONES (HBs)

(1) Period/phases for implementation

Mostly during the dry season or after short rainy season for hard soils.

(2) Objectives/remarks

• HBs are small trapezoidal structures (called also A structures) for tree and other species planting • HBs are suitable for both dry and medium rainfall areas, and medium soil depth • Based upon experience HBs are most effective in medium/low rainfall areas (500-900 mm).

• Can be constructed only on slopes < 5%. and soils > 50 cm depth

(3) Suitability, agroecology, adaptability to local knowledge

• Suitable mostly in semi-arid and medium rainfall areas
• Not very common in Ethiopia but has possibility to expand in many areas, including pastoral areas for improving grazing reserves - can support the growth of different species.

(4) Main land use

• Applicable in gentle slopes (<5%) on small plateaus, on degraded lands (widespread gullies) with portions of gentle slopes (lower sections of community closures, etc.) and homesteads

• Can be often combined/mixed with other measures such as trenches soil and stone bunds, based upon soil, slopes and stoniness.

(5) Technical preparedness

• Depth of soil and slope assessed. Discuss and agree with farmers on species, spacing and integration with other measures as required

• Training on layout and construction **(very precise for HB**)

Precise layout and follow-up/adaptations

(6) Potential to increase/sustain productivity and environmental protection

• Good potential to improve degraded areas with gentle slopes - mostly suitable for medium textured and drained soils (sandy loams, sandly clay loams). Can also be planted with a mix of trees, shrubs and cash crops

• Combined with other measures can significantly improve watershed rehabilitation, biomass production and the recharging of water tables.

(7) Minimum surveying and tools requirements

Layout: One A-frame. The A frame can directly provide the shape of the HB when laid down at ground level. Water line level not as good as A frame but can be used for marking major contour lines - then proceed with direct assessment by sight and adjusting orientation of HB based on microslopes.

Tools: sholvels and pick axes

(8) Min. technical standards (fig 1)

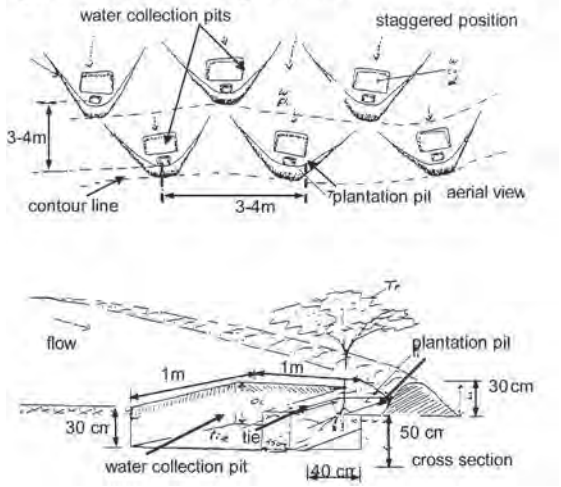
· **Spacing**: the structures are placed 3 m apart (max 4m in very dry places) along the contours and have extended arms conveying water towards the planting area.
. **A water collection ditch** (1m x 1m x 0.3 m depth at lower side) is dug behind the planting pit (40 cm diameter x 50 cm depth),· The tips of the extended arms are 2.5-3 m apart (average).
· **Embankment**: max. height downslope (0.4-0.5 m) and decreases to 20 cm at the end of the side arms.

(9) Work norm elements

· Work norm includes precise layout (using A-frame or other level), excavation of collection ditch and planting pit, embankment building and compaction.

WORK NORM: 4 HBs/Person day

Figure 1 Herring bones along the contours



(10) Integration opportunities/requirements

1. 2-3 series of staggered lines of HBs in between bunds (say every 10-15 meters) can be constructed in areas with slopes up to 5% (8% in sandy soils with good percolation).

2. Control grazing and closure of areas treated with HBs necessary.

3. Fodder legumes, shrubs and cash crops can be planted along the embankment (pigeon peas, treelucerne, sesbania, etc.).

4. Manuring of plantation pits and mulching required (decrease evaporation and enhance growth).

5. Integration with trenches and other structures as soon as slopes increase and there is a danger of overtopping.

(11) Modifications/adaptation to standard design

a) HBs can be constructed for growing two trees (**figure 2**).
b) Multipurpose HBs (tree+fodder+cash crop) (**figure 3**)

Figure 2 Double pitting and HB

Double pits are placed sideways to the water collection trench. One pit can be planted with fodder trees (Sesbania, etc.) and the second pit with fruit trees, coffee and other valuable trees.

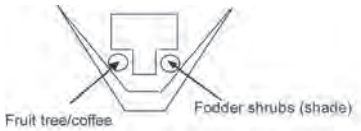
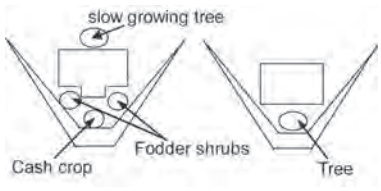


Figure 3 Multipurpose HBs

Similar to the one above - the HB can be planted with fodder shrubs mixed with cash crops + a slow growing tree planted behind the water collection pit. OR, HBs along the contours planted alternatively with cash crops mixed with fodder plants and HBs with trees only.



(12) Planning and implementation arrangements

• Agreements for use rights and management of treated areas (areas shared amongst individuals, groups or managed by community or mixed). See opportunities for land use certificates in protected areas. Arrange working groups for maintenance.

(13) Management requirements

• Control grazing is a precondition for HBs as even light trampling will compromise their function.
• HB need to be very well spaced and built as overtopping will create series of breakages on down the slope.
• Fodder/cash crops growing on HBs should not be uprooted but cut and carried.

(14) Limitations

• HBs are suitable only in gentle slopes - layout is demanding
• Require maintenance if not well constructed and stabilized.

(15) Institutional responsibility

• Fully on individuals/groups +/- community (commitment to mgt.)
• DAs and wda experts - technical support and follow-up/mgt

TECHNICAL INFORMATION KIT

MICROTRENCHES (MTRs)

(1) Period/phases for implementation

Mostly during the dry season or after short rainy season for hard soils.

(2) Objectives/remarks

• MTRs are rectangular and deep pits constructed along the contours - main purpose and effects are same as for trenches

•Can support the growth of trees, shrubs, and cash crops

• Can be constructed on slopes 3-30% max. gradient and soils at least 50 cm depth

(3) Suitability, agroecology and adaptability based upon local knowledge

. Suitable mostly in semi-arid and medium rainfall areas (600-900 mm). Introduced only recently in Ethiopia, MTRs has the potential to expand in many areas, including pastoral areas for improving grazing reserves. MTRs could be a better option than microbasins as they can collect and conserve more moisture. MTRs are more suitable than larger trenches in areas where rainfall is above 600-700 mm and for species that can be planted in denser spacing or higher density per hectare (particularly fodder shrubs).

(4) Main land use

Applicable in a broad range of soils and slopes (<30%), on degraded lands (widespread gullies, etc), hillsides, and within homesteads for planting trees and fodder species along fences and backyards. Can be often combined/mixed with other measures such as larger trenches, soil and stone bunds, and hillside terraces based upon soil and slope.

(5) Technical preparedness

. Depth of soil and slope assessed. Discuss and agree with farmers on species, spacing and integration with other measures as required.
. Training on layout and construction.

(6) Potential to increase/sustain productivity and environmental protection

. Good potential to improve degraded areas. In homesteads can support fodder production and trees/shrubs. MTR harvest less water compared to trenches (average maximum water holding capacity of each MTR is around 0.3m³ of water) but allows for denser plantation of lower water demanding trees/plants. Other effects same as tranches.

(7) Minimum surveying and tools requirements

Survey: an A-frame level. If not available use the normal water level hooked to a string linked to range poles placed at 5 meters distance and orient the MTRs along the contour line to address possible traverse microslopes.

Tools: crow bars, pick axes and shovels (1 crow bar:2pick axes: 2 shovels ratio).

(8) Min. technical standards (fig 1)

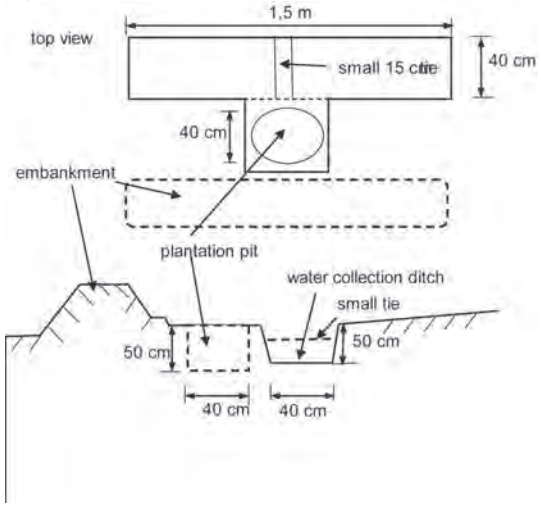
· Average size of the trench: 1.5 length x 0.4 m width x 0.5 m depth (downside),· Except for very permeable soils, trenches are provided with a small and low tie in the middle to regulate water flow (15 cm width). In this type of design trees are not planted in the middle of the trench but in front of it.
. **Spacing apar**t: along the slope spacing is 1.5-2 m and lateral distance is 30-50 cm.
. Plantation pit 50cm depth x 40 cm width (larger pits also possible).

(9) Work norm elements

· Work norm includes precise layout (using A-frame or other level), excavation of trench and planting pits, embankment building and compaction.

WORK NORM: 3 MTRs/Person day

Figure 1 Microtrench



(10) Integration opportunities/requirements

1. 3-5 series of staggered lines of MTRs in between stone bunds (every 10-15 meters) can be constructed in areas with slopes between 15%-30% gradient.

2. Control grazing and closure of areas treated with MTRs necessary.

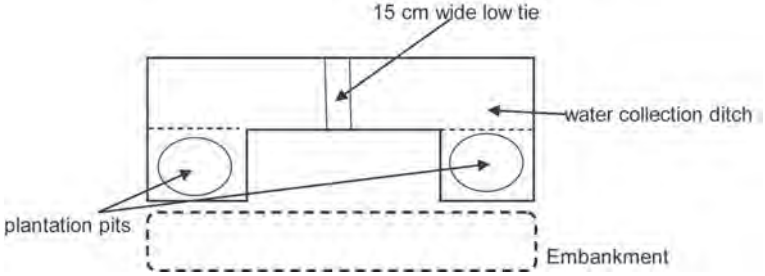
3. Fodder legumes shrubs and cash crops can be planted along the embankment (pigeon peas, etc.) in addition to the tree.

4. Manuring of plantation pits and mulching (decrease evaporation and enhance growth of plants).

5. Integration with larger trenches and other structures as soon slopes increase and there is a danger of overtopping.

(11) Modifications/adaptation to standard design

a) One or even two trees (one for fodder and one for wood for example) can be planted in one or two 40cm x 40cm x 40cm deep plantation pit (s) in front of the micro-trench (**Figure 2**)



(12) Planning and implementation arrangements

. Agreements for use rights and management of treated areas (areas shared amongst individuals, groups or managed by community or mixed). See opportunities for land use certificates in protected areas. Arrange working groups for maintenance.

(13) Management requirements

. Control grazing is a precondition for MTRs as trampling will compromise their function. MTRs need to be very well spaced and built as overtopping will create series of breakages on down the slope. Fodder/cash crops growing on MTRs should not be uprooted but cut and carried.

(14) Limitations

. Layout is demanding.
. Require maintenance if not well constructed and stabilized.

(15) Institutional responsibility

. Fully on individuals/groups +/- community (commitment to mgt.).
. DAs and wda experts - technical support and follow-up/mgt.

TECHNICAL INFORMATION KIT

Water Collection Trenches for the-growth of trees, shrubs, grass and cash crops in moisture deficit and degraded areas

(1) Period/phases for implementation

During dry season and one month before rainy season (to enable plantation pit to weather).

(2) Objectives/remarks

• Trenches are large and deep pits constructed along the contours with the main purpose of collecting & storing rainfall water to support the growth of trees, shrubs, cash crops and grass or various combination of those species in moisture stressed areas (350-900 mm rainfall)

• Trenches can have FLEXIBLE DESIGN, to accommodate the requirements of different species •Therefore they can suit what the farmer want to grow •Trenches collect and store considerable amount of runoff water, thus vegetation grows faster and vigorous

• Trenches protect cultivated fields located downstream from flood and erosion

• Part of the water captured by the trenches reaches the underground aquifer

• Therefore, water tables are recharged and supply springs and wells with good quality water and for a long period of time

(3) Suitability, agroecology, adaptability to local knowledge

• Highly suitable in many areas in the highlands to improve closures and plantations
• Also relevant in pastoral areas to improve grazing reserves, aerial pasture, etc.
• Can easily be understood/adopted after demonstration

(4) Main land use and agroecology

Applicable in steep and degraded hillsides (max slope 100%) and for community closures. Can be combined with other measures such as hillside terraces, stone bunds, and trenches based upon soil, slope and stoniness. Can also be applied inside large gully areas for tree planting.

(5) Technical preparedness

• Training required (DAs and HHs) on how to use an A-frame and space structures along the countours aswrong spacing reduces its effectiveness
• Agree with farmers on type of trenches, user rights, other catchment protection works and on-the-job training in layout and construction
• Test the measure first

(6) Potential to increase/sustain productivity and environmental protection

• Can make closures very productive and appealing for rehabilitation by farmers/ and groups
• Trenches can be planted with different species and exploit the productivity of different parts of hillsides (lower part often with better soil suitable for high value trees/fodder/cash crops)
• Effectively boost biomass production (fodder, etc.), excellent control of runoff and prevent downstream flood
• High effect on recharging water tables (increase potential for irrigation)

(7) Minimum surveying and tools requirements

Survey: an A-frame level or water hooze level linked to two poles placed at 3 meters distance. If not available use the normal water level hooked to a string linked to range poles placed at 5 meters distance.

Tools: crow bars, pick axes and shovels (1 crow bar:2pick axes: 2 shovels ratio)

(8) Min. technical standards (fig 1)

A) Site selection

. On hillsides where soil at least 50 cm deep and not too rocky (from 5-50% slopes).
. On abandoned lands that you wish to restore for growing tree/shrubs or other crops.
. On portions of forest land or closures that should be enriched.
. On homesteads for growing high value trees or other crops.

B) Layout and design

. Start from the top of the hill or field.
. Using an A-frame (or other level) the same size of the trench (2,5-3 m long) level the two tips of the frame and then mark the shape of the trench.
. Continue marking more trenches with the A-frame adjacently and below the first one
. The spacing between two trenches laterally is 25-50 cm
. Catchment Area/Trench Area ratio CA/TA is 3-5:1 (based on rainfall and tree water requirements) – normally 2-3 metres distance between lines of trenches.
. They are constructed in a staggered position one from another (triangle).
. If an A-frame is not available use another level (water level, etc).

C) TYPE OF TRENCHES

(1) Trench for the growth of trees and grass:

It can be constructed to grow 1 or up to 3 trees in each trench. The designs of the trench depend from the type of soil, rainfall, and the type and position of trees.

a) STANDARD DESIGN (construction sequence - fig 2-a)

. After layout dig soil to reach 20-25cm depth x 50cm width x 2,5-3m length (1). Keep some of the good topsoil aside for filling planting pit (s).
. Then dig a 50 x 50 cm wide x 40cm deep pit in the middle of the trench (2).
. Bottom of the pit should be 10-15 cm deeper than bottom of trench. Side ditches may slope towards ties for max. utilisation of light rain showers.
. Demarcate the tie around the pit (10cm from pit border on both sides) and proceed to deepen the collection ditch around the ties up to the required depth of 50cm (3). The embankment is to be shaped level and well compacted.

No of trenches/ha from 800-1200.

b) MODIFIED DESIGN FOR PLANTING TWO TO THREE TREES

. Take advantage o f the water harvesting effect of the trench by planting 1 fast growing tree and 1 or 2 additional slow growing trees (which require less water).

B1) Trench with two trees planted on pits dug in two ties (fig 2-b)

B2) Trench with 1 tree planted in a tie & 2 trees on pits dug in front of trench (fig 2-c)

B3) Trench with 2 trees planted in two ties & 1 tree planted in front of the trench (fig 2-d)

Fig.1 Water collection trenches in the landscape

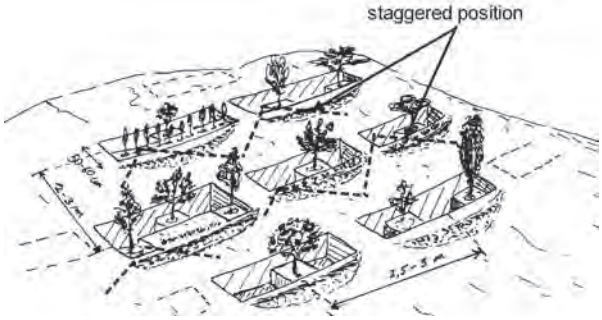


Fig 2-a Construction sequence (standard)

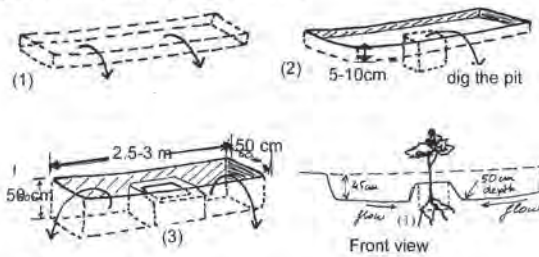


Fig 2-b Trench for 2 tress

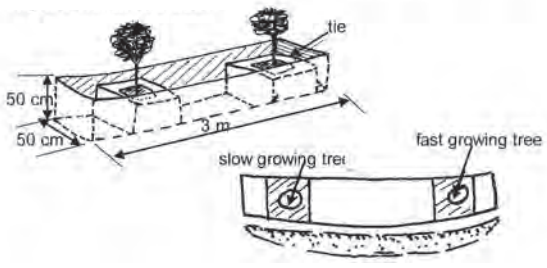


Figure 2-c Trench with 1 tree planted on the tie and 2 trees in front of trench

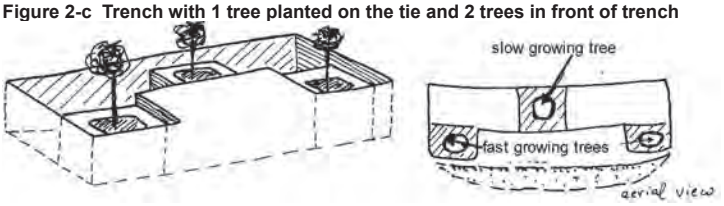
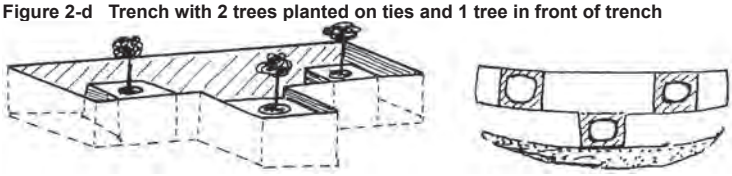


Figure 2-d Trench with 2 trees planted on ties and 1 tree in front of trench



(2) Trench for the growth of fodder shrubs + grass +/- trees or cash crops

. Trenches for species planted in close spacing for maximum and/or seeds production (Pigeon peas, Sesbania, Leucaena, etc.). Different combinations and spacing allowed based upon purpose of the activity and species selection. In **figure 3** a step is constructed along the trench (30 cm wide and 8-10 small 15x 15 cm pits are dug for planting the shrub/cash crop). A small tie is placed in the ditch to regulate lateral water flow.

. Instead of planting legume shrubs some trenches could be designed to grow a mix of cash crops (chillies, "gesho", tomatoes, sunflower, etc.) and fodder shrubs. For example, cash crops could grow on the lateral tie and fodder shrubs on the berm or embankment.

. Dimensions as standard trench.

(3) Trench for the growth of coffee or fruit trees +/- other species

. Larger, wider and deeper trench (60cmDx3-5mLx60-80cmW). Double tie (80cm wide) and plantation pit (60xcm60cmx60cm), one for coffee/fruit tree and one for shade tree.
. Heavy mulching required + compost and stabilization of embankment (legumes, etc.)

Figure 4. Trenches for coffee production

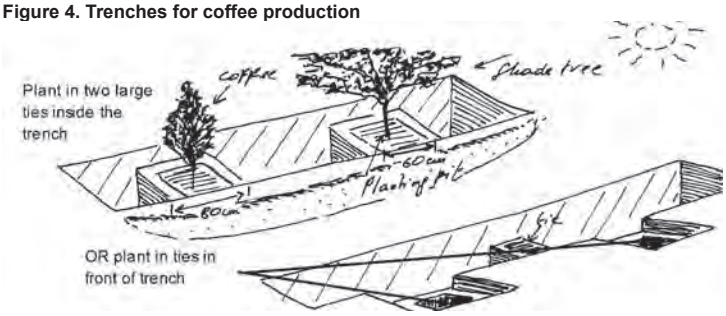
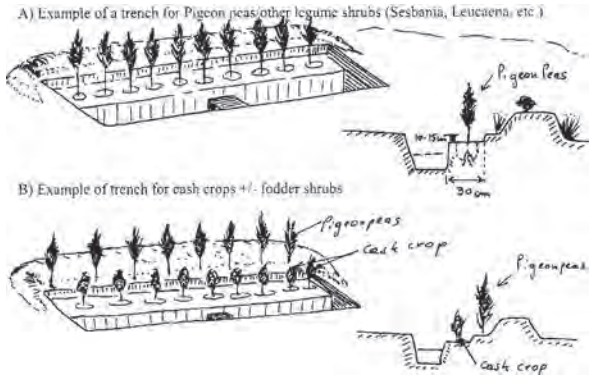


Figure 3



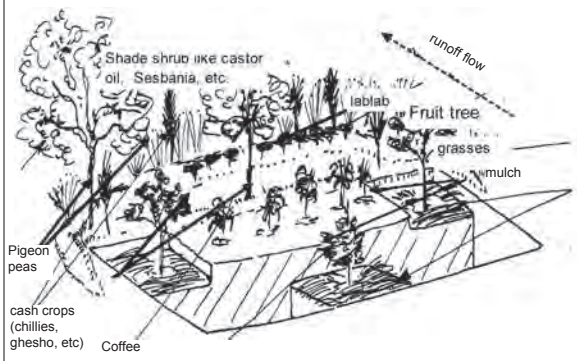
(4) For growth of multi-storey systems (for example cash crops + trees + grass + shrubs + other species)

. The trenches are constructed following a 2-b, 2-c (preferred) or 2-d designs. Trees can be planted in different combinations (figure 5) in the three pits. The size of the trench could range from 3-5 metres based upon the type of trees and their requirements.

. Fodder shrubs can be planted for the first 1-2 years along the berm and produce some fodder and/or legume seeds the first year or two. Cash crops such as chillies and "Gesho" can also be tried in fodder type of trenches or along the berm.

. The first year, the embankment can also be planted with yearly legume or oil crops such as lablab or beans, castor oil, "noug", etc. In this regard, at harvesting stage the plant should be cut and not pulled out of the trench embankment, which can create some damage.

Figure 5 Type of multipurpose trench (from Kallu woreda)



(10) Integration opportunities/requirements

. Trenches integrated with area closure to maximize productivity and protect watershed.
. Every 5-10 lines of trenches hillside terraces can be constructed (usually not required).
. Can be constructed mixed with eyebrow basins and other structures based on soil type.
. Integration within other activities such as hand-dug wells dug at the foot or base of the hillsides.
. Integrate with group formation for sharing of area closure amongst individuals and use-vegetative fencing to divide blocks (using Sisal, Aloes, Euphorbia, etc.).

(9) Work norm

. For all trenches work norm includes excavation of soil, embankment, compaction and digging of plantation pit (s). The work norm is 2 person days per 3 trenches per day.
. For trenches 5 meters long and 2-3 ties/pits (fig 4) apply 1PD/Trench/Day

(12) Planning and implementation arrangements

. Do not start the trench before groups are trained in proper layout, design and construction.
. Make sure community agrees on groups and individual sharing of degraded hillsides.
. Discuss and decide the different type of trenches to construct based upon what farmers want and what is more appropriate based on type of soils and depth.
. Do not construct trenches in rocky areas and steep slopes above 50%.
. If technology not introduced test at small scale first.

(11) Management requirements

. Cut unpalatable grass from trench and surroundings to mulch pits and water collection area. Apply compost into planting pit (s) and water collection ditch. Check distance, size and layout of trenches. If trenches have more than one tree check growth of trees and prune/thin as required.
. Heavily mulch and apply compost around fodder/cash crop belt. Mulching to continue for at least 2 years and apply compost for multipurpose trenchs.

(14) Institutional responsibility

. Individuals/groups +/- community (commitment to proper management and use).
. DAs and wda experts - technical support and follow-up/management.

(13) Limitations

. Labour intensive. Need some 50 cm of top soil to be applied.

TECHNICAL INFORMATION KIT

IMPROVED PITS (IPs)

(1) Period/phases for implementation

Mostly during the dry season or after short rainy season for hard soils.

(2) Objectives/remarks

• IPs are square shaped water collection pits constructed along the contours with a plantation pit in front of the main water storage pit - main purpose similar as micro-trenches • IP support the growth of trees and fodder shrubs, and can be used for cash crops like coffee • They are effective in medium and low-medium rainfall areas (above 600-700 mm).

(3) Suitability, agroecology and adaptability based upon local knowledge

• Suitable mostly in gentle slopes of semi-arid and medium rainfall areas
• Introduced only recently in Ethiopia
• IPs has the potential to expand in many areas
• IPs are a better option than normal pitting in degraded and moisture deficit areas
• Easy to replicate
• IPs are suitable for species that can be planted in denser spacing or higher density per hectare

(4) Main land use

• Applicable on slopes up to 8% max. gradient and soils at least 50 cm depth on degraded lands (widespread gullies), hillsides, and within homesteads for planting trees and fodder species along fences and backyards • Can be combined/mixed with other measures such as trenches, soil and stone bunds, hillside terraces, etc, based upon soil and slope

(5) Technical preparedness

• Depth of soil and slope assessed
• Discuss and agree with farmers on species, spacing and integration with other measures as required
• Training on layout and construction (very precise for IPs)

Precise layout and follow-up/adaptations

(6) Potential to increase/sustain productivity and environmental protection

• Good potential to improve parts of hillside areas with gentle slopes and better soils • In homesteads IPs can support fodder production and trees/shrubs • IPs harvest less water compared to other structures but allows for denser plantation of lower water demanding trees/plants
• Other effects are same as microbasins

(7) Minimum surveying and tools requirements

Survey: a water line level hooked to a string attached to range poles placed at 5-10 meters distance and orient the IPs along the contour line

Tools: crow bars, pick axes and shovels (1 crow bar:2pick axes + 2 shovels ratio)

(8) Min. technical standards (fig 1)

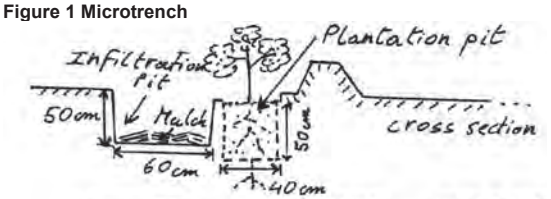
• **Dimension**: 0.60 length x 0.6 width x 0,5 m depth (downside) or other shapes equivalent to the pit volume are also possible
• **Spacing**: distance between pits 30-40cm along the contour and 1.5-2 meters along the slope
• A 40cm x 40cm x 50cm deep or wider plantation pit is planted in front of the pit in the middle of a shallow platform
• The distance between planting pits should be 2-3 times denser as for trenches

(9) Work norm elements

• Work norm include precise layout (using A-frame or other level), excavation of water collection and planting pits, small embankment building and compaction

WORK NORM: 5 IPs/Person day

Figure 1 Microtrench



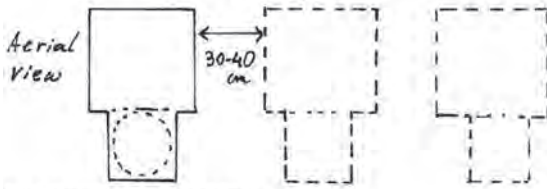
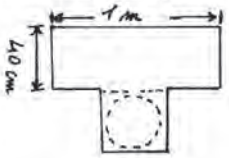


Fig 2. Variations in design/shape



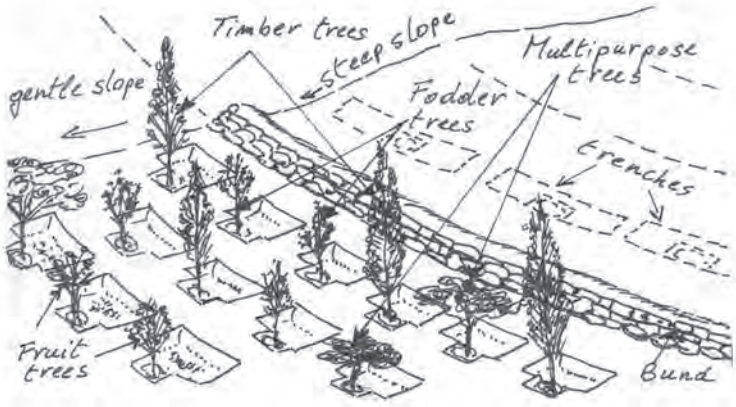
(10) Integration opportunities/requirements

1. 3-5 series of staggered lines of IPs in between bunds (say every 8-10 meters) can be constructed in areas with slopes up to 15%
2. Control grazing and closure of areas treated with IPs necessary
3. Manuring of plantation pits and mulching of grass (decrease evaporation and enhance growth).
5. Integration with larger trenches and other structures as soon as slopes increase and there is a danger of overtopping.

(11) Modifications/adaptation to standard design

a) The shape can be rectangular - similar to a micro-trench: 1 m length x 0,4 width x 0,5 depth (Figure 2)
b) The type of trees and shrubs can be selected to avoid competition for water and soil (for instance 1 IP with tree and 2-3 Ips with fodder shrubs -Figure 3)

Figure 3. Combination of Species in IPs



(12) Planning and implementation arrangements

• Agreements for use rights and management of treated areas (areas shared amongst individuals, groups or managed by community or mixed)
• See/discuss opportunities for land use certificates
• Arrange working groups for maintenance

(13) Management requirements

• Control grazing is a precondition for IPs as cattle trampling will compromise their function
• IPs need to be spaced with care as overtopping can create series of breakages down the slope
• Fodder/cash crops growing on IPs should not be uprooted but cut and carried

(14) Limitations

• Not applicable in areas with lots of rills and shallow gullies.
• Can be easily silted up if not distanced properly.

(15) Institutional responsibility

• Fully on individuals/groups +/- community (commitment to mgt.)
• DAs and wda experts - technical support and follow-up/mgt.

TECHNICAL INFORMATION KIT

MULTI-STOREY GARDENING

(1) Period/phases for implementation

. Based upon tree/shrubs/crops requirements - usually from beginning to mid rainy season.

(2) Objectives/remarks

. Multi-storey gardening is a way of planting a mixture of crops, shrubs and trees of different heights and different uses: food crops, cash crops, fruit trees, woody perennials, and forage plants. It makes the land more productive and improves soil fertility, reduces temperature, provides shade, and increase family income, particularly during a period of drought.

. Fields close or within homesteads can be converted into diversified productive units (decreasing risk factors, increased income, etc.). Such systems have higher resistance to pests and insects.

. A broad network of such homesteads can extend into open fields and constitute large erosion-protected zones or a "web" of green fences and mutually supporting units.

(3) Suitability, agroecology, adaptability to local knowledge

. There are several examples of such systems in Sidama, South Omo and Gedeo areas. The system is not common elsewhere and virtually absent in central highlands. Different systems, from simple to complex can be introduced and tested before wider dissemination.

(4) Main land use and agroecology

. Suitable sites are usually the homesteads or fields located close to the homesteads to protect fruits and other produce. If possible the site should be located close to a water source.

. Suitable mostly is areas with rainfall > 600 mm. Possible in lower rainfall ranges integrated with irrigation (drip, hand dug wells, etc).

(5) Potential to increase/sustain productivity and environmental protection (impacts)

. Multi-storey systems are usually very resilient as relying on multiple crops and responding to various market demands. They are also environmentally sound and custodians of considerable biodiversity and erosion proof. Such systems drastically reduce the need to use natural forests. The cumulative productivity is also high and sustainable.

(6) Description of the technology and steps

• Drainage and soils should be good, soil depth not less than 50-100 cm and slope < 5-8%.

• A minimum of 0.25 ha of land is usually required for a good mixture of plants. However this size can vary and decrease based upon local conditions.

• Choose trees/shrubs/crops:

--> Choose the trees and crops to grow within agro-ecology and support measures, including cash crops.

--> Chose the major fruit trees, i.e. those that would provide the highest income, for instance: mango, avocado, coffee,

--> Chose the secondary fruit trees, i.e. those that can grow and produce quickly and provide secondary source of money, for instance: lime, guava, castor oil, papaya (if supplementary water is available).

--> Choose the multipurpose trees: these trees produce poles, post, timber, fuelwood fodder, leaves for vegetables and medicines, for example: leucaena, cassia, neem, cordia, etc.

--> Choose some slow growing indigenous species for planting in selected spots (1-3/homestead): olea, podocarpus, hygenia, etc.

--> Choose additional mixed-species (woody-perennials or shrubs or grasses) useful for different purposes, for example: sesbania, sisal, napier grass, bamboo, aloe, dovalis, euphorbia, erythrina,

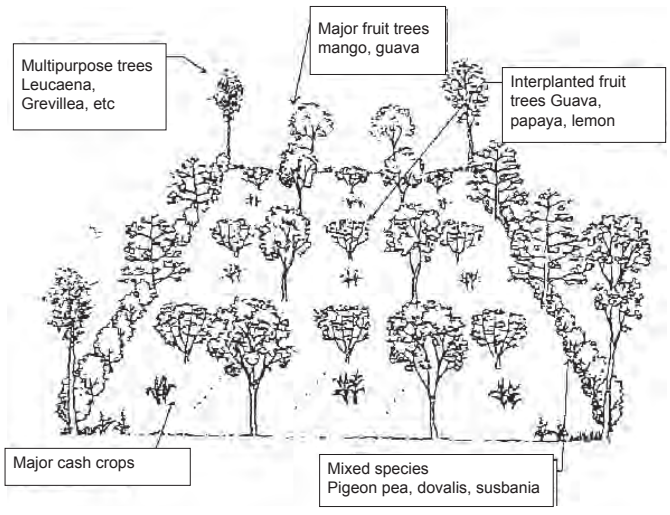
--> Chose specifc grasses and legumes to fill gaps, plant behind or around trees, fences, etc.

• Weeding, mulching, pruning, pollarding and thinning are required. Caution is needed on the selection of species that may shade or compete with crops and reduce yields.

• Multi-storey gardens can be protected by bunds on slightly higher slopes or to divert runoff into the plots.

Figure 1. Example of Multi-storey system

Species	Examples	Spacing	Remark
Major cash crop	-	Closer	As normally practised or improved.
Major fruit tree	Mango, avocado, coffee, orange, etc.	8-10m x 8-10	Planted in rows
Interplanted fruit tree	Lime, guava, papaya, annona, etc.	3-4 x 3-4 5m x 5m	Planted in rows between major fruit trees
Multi-purpose tree	Leucaena, cassia, Grevillea, etc.	4m x 4m for woody trees 0.5 -1m x 0.5-1m for fodder species	Planted around the edges of the farm
Mixed species	Sesbania, pigeon pea, Napier grass, bamboo, Dovalis, Euphorbia	1.5-2m x 1.5-2m or varied as required	Planted in suitable places in the cash crop or in gaps



(7) Integration requirements and opportunities

1. This system will be greatly enhanced by upper watershed rehabilitation aimed to replenish water tables and provide access to water within homesteads (hand dug wells).

2. Compost making, half-moon and eyebrows basins to support growth of trees and any other activity enhancing fertility is recommended.

(8) Constraints and limitations

. Difficult to apply under 600mm rainfall unless supported by irrigation.
. Requires considerable skills and provision of planting material.

TECHNICAL INFORMATION KIT

SEED COLLECTION FROM CLOSURES, STABILIZED TERRACES, FORESTS AND HOMESTEADS

(1) Period/phases for implementation

Based on tree species. Divided into two phases:

1. Seed Collection
2. Dormancy, storage and treatment

(2) Objectives/remarks

. Seed collection is divided into two:

(1) Seed collection of tree species: mostly for indigenous trees to grow in nurseries for specific and multipurpose uses.

(2) Legume shrubs and grass seeds: mainly legume shrubs seeds and grass/plant species that can be used for stabilisation, homestead plantations, grazing lands improvement, support to nurseries, fencing, gully control. This activity is especially valuable for grass seeds collected outside the nursery areas and seed multiplication centers, particularly native grasses of particular value for their palatability and adaptation to local conditions.

. Valuable seeds can be collected and networked between woredas and regions (see MoARD seed networking initiative). The collection of local seeds is an effective way to protect valuable planting materials from extinction and to replenish depleted areas with materials collected from other areas.

(3) Suitability, agroecology, adaptability to local knowledge

This activity is applicable in all agroclimatic zones. Important traditional knowledge in collection and management of local seeds is available in most parts of the country - for those seeds not known to farmers of one locality training is required from forestry experts.

(4) Potential to increase/sustain productivity and environmental protection

Seed collection of diversified and multipurpose species is a primary element for **biodiversity conservation** and supply to households of diversified products, **from timber, firewood, bark, medicines, fodder, fertilizer, shade, dyes, gums, fibre and food**. Both tree and grass/legume species can be collected in large amount and networked to regions and to areas affected by lack of species and monocoltural approach to forestry. This activity is also aimed to contrast and **replace the dominance of Eucalyptus with the dominance of mized and productive plantations** in all land uses and re-vegetation of degraded area.

(5) Seed need assessment, collection plan and networking

Region and woredas need to identify existing seed collection areas. Each woreda should:

1. Assess seed needs (A):based on discussion with farmers (mainly elders) and forestry experts, assess what are the species that have disappeared, those which are endangered and highly valuable and those which are not available but of possible interest for the woreda.

2. Inventory of type of species that can be collected locally (B) and sources for collection: check nurseries, existing forests, closures, stabilized areas, homesteads, churches, etc, for source of seeds.

3. Assessment of gaps (C) = (A)-(B)

4. Group different categories of seeds based upon their use: (i) for conservation as well as (ii) farmers' interest (around terraces, farms, homesteads, etc.).

5. Estimate of labour resources and skills available to collect seeds: develop a realistic seed collection plan (may include species for other areas if requested by region). Use traditional knowledge and farmers who know how to collect seeds and use such persons to train others.

6. Organize farmers and provide training for those species they are not familiar with.

7. Organize delivery and storage at specific collection points (nurseries, stores, etc.).

9. Seed treatment before planting of some species required.

(6) Minimum tools/requirements

. Ladders and sticks to collect seeds, pods, etc.

. Plastic sheets or sacks to avoid seeds to get dirty with soil and moisture.

. Different size bags, baskets and other containers to store seeds.

. Areated and dry store.

(7) Germination of specific tree species

No.	Species	Number of seeds/kg	Germination %
1	Faidherbia albida (A. albida)	10,000	60
2	Acacia decurrens	60,000	85
3	Acacia Mearnsii	60,000	50
4	Acacia melanoxylon	40 000	50
5	Acacia nilotica	8 000	60
6	Acacia saligna	20 000	60
7	Acacia senegal	8,000	80
8	Acacia seyal	30 000	50
9	Albizia gummifera	10,000	70
10	Albizia lebbeck	8 000	70
11	Azadirachta indica	6 000	40
12	Cassia siamea	39,000	
13	Casuarina equisetifolia	1,000,000	60
14	Cordia africana	3,000	60
15	Croton macrostachyus	20,000	40
16	Cupressus lusitanica	200,000	40
17	Dodonaea angustifolia	80,000	40
18	Dovyalis abyssinica	6,000	30
19	Erythrina brucei	6,000	30
20	Eucalyptus species	150,000	70
21	Grevillea robusta	90,000	50
22	Hagenia abyssinica	400,000	20
23	Juniperus procera	450,000	20
24	Leucaena leucocephala	20,000	60
25	Melia azedarach	2,000	70
26	Millettia ferruginea	1,500	50
27	Moringa Species	4,000	60
28	Olea europaea	6,000	30
29	Parkinsonia aculeata	12,000	40
30	Podocarpus falcatus	2,000	50
31	Rhamnus prinoides		
32	Sesbania species	100,000	80
33	Schinus molle	40,000	70
34	Syzygium guineense	2,500	70
35	Ziziphus mauritiana	1,000	50

(8) Work norm

1. Tree seed collection:

Work norm is 20 person days/kg. This includes:

. Selection of healthy and vigorous mother trees, . Collection of tree seeds at proper time (not fresh, fallen or old),

. Removal from pods or cover (treshing), drying, and seed extraction and removal of impurities (cleaning), bagging and storing.

Only exception is for Grevillea robusta for which the work norm is 60PD/kg of clean seeds.

2. Grass/legume/other seeds collection (closures, bunds, etc.):

Work norm: 10 person days per kg of grass seeds and small legume pasture seeds (does not include pigeon peas).

The norm includes collection of seeds at the right time of maturity, treshing and cleaning, bagging and storage. Seeds differ in size and weight and a standard work norm is of difficult application.

Woreda experts can take this norm as average for different seeds and adjust to reach the maximum indicated in the work norm.

(9) Useful tree seeds characteristics

No.	Species	Collection method	Collection calendar	Remark
1	Faidherbia albida	Harvesting is done by shaking the tree and catching the pods in a tarpaulin. Collection from the ground should be avoided.	July - October	Ripe seeds should be collected as soon as their colour changes from green to yellow, to avoid insect infestation.
2.	Acacia seyal	Full-sized pods are harvested from the tree before they open		Flowering is concentrated in the middle of the dry season and rip fruits are available about 4 months later.
3.	Balanites aegyptiaca	Fruits will not persist long on the tree. Discharged stones can be collected under the trees, but they are often prone to insect attack. Usually only a fraction of the fruits can be collected. Several collections may be necessary due to prolonged fruiting.	Nov. - April	Fruits are harvested when they turn yellow and the flesh becomes soft and sweet.
4.	Acacia tortilis	Pods should be harvested from the tree by shaking them down from the canopy on to tarpaulins. Pods that have been lying on the ground for some time are often infested with insects.	April– Jun. Dec.- Feb.	Mature seeds change colour from green to yellow/light brown
5.	Grvillea robusta	Seeds do not mature at the same time. Collection is difficult because of the short time (only 2-3 days) between seed maturity and dispersal. Only mature seeds should be harvested. Collection of seeds from the ground is possible but very time consuming and it should only be done in dry weather as the wings stick to the ground if wet.	Oct.- May	Fruits are collected when the colour changes from green to yellow and the first hint of brown appears. If the capsul do not open, drying in the shade will often help.
6.	Dovyalis abyssinica	Seeds are collected from the ground after soaking the fruits for 2-3 days, the pulp is removed by squashing and then rubbing the fruits through a wire mesh. Fruits are dried in the shade in a place with good ventilation and the remaining pulp is removed by winnowing.	Dec.- Jan.	Collection takes place when the fruits change from green to yellow/orange and have become soft. Moisture content at the time of harvest is high, about 35%, and the dry seed (pyrene) should have moisture content of 6-10%.
7.	Casuarina equisetifolia	The seeds are mature when the cones turn yellow and begin to open. Seed coat should be partly brown and the endosperm firm.	Nov.- April	Fruits are dried in the sun before the seed is extracted.
8.	Azadirachta indica	Easiest way of collection is to spread tarpaulin under the trees and collect the fruits after they have been manually stripped of the branches or shed by shaking or beating the braches. Fully matured fruits are depulped immediately to avoid fermentation.	Jan. – Aug.	Fruits are best collected from the tree since fallen fruits tend to have low viability. The right time of collection is when the colour of the fruit turns from green to yellowish green.
9.	Albizia lebbeck	Collection should not be delayed as insects can very quickly infest mature pods. Early collection followed by after ripening in the shade could minimize the damage.	Jan.- March	Mature pods have light yellow colour and should be harvested when the last patches of green are disappearing. The seed is extracted by beating or in a flailing thresher, which is very effective for this species.
10.	Acacia senegal	Pods are harvested before they open by shaking the branches over a tarpaulin on the ground.		To minimize insect attack the pods are often collected early when they are still green.
11.	Acacia mearnsii	There is great variation within and between trees in regard to time of ripening. Collection can take place when the pods have turned yellow. There are typically 2-3 weeks from seed maturity until they are dispersed. Collection can be from the tree or from covers on the ground.		The pods are dehiscent and seeds are dispersed when the pods open. When the seeds are mature, they change colour from white to black and the pod colour changes from green through yellow to brown.
12.	Tamarindus indica	When the pods begin to show cracks on the surface and rattle when shaken and the first pods fall to the ground, the seeds are ripe and collection can begin. Collection can be done from the tree or from the ground after shaking the branches but it is suspected that weevil infection is more prevalent in pods collected from the ground.	Oct.- Jan.	
13.	Croton	Climbing and hand picking of pods with seeds	Oct-Dec.	
14.	Cordia africana	Climbing and hand picking of yellowish fruit with each fruit containing 4-6 seeds. January	January	
15.	Schinus molle	Climbing and hand picking of pods with seeds.	Dec.-Jan.	
16.	Dodonaea angustifolia	Climbing and hand picking of pods with seeds.	Sept.-Oct.	
17.	Leucaena	Climbing and hand picking of pods with seeds	June-Aug.	
18	Parkinsonia aculeate	Hand picking of bunches of woody pale brown pods.	Sept.-Dec	
19.	Ziziphus spps.	Climbing and hand picking of ripening fruits, yellow to red, with 2-3 seeds inside the edible flesh.	Feb.-April	
20	Juniperus procera	Collect pulpy fruit containing 1-4 hard seeds.	Dec.-Feb	
21.	Psidium guajava	Hand picking of fruit containing many hard angular seeds surrounded by sweet flesh.	Nov.-Feb	
22.	Acacia decurrens	Climbing and collecting the thin pods with brown to dark brown colour.	Dec.-April	
23	Chamaecytisus palmensis	Hand picking of matured pods.	Oct.-Jan.	
24.	Coffea arabica	Hand picking of only the red cherries	Sept.-Nov.	
25.	Moringa species	Climbing and hand picking of matured pods.	Sept.-Dec	
26.	Teminalia brownii	Collect a winged oval seed, red to purple in colour.	Dec.-Jan.	The fruit from which the see is taken must not be allowed to touch the ground.
27.	Persea americana	The fruit should be picked just before it is ripe and before brown splashes have began to form on the skin.	Dec.-Feb.	
28.	Olea europaea		Jan.-Feb.	
29.	Cajanus cajan	Hand picking of natured pods.	Feb.-Mar.	
30.	Mangifera indica		Dec.-Feb. May-Jan.	

(9) Seed collection as income generation

GROUP FORMATION ON SEED COLLECTION:

· This applies only for collection of valuable seeds that can be sold in the market/to farmers or become part of other income generation activities. For example a group of farmers contracted by other farmers to stabilise terraces, gullies and other degraded lands.

Example: A seed collection group can be created to undertake such business and look for seeds of interest, create its own multiplication centre or directly plant seeds in conserved areas. For example different type of “Sembelete” (Hyparrhenia sp.) are very good for roofing and can be disseminated along terraces or in treated gullies and hillsides. Other species can also be used.

· Other seeds, for instance from Neem (Azadiractha indica) can make excellent pesticides against aphids and other insects if 1 kg of Neem seeds is crushed and soaked in 10 litres of water for 24hrs or more.

· Discuss with farmers and start to form manageable groups of maximum 5-10 poor households per group – start with one group and then expand. This group should be also doing other income generation activities such as offer itself as roof thatch makers + compost makers, pest control, etc.

Remember to:

. Agree on tasks and benefits on individual basis.

. Groups should be given permission to collect seeds from closures or other areas by community.

. DAs or woreda experts need to provide training on management of seeds or other activities linked to seed collection and management of planted areas.

Gully Control

1. Stone Checkdams
2. Brushwood Checkdams
3. Gully Resheping, Filling and Revegetation
4. Sediment Storage and Overflow Earth Dams (SS Dams) for Productive Gulley Control
5. Sediment Storage and Overflow Soil Bunds (SS Bunds)

TECHNICAL INFORMATION KIT

STONE CHECKDAMS

(1) Period/phases for implementation

. Only during the dry season and period not interfering with land preparation.

(2) Objectives/remarks

. A stone checkdam is a structure across the bottom of a gully or a small stream, which reduces the velocity of runoff and prevents the deepening and widening of the gully.

. Sediments accumulated behind a checkdam could be planted with crops or trees/shrubs grass and thus provide additional income to the farmer.

(3) Suitability, agroecology, adaptability to local knowledge

. Suitable all over the country, provide stones are available. Commonly used to check gullies on highly eroded grazing and cultivated lands and hillsides. Considerable local experience exists.

(4) Main land use

. Highly eroded gully areas in all land uses. Not suitable for large gullies without catchnment treatment and protection.

(5) Technical preparedness

. Land use, soil and topography assessed.
. Discuss/agree with farmers on design and layout + provide on-the-job training.
. Precise layout and follow-up/adaptations.

(6) Potential to increase/sustain productivity and environmental protection

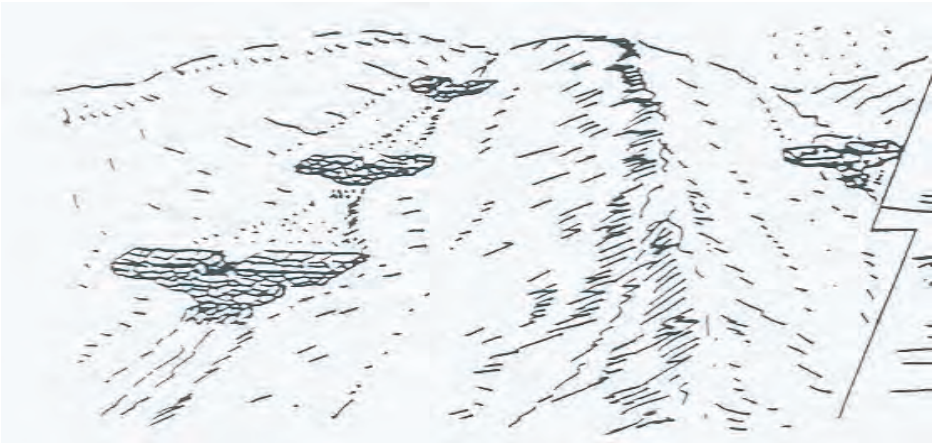
. Reduced erosion and accumulated soil sediments used for revegetation.
. Gullies could be reclaimed for production of trees (including fruits) and crops.
. Gullies control run-off and conserve moisture in the soil that give rise for springs at downstream sites.

(7) Minimum surveying and tools requirements

Layout: One water line level, one range graduated in cm and 10 meters of string.

Work: shovels, pick axes, crow bars and sledgehammer.

Figure 1. Checkdams in the landscape



(8) Work norm

The worknorm involves stone collection, foundations/key excavation and proper placement of checkdams and drop/apron structures.

WORK NORM: 0.5 m³/Person day

(9) Minimum Technical Standard

Checkdams could be constructed in a wide range of conditions: (1) small gullies serving a large one, (2) as outlets for traditional or newly constructed bunds or terraces unable to accommodate all runoff and, (3) to trap silt before a water pond.
. Spacing estimated on the safe side $S(\text{spacing}) = \frac{\text{Height(m)} \times 1.2}{\text{Gully bed slope(decimals)}}$
Side key: 0.7-1m per side;
Bottom key and foundation: 0.5m deep;
Height: 1-1.5m excluding foundation;
Base width: 1.5-3.5m;
Stone face vert/horiz. ratio =1:3/1:4 for increased stability;
Spill way (trapezoidal): 0.25-0.30m permissible depth and 0.25m free board; and width 0.75-1.2m;
Drop structures on steep slopes (above 15%) before the apron (ladder placed stones before the apron;
. Apron at least 50 cm wide on both sides of spillway fall (1.5 -3m wide) and 1m long.

(10) Modifications to standard design

. Since checkdams are built on volumetric units, it is flexible to maximise the size as the need arises. Better to estimate catchment area and run-off for designing the size of the structure including spillway (see cutoff drain infotech).

. Gully sides should be reshaped and planted with rows of grasses possibly reinforced with plants such as Sisal, Euphorbia, etc, placed along the upper and/or lower side of the checkdam.

(11) Integration and Management requirements

. Checkdams require regular follow-up and some maintenance. Upgrading or rising of the check may be required. Group of people sharing the gully area should ensure maintenance.

. Gully protection/closure is important for quick revovery of vegetation.

Checkdams are integrated with plantation on sediments, reshaping and stabilization of gully sides.

(12) Planning and Implementation arrangements

. Planning follows community/groups and individual owners' discussions/agreement on layout, spacing and management requirements. Groups of 5-20 households work

(13) Limitations

. Stone checkdams are effective to plug small gullies and not very easy for large gullies. This works only where stones are available.

(14) Institutional responsibility

. Fully on individuals/groups +/- community (commitment to mgt.)
. DAs and wda experts - technical support and follow-up/mgt.

Figure 1 Example and main standards

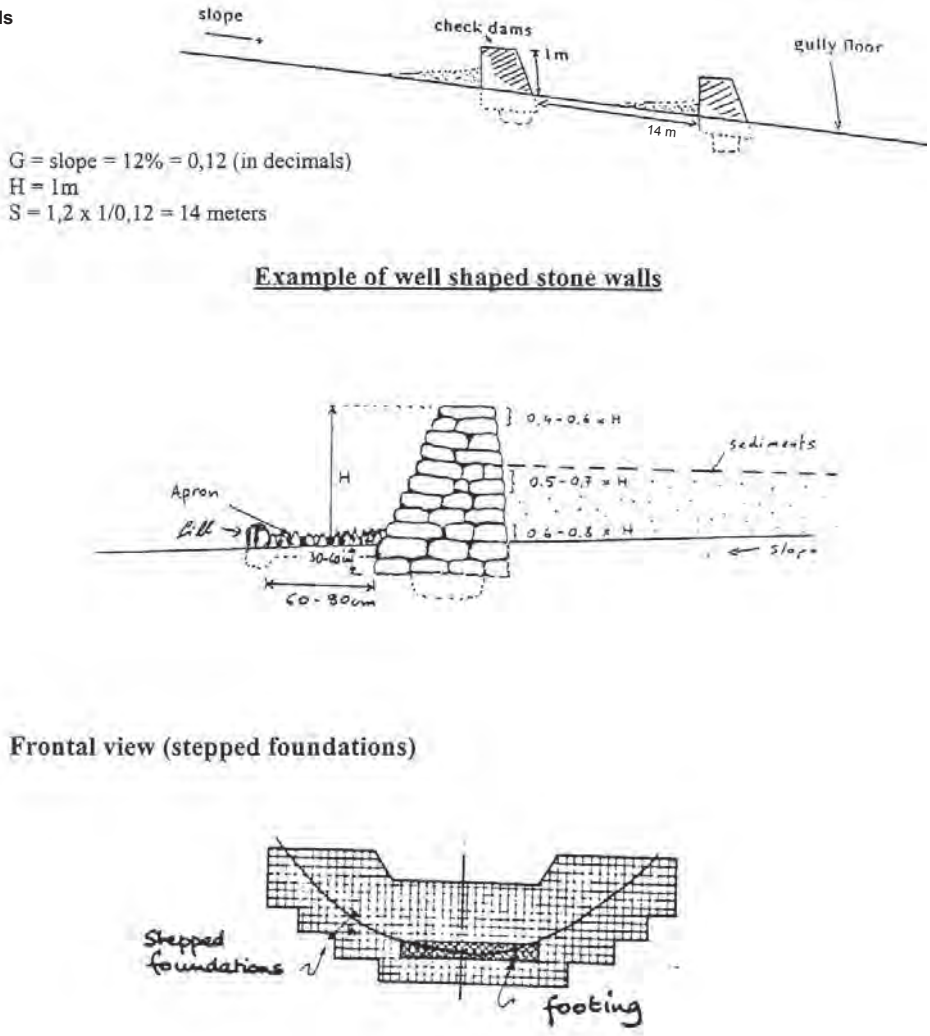


Figure 2 side view on steep slope (high drop)

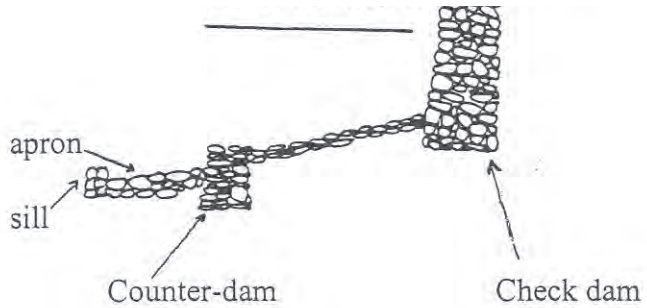
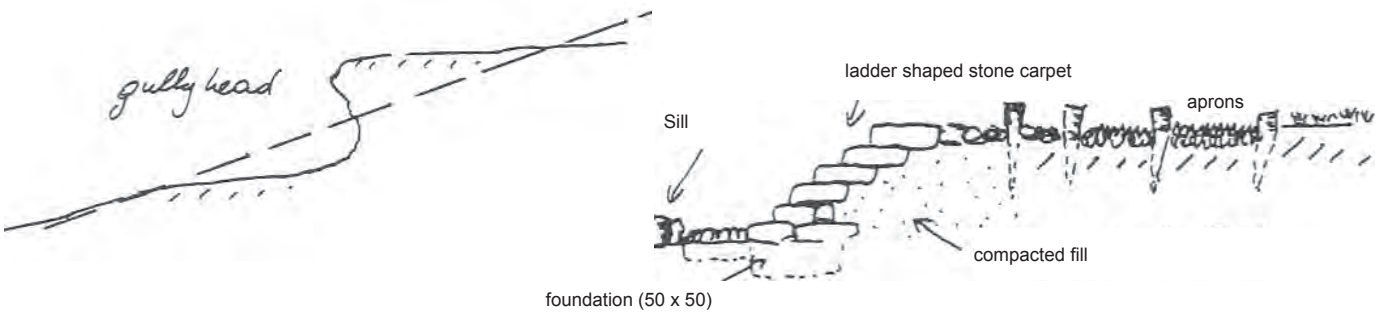


Figure 3 Checks at the gully head (ladder shaped + wood posts + aprons)



TECHNICAL INFORMATION KIT

BRUSHWOOD CHECKDAMS (BWs)

(1) Period/phases for implementation

. During belg rains or before main rainy season.

(2) Objectives/remarks

- Brushwood checkdams are vegetative measures constructed with vegetative materials, branches, poles/posts and twigs. Plant species which can easily grow vegetatively through shoot cuttings are ideal for this purpose. The objective of BWs is to retain sediments and slowdown runoff, and enhance the revegetation of gully areas. They are constructed either in single or double row.
- Some of the vegetation can be used for fodder.
- BWs are also ideal to stabilize conservation structures bunds, SS bunds, check dams, bench terraces, road sides, etc (see examples below).

(3) Suitability, agroecology, adaptability to local knowledge

BWs are commonly used in parts of Ethiopia to stabilise small gullies. Traditional use of vegetative checks is common also in cultivated fields cut by small gullies as a result of strong showers (especially in SNNPR). It is a technique that can be easily adapted to many local conditions and integrated with others.

(4) Main land use and agroecology

. In all land uses affected by small gullies or as additional support to stone checkdams. Suitable from dry-weyna dega to dega zones. In drier places need to be combined with stone checkdams. Also recommended along farm boundaries affected by small gullying. Brushwood checks can also be adapted to stabilize depression points along bunds. Can also reinforce bench terraces and SS bunds, road sides affected bu gullies,etc.

(5) Technical preparedness

. Mostly based on local knowledge on when and how to plant species.

. Training required on spacing and type of species combination, and integration with other SWC measures.

(6) Potential to increase/sustain productivity and environmental protection

. BWs can stabilize small gullies and complement other measures such as plantations inside gullies.
. Fruit trees and other species can also be planted behind the brushwood checkdam.
. A great potential exists for BWs as a support measure to reinforce other physical structures.Example:
1) To reinforce SS bunds and large check dams - **See figure 2**.

2) Small brushwoods along roads affected by gullies - **See figure 3**.

3) BWs to reinforce bunds along depression points (for example placed on lower side of soil or stone bunds) - **See figure 4**.

4) BWs placed along bench terraces can strongly support the embankments in fragile soils, particularly in slopes > 15-20% - **See figure 5**.

(7) Minimum surveying and tools requirements

Survey: Assess potential for BWs and determine type and availability of planting and dry materials as required

Tools: farmers tools sufficient (machetes, small hatchets, axe and hooks) some crow bars or hard wood sticks to plant posts and plants on bottom and side of gullies and structures.

(8) Min. technical standards, steps and work norm

a) Brushwood checkdams are suitable only for small gullies of less than 1.5-2 m depth and 2-3 meters wide .

b) Post with vegetative propagation capacity (bamboo, Erythrina, etc.) are best and should be also used wherever available.

c) Thicker branches (6-10cm) will be used as vertical posts. Their height depends from the height of the gully but should not be more than one meter above the ground. The vertical posts should be driven into the soil at least 50-60 cm depth, spaced apart 30-50 cm. They should also gently lean backslope for better resistance. After the posts are driven into the soil, the thinner **branches or limbs are interwoven through the posts, to form a wall.** Each branch should be pushed into the banks, up to 30-50 cm inside. If vegetative materials are used, these branches will strike roots into the banks and strengthen the BW. The soil at both ends of the dam is carefully patched down with feet. Some roughage can be placed on a 20 cm layer on the upper side mixed with soil. Water should percolate through the check.

d) **Spacing: Use the same calculation for stone checkdams and divide the distance by two or three.**

e) The BW should be reinforced with plants such as Sisal, finger Euphorbia and Aloe placed along the upper + lower side of the check.

WORK NORM: 3 linear meters/person day

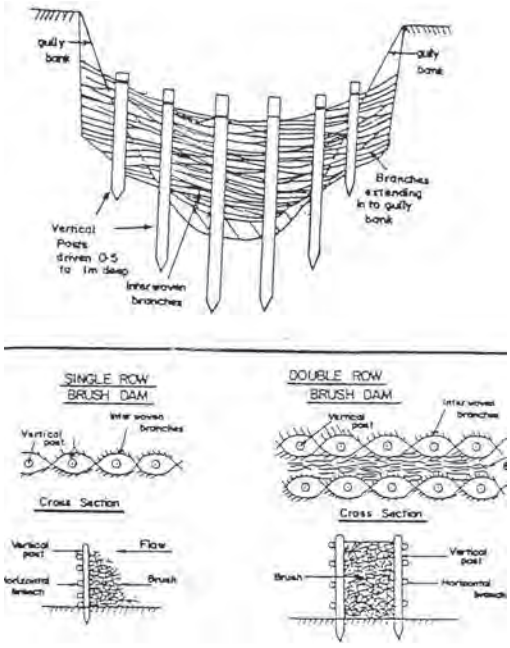


Fig. 2 BWs reinforcing SS bunds

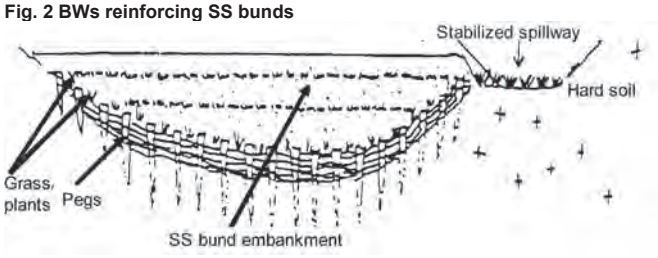
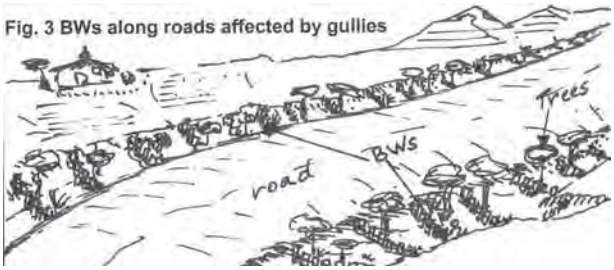


Fig. 3 BWs along roads affected by gullies



(9) Integration

Can be integrated with physical structures on various land uses, with plantation of fruit trees and high valued species.

(10) Management requirements

. Check solidity of the check after first rains and plant addional pots and vegetation on deposited soil. Control grazing on areas treated with BWs.

(11) Integration	(12) Institutional responsibility
Not applicable in large gullies and in areas with limited vegetative materials or very far from treated sites. Needs frequent maintenance if not stabilized properly.	. Fully on community members (commitment to mgt.). . DAs and wda experts - technical support and mgt.

Fig. 4 BWs reinforcing bunds along depression points

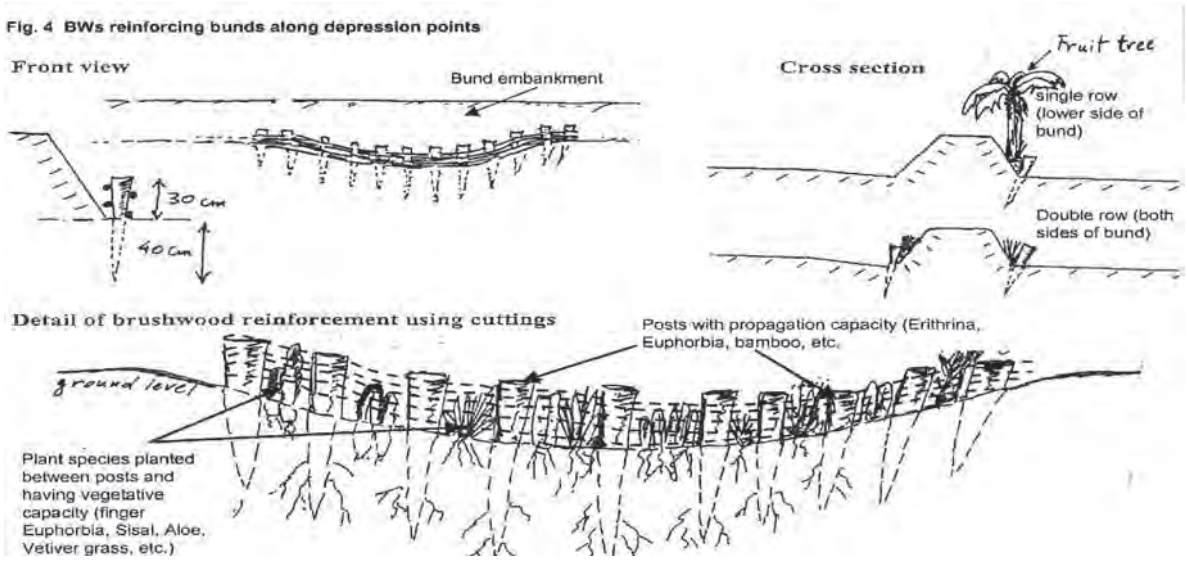
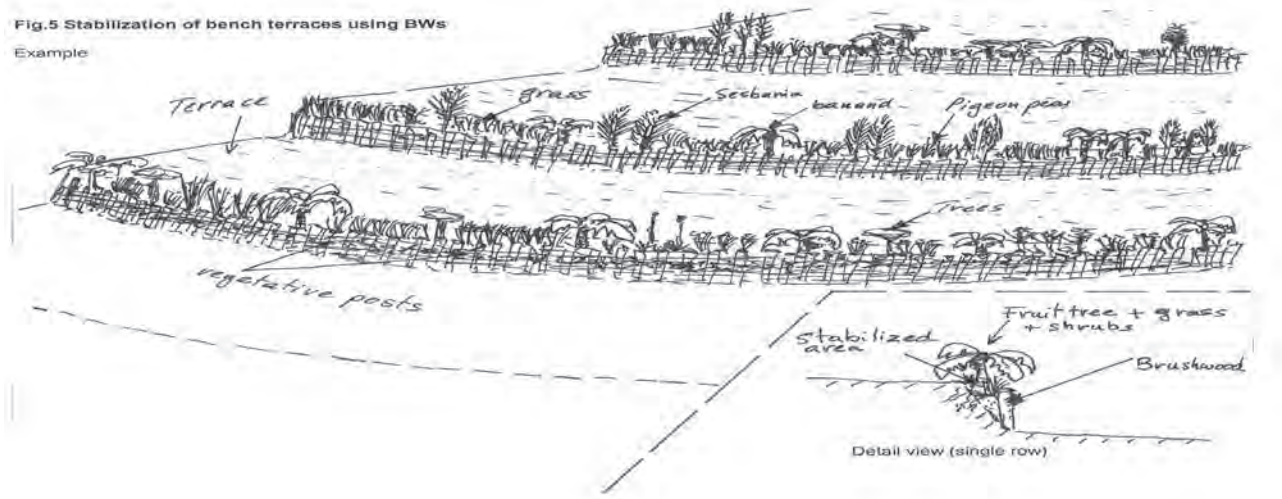


Fig.5 Stabilization of bench terraces using BWs

Example



TECHNICAL INFORMATION KIT	(1) Period/phases for implementation	(2) Objectives/remarks
GULLY RESHAPING AND FILLING AND REVEGETATION	. Shaping and leveling before ains. Re-vegetation at the beginning of the rainy season.	. Reshaping & Filling is an operation meant to decrease the gully erosion angle of incidence, create planting areas and encourage revegetation & stabilization, usually in small gullies or in other medium sized gullies from which most runoff has been diverted into a stable waterway or drainage line. . When these gullies are shaped and smoothed, vegetation can be established over the levelled gullies. Some of these areas can be used for farming purposes. . Revegetation of a gully is the plantation of the reshaped gully sides and bottom with multipurpose species so that it reduces runoff and control erosion and make the land productive. Gully revegetation implies reaching a dense vegetation cover over the entire gully surface, i.e. both sides and bottom by planting grasses, legumes and a variety of trees and shrubs.

(3) Suitability, agroecology, adaptability to local knowledge

This measure is common on small gullies. Traditional and recently introduced gully reshaping and re-vegetation efforts are found in various parts of the country with promising results. Combined with other watershed rehabilitation efforts this measure is highly suitable.

(4) Main land use and agroecology

. Treatment of gullies of different dimensions cutting through various land uses, particularly cultivated land. Suitable in all agroclimatic conditions. In dry areas need to be always combined with physical measures.

(5) Potential to increase/sustain productivity and environmental protection (impacts)

. The potential is huge if integrated within a proper watershed rehabilitation effort. Countless gully networks can be converted into productive units through a combination of gully reshaping, leveling and revegetation. In addition, gullies will benefit from check dams, brushwood checks and SS dams/bunds as compementary measures.

(6) Description of the technology and steps

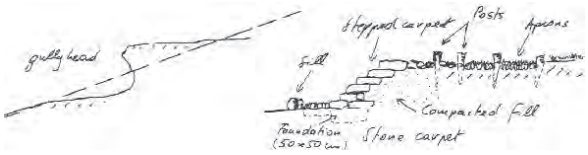
1. Reshaping and filling

. Divert excess runoff into another drainage line (stable) or treat the catchment area.
. Control the gully head and the side banks by cutting & filling (see figure 1).
. Gully heads can be stabilized by the means of stepped stone carpets, brushwood layering or a combination of both.
. Using stepped stone carpet is more appropriate for dry areas because of intensity of rainfall.
. The stepped stone carpet occurs following the semi-circular shape of the gully head, moving backwards and filling empty space with soil and small stones until reaching the gully edge.

2. Revegetation: Three conditions and steps are important for revegetation.

. Exclude the cattle throughout the year and use cut and carry.
. Reshape the steep gully sides (1 horiz.:1 vertical minimum). Reshaping can be done either by cutting the edges or shaping the slope in grades or steps for tree/grass planting. Reshaping should be supplemented or directly implemented by shaping the gully sides into series of small steps or micro-benches (every 0.75-1m distance - Figure 2),
. The gully sides should be planted with both a mixture of creeping and drought resistant grasses and tree & shrubs. Trees and shrubs should be planted at a density not lower than 3-4/m² and not higher than 6/m² to reach dense vegetation and not to overshadow the grass growing the first year. Grass should be planted in dense rows along the steps on simply on the reshaped gully sides. Do not plant grass in scattered spots. Plant trees and grass which are drought resistant and colonize the soil rapidly. Elephant grass, Vetiver, Rhodes, Buffle grass, etc, and suitable native grass are recommended. For trees/shrubs, Sesbania sesban, Pigeon peas and Acacia species (Saligna for example). Other species include Sisal and Euphorbia, and Erithryna.
. The gully edges adjacent to the fields should be stabilized with strong rooting trees and vegetation (Sisal, Acacias, etc) to impede the widening of the gully and clumping.
. Revegetation of a gully is often combined with physical structures (checkdams, SS dams/bunds, etc.).
. Work norm: is 500 person days per ha of gully area

Figure 1 Reshaping and treatment of gully head



See infotech on stone checkdam

Figure 2 Example of Gully Reshaping and Revegetation

(7) Integration requirements and opportunities

1. This system will be greatly enhanced by upper watershed rehabilitation aimed to replenish water tables and provide access to water within homesteads (hand dug wells).

2. Compost making, half-moon and eyebrows basins to support growth of trees and any other activity enhancing fertility is recommended.

(8) Constraints and limitations

. Difficult to apply under 600mm rainfall unless supported by irrigation.
. Requires considerable skills and provision of planting material.

TECHNICAL INFORMATION KIT

Sediment Storage and Overflow earth dams (SS Dams) for productive gully control

(1) Period/phases for implementation

. Only during dry season and min. one month before rains likely to occur. Should be completed within one season.

(2) Objectives/remarks

• SS dams are water harvesting and conservation systems that convert unproductive large and active gullies into productive areas (fertile cultivated or fodder producing areas, mixed plantations, and fruit tree orchards).

• SS dams are stone-faced earth dams constructed across medium/large size gullies to trap sediments, collect water and divert excess runoff. SS dams accommodate the runoff generated by the catchment located above the gully. The structures are often constructed in series along the gully. It is just like creating a land that does not exist.

• Contribute significantly to protect cultivated lands, arrest gully expansion and recharge water tables

• Huge potential in Ethiopia - can provide tens of thousand Km of gullies to poor households (small land holders and landless).

(3) Suitability, agroecology, adaptability to local knowledge

. Traditional structures similar to SS dams are common in several parts of drylands in Ethiopia (Dire Dawa, Tigray/Erob, Wollo, Hararghe, etc). SS dams can be easily introduced in those areas, particularly where local structures are damaged by excess runoff. In other areas, start small scale and develop local interest by introducing high value crops and allocating SS dams to needy farmers - SS dams can become a "food ensurance" site for food insecure households. Deep rooted perennials/annuals make use of the moisture and nutrient available in the accumulated soil behind SS dams.

(4) Main land use and agro-ecology

. Highly eroded gully areas in all land uses. Not suitable for large gullies without catchnment treatment and protection.

(5) Technical preparedness

. Training required (DAs and HHs).
. Agree with farmers on location, user rights, size, production area, catchment protection works and on-the-job training. Test measure first.

(6) Potential to increase/sustain productivity and environmental protection

. Very high - for cash and staple crops, introduction of fruit trees in gullies, valuable trees, etc.
. Provide opportunities for income generation to small land holders and landless.
. Drought proof activity - even when rainfall is low SS dams collect sufficient moisture.
. Promote fertility management (compost, etc) and watershed protection, raise water table.

(7) Minimum surveying and tools requirements

. Survey: long rope and wooden pole, measuring tape or marked string Tools: crow bars, shovels, pick axes, local stretchers (barella) to carry soil, sledge hammers.
. 10-20 workers per SS dam site.

(8) Design & technical standards (fig 1)

A) Site Selection:

. Inside gullies and natural depressions that you wish to convert into productive fields.
. Below catchments with less than 40 ha max. because of the increased costs for larger structures.
. The site should allow the maximum formation of a cropped field area (wide portions of a given gully are preferred to narrow and deep portions).
. One side of the gully needs to have suitable hard structure to put the spillway (stony areas, limestones, very hard pans and soft rocks).
. When suitable soil conditions do not exist, reinforcement of spillway is required (riprap and drop structures).

B) Design/size: Estimate the size of the structure

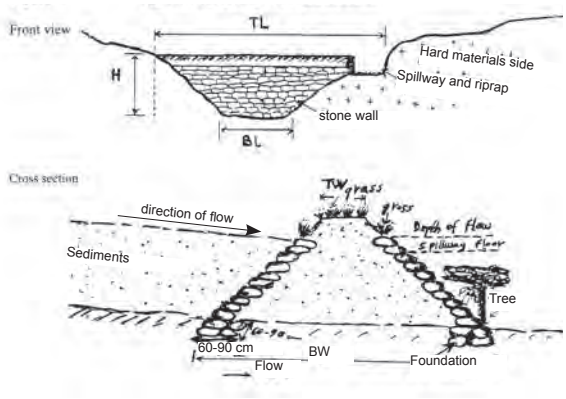
(1) With a meter tape and a graduated long pole (5-7 m) measure the base width and length, height and top width and length of the structure.
(2) Select the best emplacement of the spillway. Estimate spillway construction standards (see below) including gradient and length.
(3) Dimensions and volume of the structure: they are selected based on the area of the catchment, the width of the gully and specially its depth. Apply the following criteria to **approximately estimate the dimensions of the SS dam** (simplified for trapezoidal design).

Height = H,			
Base width = BW,	H < 2m	H:BW is 1:2-2,5	TW = 1,5m
Top width = TW,	H = 2-3,5m	H:BW is 1: 2,5-3	TW = 1,5m
Top length = TL,	H = 3,5-5m	H:BW is 1: 3	TW = 3 m
Bottom length = BL			

(4) V1 = Volume of embankment earth/stone work (m^3) = $\frac{H \times (TW+BW) \times (TL+BL)}{4}$

V2 = Volume of spillway (SP) earth work = Length SP (~~equivalent to BW~~) x base width of SP (see table) x total depth of channel (see table)

V1 + V2 = Total volume of earth work (including foundation)



C) Construction standards and phases:

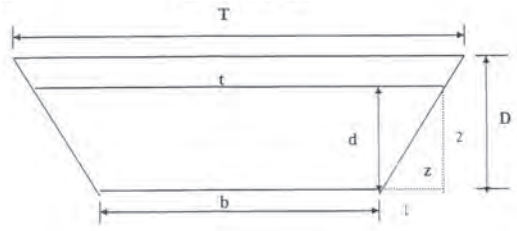
(1) Scrape and **remove grass** and vegetation from the whole bottom width and sides of the gully where the dam is to be constructed (structural continuity).
(2) Proceed with construction of the **key & foundation** of the downstream wall (called riser or lower retention wall) in front of the structure. A second stone wall or rip-rap is placed on the upstream side of the dam (upper retention wall).
. Large flat stones used for the key foundation, side keys (abutments) and retention walls. Make this key & foundation 60-90cm deep x 100cm large and start filling it with large stones. Fill the space between stones with small stones. The first 2-3 lines of large stones inside the foundation inclined 10-20% uphill (stability of foundation).
(3) Erect retention walls with care **following the correct H:BW ratio**:
. Use a rope and a water level placed across the entire gully to adjust the position of the stones of the retention wall (straight level).
. The retention walls are then carefully constructed ladder-shaped.
. Fill space between stone lines with soil and compact. Soil is taken from reshaping the gully or (if not suitable) nearby suitable site and spillway canal. Compaction should be carefully done by repeated passes of oxen over the piled layers of soil (use oxen-pulled compactors-rollers or manual compactors such as buckets filled with heavy soil & stones, wood beams, etc.).

(8) Design & technical standards (fig 1)

D) Spillway design and construction

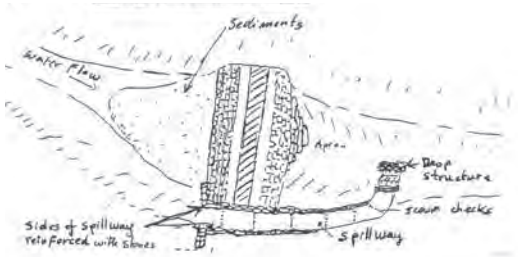
. Start digging the spillway at the desired height (see total height of the structure and deduct the total depth of the spillway = maximum permissible depth of the flow (d) + free board).
. Length of spillway equivalent to base width of dam or more,
. Slope of the spillway is 0,4-0,8% and outlet with drop structure and apron if necessary.
. Construct the spillway at the appropriate side (hard materials) of the gully.
. If both sides are of hard materials, construct the spillway at the side which is facing the direction of the water flow.
. The size of the spillway is determined by the catchment area and runoff estimations.
. The side of the spillway looking towards the dam should be stone faced & reinforced (see fig 2 and fig 3). Shape is trapezoidal.
. The dimensions of the spillway (see table 1 below) have been computed based on "safe standards" for rainfall intensity of 100-150 mm/hour.

Figure 2 Section of a spillway



CATCHMENT AREA (hectares)	BASE WIDTH (b)		DEPTH OF FLOW (d)	TOTAL DEPTH (D)
	medium/low runoff coefficient (0,4)	high runoff coefficient (0,7)		
2	0,8	1,1	0,30	0,70
3	0,9	1,4	0,30	0,70
4	0,9	1,4	0,35	0,75
5	1,0	1,6	0,35	0,80
6	1,0	1,6	0,40	0,90
8	1,0	1,8	0,50	1,00
10	1,0	2,1	0,55	1,05
12	1,0	2,2	0,60	1,10
14	1,1	2,5	0,60	1,20
16	1,1	2,7	0,60	1,20
18	1,1	2,8	0,60	1,20
20	1,2	3,2	0,60	1,20
24	1,6	3,6	0,60	1,20
28	2,0	4,4	0,65	1,25
32	2,3	5,1	0,70	1,30
36	2,7	5,5	0,70	1,30
40	3,2	6,1	0,75	1,35
45	3,7	7,0	0,75	1,35
50	4,2	7,8	0,75	1,35
60	5,1	9,6	0,75	1,35
70	6,1	11,3	0,75	1,40
80	7,1	13,0	0,75	1,45
80	8,1	14,8	0,75	1,50
100	9,1	16,5	0,75	1,50

Figure 3 Aerial view SS dam and spillway



(9) Work norm

Estimate labour requirements based on the following work norms:

. The work norm for the SS dam embankment (inclusive of all elements) is estimated of 0,75 m³ of volume work (earth & stone fill) per person per day.

. The work norm for the spillway is 0,5 m³ of spillway excavated soil & stone work (including drop structure and rip rap if necessary) per person per day.
. The work norms for Gully cut & fill/reshaping/leveling: 1PD/1m³/day

(10) Integration opportunities/requirements

. SS dams are part of a sub-watershed treatment. This is required to allow fine and fertile sediments to be trapped behind the SS dam and avoid coarse materials accumulation. SS dams are then constructed simultaneously or preferably after closure and treatmment of fragile/unstable parts of the catchment with conservation measures (trenches, eyebrows, etc.). Smaller gullies feeding into the main one where SS dams are placed should be laso treated with checkdams.
. This activity is integrated with revegetation of gully sides after sedimentation is completed. Hand-dug wells often possible at lower side of embankment for irrigation.
. This activity is also integrated with conservation works on cultivated lands adjacent to the gully sides (bunds, grass strips, etc.).
. Apply compost in sedimented areas. Apply ring cultivation following receding moisture in large SS dams that fill slowly (few years).

(11) Management requirements

. Check conditions of the spillway (enlarge it if necessary, check scouring, apply paved systems, side protection, etc.).
. Continue gully reshaping for filling SS dams and check quality of sedimentation from catchment and apply additional protection measures (expand closure, SWC, etc.) as required.
. After 1-3 years try hand-dug well close to lower side of embankments (2-3 meters from the wall)
. Check stability of retention walls, riprap and embankment.
. Make sure that each households owning/using their own SS dams along a common gully agree to form a group for management of SS dams (mutual help).

(12) Planning and implementation arrangements

. Agree with the land-owners/users (or those that have lands on both sides of the gully) where to place the structure (s). If SS dams are constructed in series start from the top of the gully. Sample soil profile cuttings to check soil/parent material conditions in order to decide best placement of the dam and spillway.

(13) Limitations

. Labour intensive and needs thorough follow-up - difficult in areas with limited expertise.
. Not suitable in sandy and sodic soils

(14) Institutional responsibility

. Fully on individuals/groups +/- community (commitment to management).
. DAs and wda experts - technical support and follow-up/management.

TECHNICAL INFORMATION KIT	(1) Period/phases for implementation	(2) Objectives/remarks
SEDIMENT STORAGE & OVERFLOW SOIL BUNDS (SS BUNDS)	. During the dry season only and to be completed within one season.	. SS bunds are large and strongly built soil embankments, constructed across gullies, often in series. . As for SS dams, their purpose is to create a new field for cultivation by allowing and helping the sedimentation (filling) of the space behind each bund. After rains, the new fields fill up and retain enough soil and moisture to grow crops. . The excess runoff move to the next structure downstream through a spill-way.

(3) Suitability and adaptability to local knowledge

. Applied in few dryland areas without spillways and across small valleys as traditional systems to store or spread water and cultivate on residual moisture.

(4) Main land use & agro-ecology

. Across medium-small gullies, usually not very deep (2-3 m) and U shaped. SS bunds are suitable for areas without many stones and for small catchments, and where farmers can not afford lot of labour.

(5) Potential to increase/sustain productivity and environmental protection (impacts)

Same as SS dams - can effectively convert gullies in productive fields. Suitable for sandy loams and sandy clay loams.

(6) Description of the technology and steps

a) Site selection:

• Along medium-small gullies and natural depressions that you wish to convert into productive fields.

• The catchment area should be treated (closure) and less than 8-10 hectares, preferably even less than 5-6 ha. One side of the gully should be of hard materi-als such as sandstone, rocks, limestone, etc, in order to construct a proper spillway. If there is no hard rock, the spillway should be enlarged and stabilized with grasses (see dry combs).

• The SS bund site should allow the maximum formation of a cropped field area at a minimum cost, and thus decide carefully where is best to close the gully.

• Burrow soil should be found close to the site and must be of good quality (not very sandy or very heavy.

• If SS bunds are constructed in series start from top of gully.

c) Estimate the size and dimensions of the embankment:

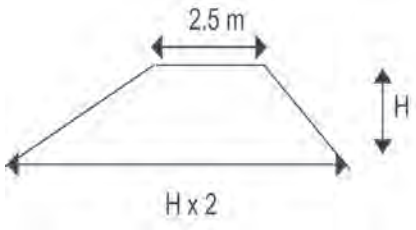
--> Height of bund (H) should not be more than 2.5 m;

--> Base width (BW) should be at least double of the height (H);

--> Top width (TW) should be minimum 2.5 m;

--> Top length (TL) and Bottom length (BL) are according to the size of the gully;

--> Calculate the earth volume work as for the SS dam.



d)Construction phases:

• Plough the area where to place the bund and remove all grasses, branches, roots and decaying leaves.

• Ploughing and moving & piling of soil from the burrow area to the bund area until it reaches the required size. Burrow soil should be found close to the site and of good quality (not very sandy or very heavy).

• Compaction should be carefully done by cattle trampling and/or manual compactors made out of metal cylinders filled with stones and heavy soil.

• Start digging the spillway at the appropriate side (hard materials). If both sides are of hard materials, construct the spillway at the side which is at the direction of the water flow. The SS bund site should allow the maximum formation of a cropped field area at minimum cost, and thus decide carefully where is best to close the gully.

• If both sides are not of hard materials the spillway should be reinforced with a stone riprap.

• If stones are not available protect the spillway sides with branches and push hard straws (wheat, sorghum, etc.) in rows across the spillway floor at 30cm interval (those “combs” will slow down runoff and arrest natural grass seeds that will then constitute thick grass transversal buffers – see soil bunds, see fig 2).

• The length of the spillway twice longer the width of the bund and with very gentle slope (0.5% max.).

• The size of the spillway should be according to the size of the catchment (see table 1)

CATCHMENT AREA (hectares)	BASE WIDTH (m)	DEPTH OF FLOW (m)	TOTAL DEPTH (m)
0.4	0.4	0.15	0.6
0.8	0.7	0.15	0.6
1.2	1.1	0,15	0.6
2	1.5	0.15	0.6
3	1.7	0.16	0.65
4	2	0.17	0.7
5	2.2	0,2	0.75
6	2.4	0.25	0.8
8	2.6	0.3	0.9

Figure 1 Example of SS bund

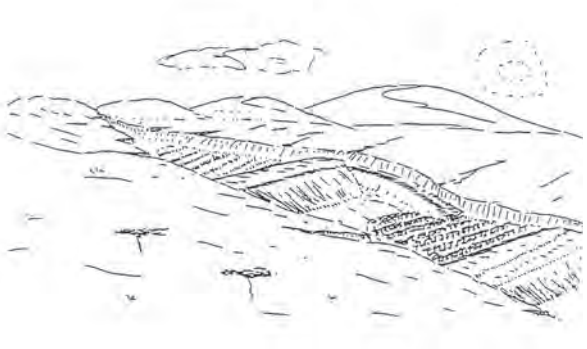
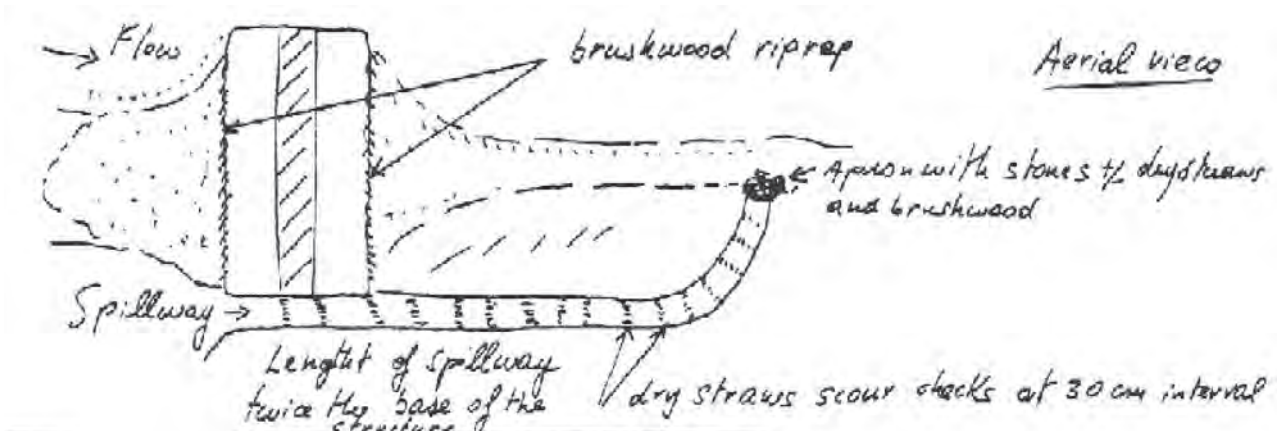


Figure 2. Aerial view of SS bund and spillways



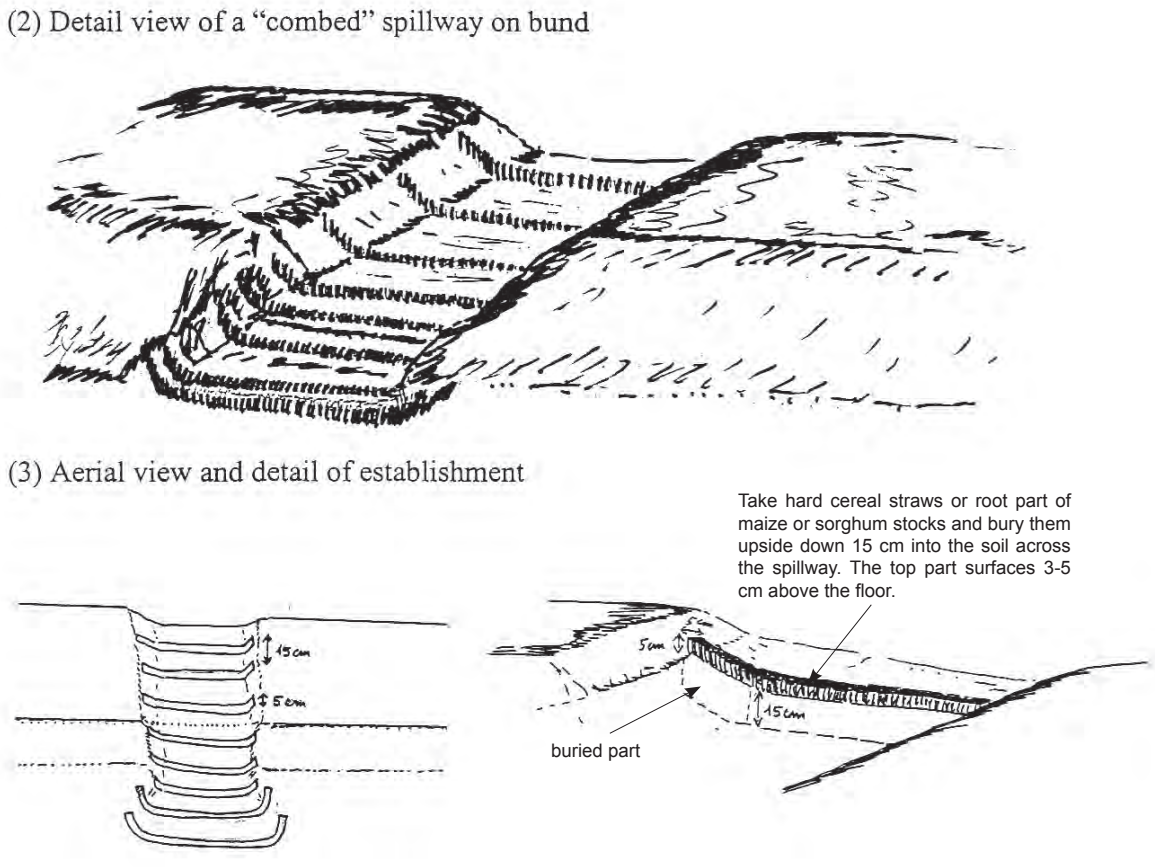
(7) Work norms

Use a combination of:

- The work norm for the spillway is lower, i.e. 0.5 m³ of spillway excavated soil & stone work (including drop structure and rip rap if necessary) per person per day.
- The work norms for Gully cut & fill/reshaping/leveling: 1PD/1m³/day.
- Brushwood checkdams: 1 person day per 3 linear meters of brushwood checkdam.

(8) Integration requirements and opportunities	(9) Constraints and limitations
. In absence of stones both sides of the soil embankment should be reinforced using brushwood ripraps similar to brushwood checkdams across gullies (Figure. 3). The brushwood ripraps should cover the entire width of the structure and extend 1-1.5 m onto the gully sides. . Revegetation of the embankment is also recommended with fast covering and vigorous grass/ shrubs. . Upper part of the catchment should be properly treated.	. SS bunds are not as stable as SS dams and need to be reinforced with brushwoods and planted with grasses. . Labour intensive, especially if applied in series.

Figure 3 Brushwood checkdams along lower side of SS bund



Feeder Roads

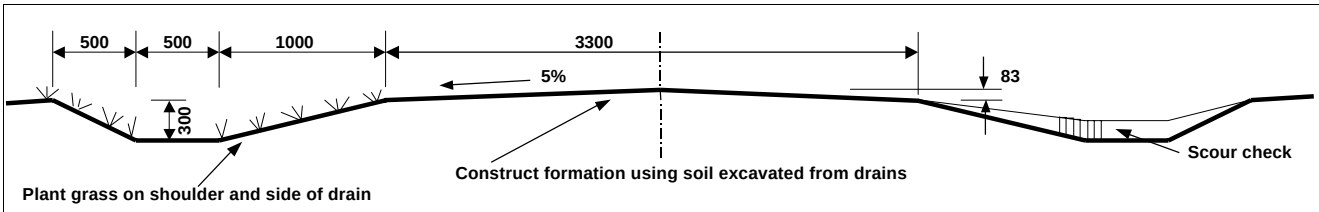
1. R1 Earth road on flat and rolling terrain – stable soils
2. R2 Earth road on mountainous terrain–stable soils
3. R3 Graveled road on flat and rolling terrain – sandy or weak soils
4. R4 Graveled road on mountainous terrain – weak soils
5. R5 Graveled road on flat and rolling terrain– black cotton soils
6. R6 Road on escarpment
7. R7 Typical pipe culvert using concrete rings
8. R8 Standard drift

Ethiopia Productive Safety Net Programme

Community Roads - Standards and Work Norms

R1

Earth Road on Flat and Rolling Terrain - Stable Soils



Standard Cross Section

Dimensions in mm

Minimum Horizontal Curve Radius	**50 metres**
Maximum Gradient	**7%**
Max. Spacing of Passing Bays (Passing bays 20m long x 5m wide)	**500 metres**

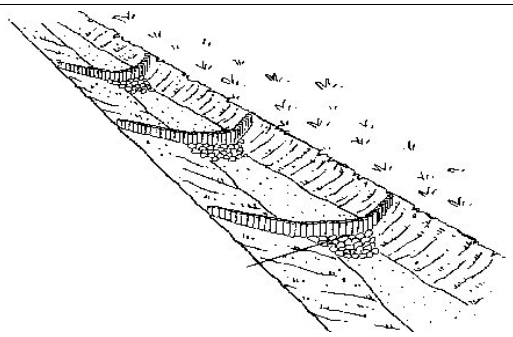
DAILY WORK NORMS

General Norm - 3,000 person days / km

Clear grass and bush (light)	150m^2	Compact by hand	100m^3
Clear grass and bush (heavy)	50m^2	Collect stones (near)	1m^3
Excavation (soft soil)	3m^3	Collect stones (far)	0.5m^3
Excavation (hard soil)	2m^3	Break rocks	0.5m^3
Excavation (rock)	0.5m^3	Scour checks	2/person/day
Spread fill material	7m^3		

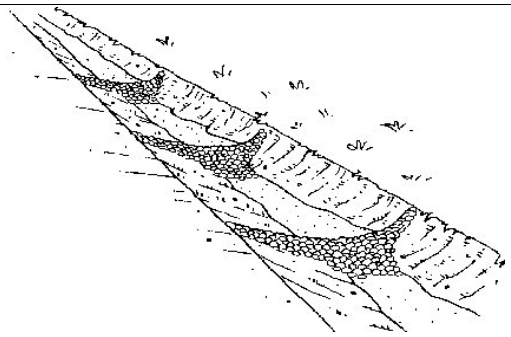
Scour Checks

Gradient	Spacing
< 3%	Not required
3% - 5%	20 metres
5% - 7%	10 metres



Scour check made from sticks

- Sticks about 3 cm diameter 40cm long.
- Hammer sticks into ground so check is 15cm high.
- Apron of stones or grass sods.

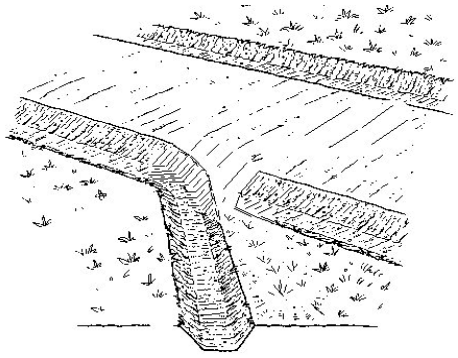


Scour check made from stones

- Same dimensions as stick scour check

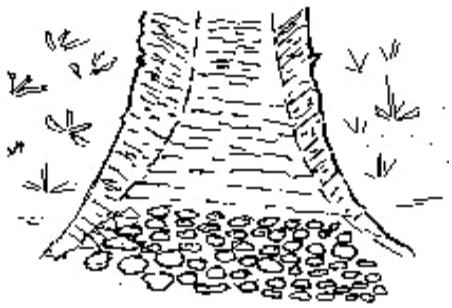
Turnout Ditch

Gradient	Spacing
< 4%	100 metres
4% - 6%	80 metres
6% - 7%	60 metres



Turnout detail

- Minimum 10 metres long



- Provide stones at end of turnout to prevent scouring

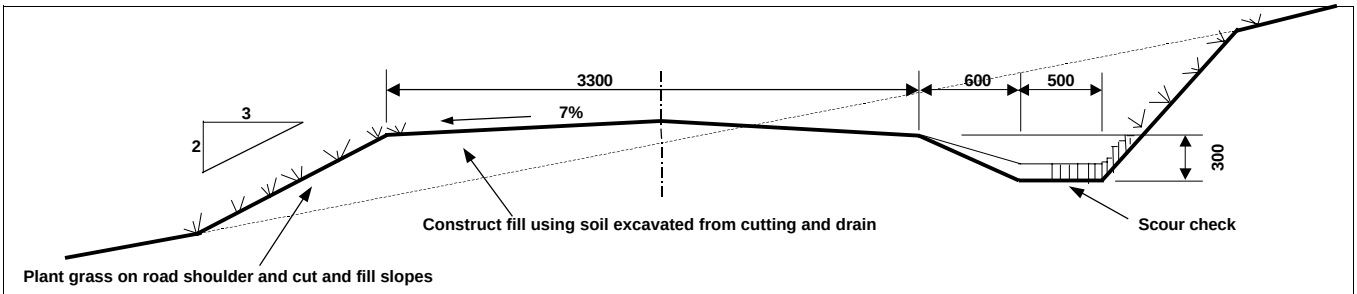
For futher details see: Ethiopian Road Authority. Rural Travel and Transport Programme. Manual for Rural Transport Infrastructure Development

Ethiopia Productive Safety Net Programme

Community Roads - Standards and Work Norms

R2

Earth Road on Mountainous Terrain - Stable Soils



Standard Cross Section

Dimensions in mm

Minimum Horizontal Curve Radius	**30 metres**
Maximum Gradient	**14%**
Max. Spacing of Passing Bays (Passing bays 20m long x 5m wide)	**200 metres**

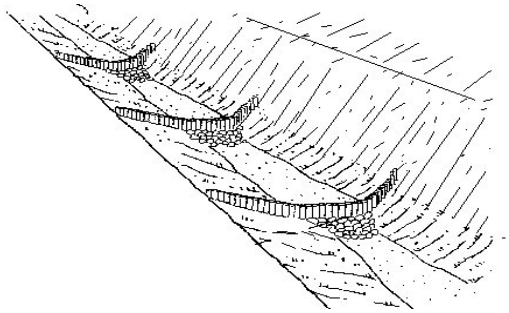
DAILY WORK NORMS

General Norm - 4,000 person days / km

Clear grass and bush (light)	150m^2	Compact by hand	100m^3
Clear grass and bush (heavy)	50m^2	Collect stones (near)	1m^3
Excavation (soft soil)	3m^3	Collect stones (far)	0.5m^3
Excavation (hard soil)	2m^3	Break rocks	0.5m^3
Excavation (rock)	0.5m^3	Scour checks	2/person/day
Spread fill material	7m^3		

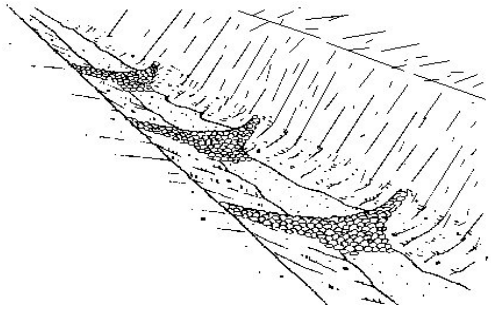
Scour Checks

Gradient	Spacing
< 3%	Nil
3% - 5%	20 metres
5% - 10%	10 metres
> 10%	Lined Drains (Engineering design required)



Scour check made from sticks

- Sticks about 3 cm diameter 40cm long.
- Hammer sticks into ground so check is 15cm high.
- Apron of stones or grass sods.



Scour check made from stones

- Same dimensions as stick scour check

Turnout Ditch or Culvert Spacing

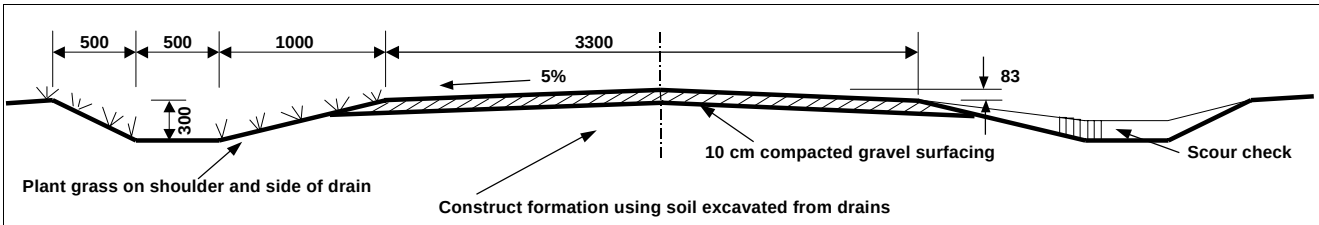
Gradient	Spacing
< 4%	100 metres
4% - 6%	80 metres
6% - 8%	60 metres
8% - 14%	40 metres

For futher details see: Ethiopian Road Authority. Rural Travel and Transport Programme. Manual for Rural Transport Infrastructure Development

Community Roads - Standards and Work Norms

R3

Gravelled Road on Flat and Rolling Terrain - Sandy or Weak Soils



Standard Cross Section

Dimensions in mm

Minimum Horizontal Curve Radius	**50 metres**
Maximum Gradient	**7%**
Max. Spacing of Passing Bays (Passing bays 20m long x 5m wide)	**500 metres**

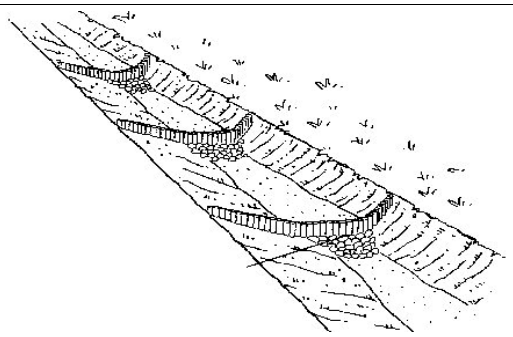
DAILY WORK NORMS

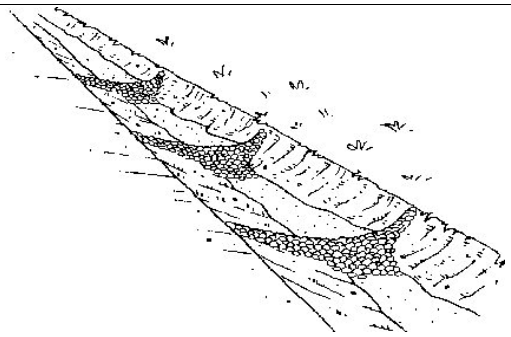
General Norm - 3,000 person days / km

Clear grass and bush (light)	150m^2	Compact by hand	100m^3
Clear grass and bush (heavy)	50m^2	Collect stones (near)	1m^3
Excavation (soft soil)	3m^3	Collect stones (far)	0.5m^3
Excavation (hard soil)	2m^3	Break rocks	0.5m^3
Excavation (rock)	0.5m^3	Scour checks	2/person/day
Spread fill material	7m^3		

Scour Checks

Gradient	Spacing
< 3%	Not required
3% - 5%	20 metres
5% - 7%	10 metres





Scour check made from sticks

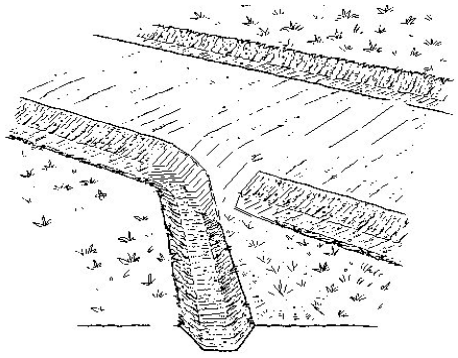
- Sticks about 3 cm diameter 40cm long.
- Hammer sticks into ground so check is 15cm high.
- Apron of stones or grass sods.

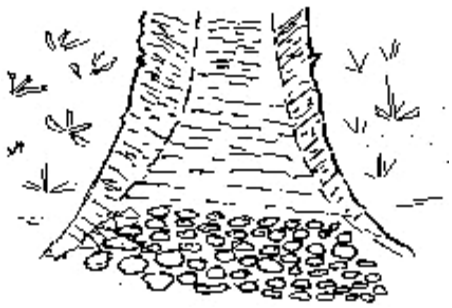
Scour check made from stones

- Same dimensions as stick scour check

Turnout Ditch

Gradient	Spacing
< 4%	100 metres
4% - 6%	80 metres
6% - 7%	60 metres





Turnout detail

- Minimum 10 metres long
- Provide stones at end of turnout to prevent scouring

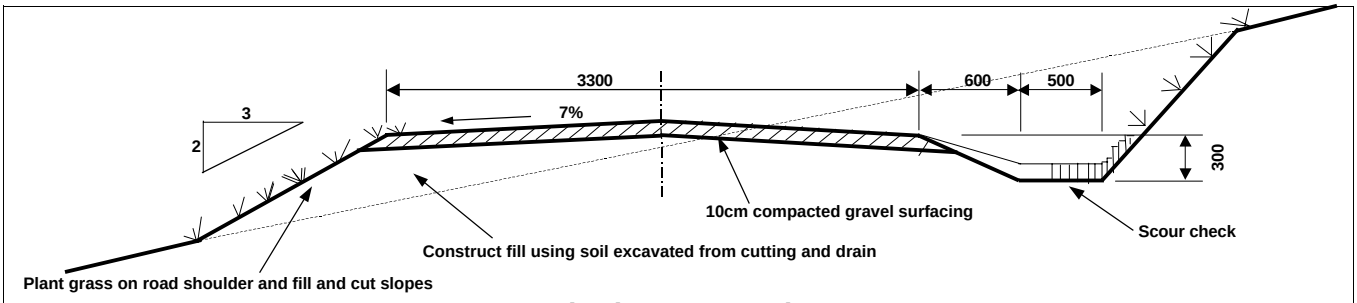
For futher details see: Ethiopian Road Authority. Rural Travel and Transport Programme. Manual for Rural Transport Infrastructure Development

Ethiopia Productive Safety Net Programme

Community Roads - Standards and Work Norms

R4

Gravelled Road on Mountainous Terrain - Weak Soils



Standard Cross Section

Dimensions in mm

Minimum Horizontal Curve Radius	**30 metres**
Maximum Gradient	**14%**
Max. Spacing of Passing Bays (Passing bays 20m long x 5m wide)	**200 metres**

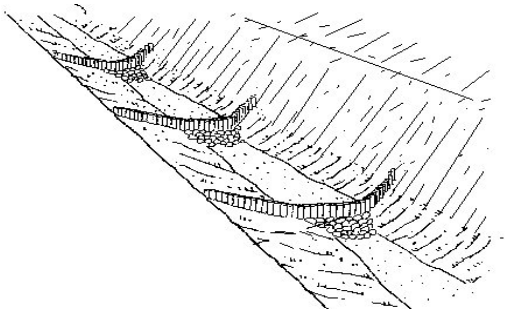
DAILY WORK NORMS

General Norm - 4,000 person days / km

Clear grass and bush (light)	150m^2	Compact by hand	100m^3
Clear grass and bush (heavy)	50m^2	Collect stones (near)	1m^3
Excavation (soft soil)	3m^3	Collect stones (far)	0.5m^3
Excavation (hard soil)	2m^3	Break rocks	0.5m^3
Excavation (rock)	0.5m^3	Scour checks	2/person/day
Spread fill material	7m^3		

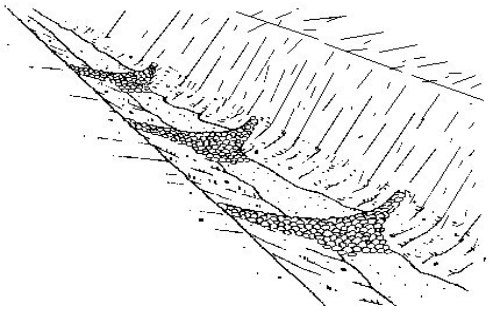
Scour Checks

Gradient	Spacing
< 3%	Nil
3% - 5%	20 metres
5% - 10%	10 metres
> 10%	Lined Drains (Engineering design required)



Scour check made from sticks

- Sticks about 3 cm diameter 40cm long.
- Hammer sticks into ground so check is 15cm high.
- Apron of stones or grass sods.



Scour check made from stones

- Same dimensions as stick scour check

Turnout Ditch or Culvert Spacing

Gradient	Spacing
< 4%	100 metres
4% - 6%	80 metres
6% - 8%	60 metres
8% - 14%	40 metres

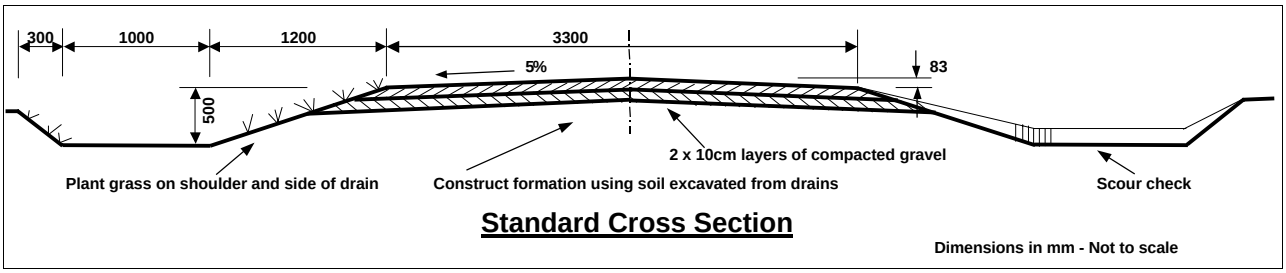
For futher details see: Ethiopian Road Authority. Rural Travel and Transport Programme. Manual for Rural Transport Infrastructure Development

Ethiopia Productive Safety Net Programme

Community Roads - Standards and Work Norms

R5

Gravelled Road on Flat and Rolling Terrain - Black Cotton Soils



Standard Cross Section

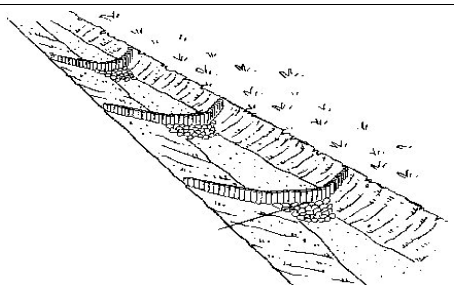
Dimensions in mm - Not to scale

Minimum Horizontal Curve Radius	**50 metres**
Maximum Gradient	**7%**
Max. Spacing of Passing Bays (Passing bays 20m long x 5m wide)	**500 metres**

DAILY WORK NORMS			
General Norm - 4,500 person days / km			
Clear grass and bush (light)	150m^2	Compact by hand	100m^3
Clear grass and bush (heavy)	50m^2	Collect stones (near)	1m^3
Excavation (soft soil)	3m^3	Collect stones (far)	0.5m^3
Excavation (hard soil)	2m^3	Break rocks	0.5m^3
Excavation (rock)	0.5m^3	Scour checks	2/person/day
Spread fill material	7m^3		

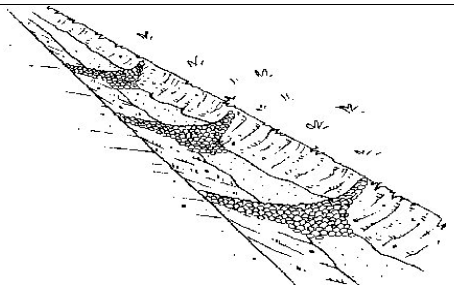
Scour Checks

Gradient	Spacing
< 3%	Not required
3% - 5%	20 metres
5% - 7%	10 metres



Scour check made from sticks

- Sticks about 3 cm diameter 40cm long.
- Hammer sticks into ground so check is 15cm high.
- Apron of stones or grass sods.

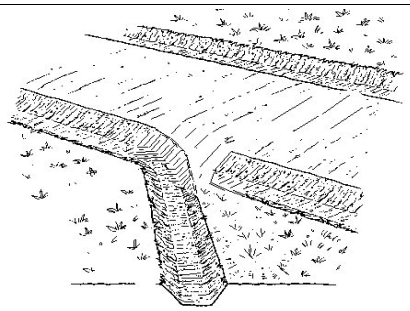


Scour check made from stones

- Same dimensions as stick scour check

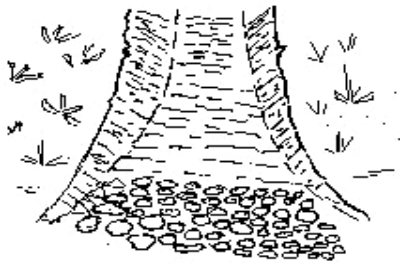
Turnout Ditch

Gradient	Spacing
< 4%	100 metres
4% - 6%	80 metres
6% - 7%	60 metres



Turnout detail

- Minimum 10 metres long



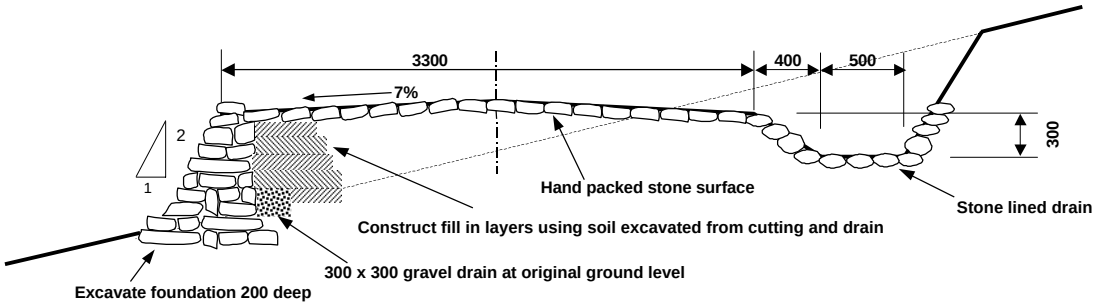
- Provide stones at end of turnout to prevent scouring

For futher details see: Ethiopian Road Authority. Rural Travel and Transport Programme. Manual for Rural Transport Infrastructure Development

Community Roads - Standards and Work Norms

R6

Road on Escarpment



Standard Cross Section

Dimensions in mm - not to scale

Minimum Horizontal Curve Radius	**15 metres**
Maximum Gradient	**14%**
Max. Spacing of Passing Bays (Passing bays 20m long x 5m wide)	**200 metres**

DAILY WORK NORMS

General Norm - 6,000 person days / km

Clear grass and bush (light)	150m^2	Compact by hand	100m^3
Clear grass and bush (heavy)	50m^2	Collect stones (near)	1m^3
Excavation (soft soil)	3m^3	Collect stones (far)	0.5m^3
Excavation (hard soil)	2m^3	Break rocks	0.5m^3
Excavation (rock)	0.5m^3	Scour checks	2/person/day
Spread fill material	7m^3		

Turnout Ditch or Culvert Spacing

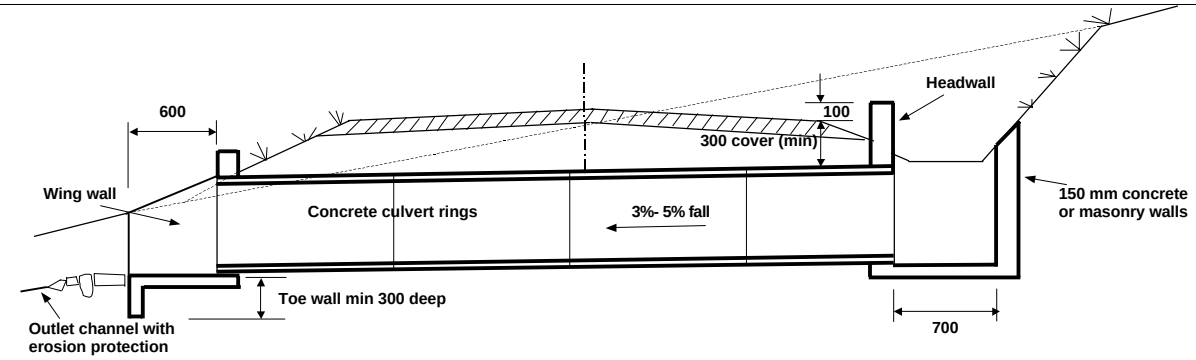
Gradient	Spacing
< 4%	100 metres
4% - 6%	80 metres
6% - 8%	60 metres
8% - 14%	40 metres

For futher details see: Ethiopian Road Authority. Rural Travel and Transport Programme. Manual for Rural Transport Infrastructure Development

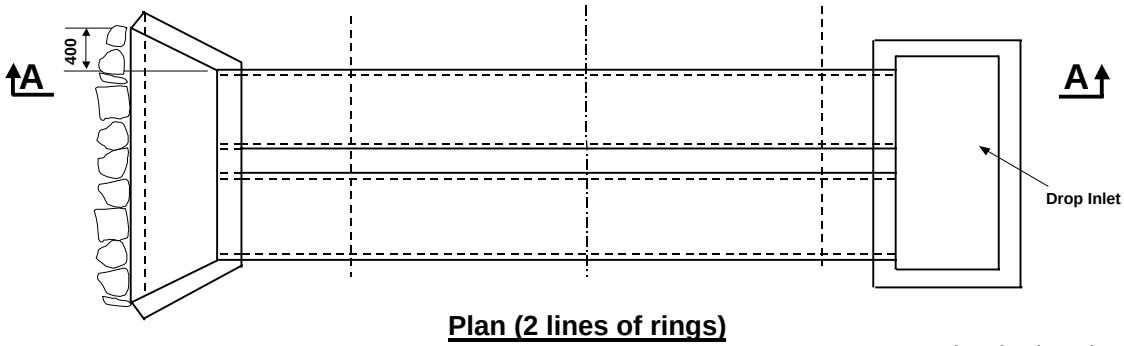
Community Roads - Standards and Work Norms

R7

Typical Pipe Culvert using Concrete Rings



Section A - A



Plan (2 lines of rings)

Dimensions in mm (not to scale)

Notes:

1. **A culvert or drift is required at all locations where water crosses the road**
2. **For outlet channel construction use the Waterway standards and works norms (conservation activities)**

Size of Culvert - Flat and Undulating Terrain	
Catchment area	**Number of lines of pipes**
?	1 x 75cm diameter pipe
?	1 x 90cm diameter pipe
?	2 x 75cm diameter pipes
?	2 x 90cm diameter pipes
?	Engineering design required

Size of Culvert - Steep and Mountainous Terrain	
Catchment area	**Number of lines of pipes**
?	1 x 75cm diameter pipe
?	1 x 90cm diameter pipe
?	2 x 75cm diameter pipes
?	2 x 90cm diameter pipes
?	Engineering design required

DAILY WORK NORMS

Clear grass and bush (light)	150m^2	Compact by hand	100m^3
Clear grass and bush (heavy)	50m^2	Collect stones (near)	1m^3
Excavation (soft soil)	3m^3	Collect stones (far)	0.5m^3
Excavation (hard soil)	2m^3	Break rocks	0.5m^3
Excavation (rock)	0.5m^3		

Place culvert rings 75cm diameter - 1.3 metres per person day

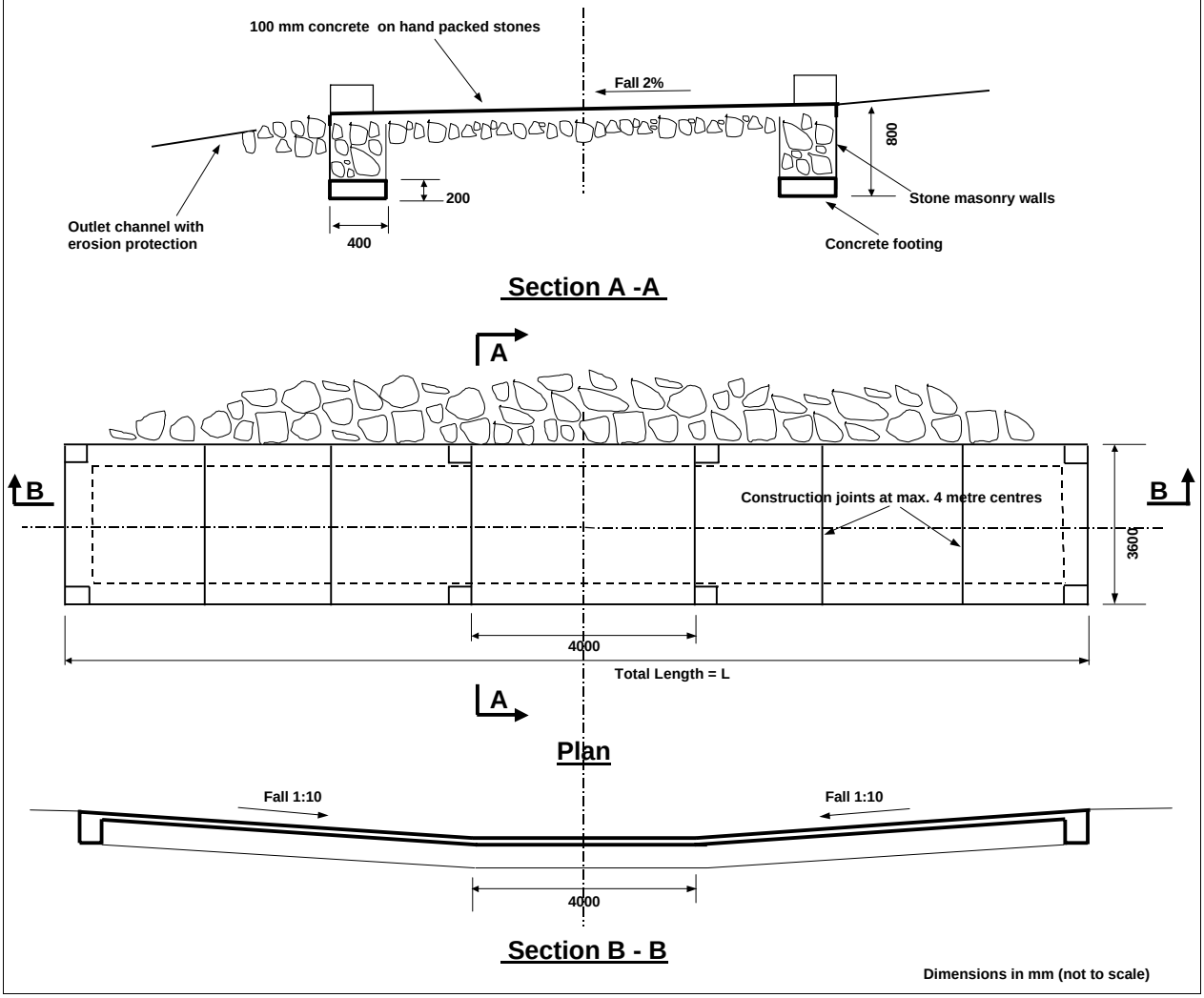
Place culvert rings 90cm diameter - 1.6 metres per person day

For futher details see: Ethiopian Road Authority. Rural Travel and Transport Programme. Manual for Rural Transport Infrastructure Development

Community Roads - Standards and Work Norms

R8

Standard Drift



Notes:

1. **A culvert or drift is required at all locations where water crosses the road**
2. **For outlet channel construction use the Waterway standards and works norms (conservation activities)**

Length of Drift - Flat and Undulating Terrain	
Catchment area	**Length = L**
?	?
?	?
?	?
?	**Engineering design required**

Length of Drift - Steep and Mountainous Terrain	
Catchment area	**Length = L**
?	?
?	?
?	?
?	**Engineering design required**

DAILY WORK NORMS			
Clear grass and bush (light)	150m^2	Compact by hand	100m^3
Clear grass and bush (heavy)	50m^2	Collect stones (near)	1m^3
Excavation (soft soil)	3m^3	Collect stones (far)	0.5m^3
Excavation (hard soil)	2m^3	Break rocks	0.5m^3
Excavation (rock)	0.5m^3		
Mix and place concrete			

For futher details see: Ethiopian Road Authority. Rural Travel and Transport Programme. Manual for Rural Transport Infrastructure Development