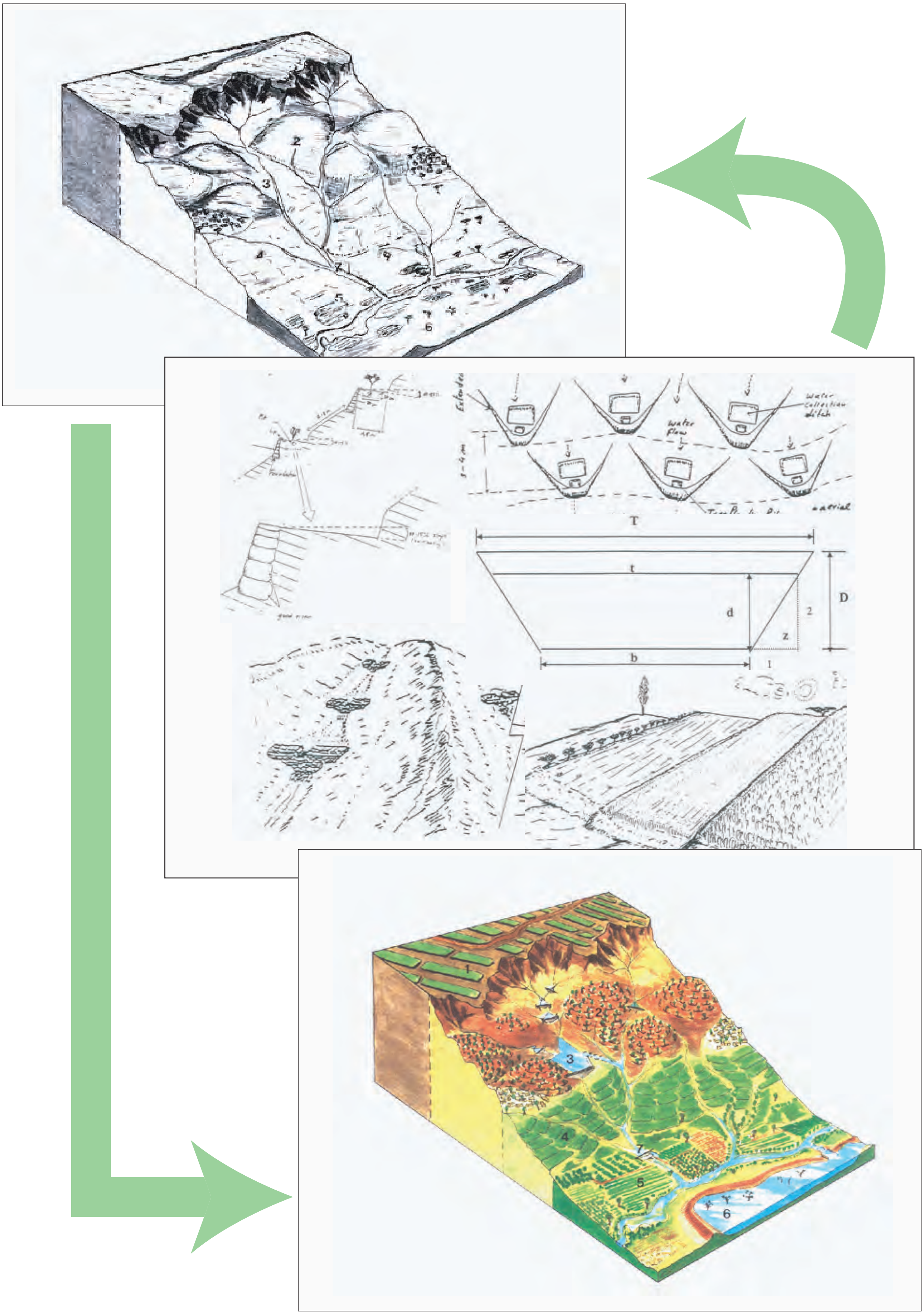
Success Stories in Pictures

1. Southern Wello, Dessie Zuria Wereda, on the road from Kombolcha to Dessie
   Watershed site connected with Yegof forest area
2. Dire Dawa - Bishan Behe
   Subwatershed catchment treatment and runoff farming
3. East Hararghe, Gorogutu Wereda
   Mekanisa subwatershed development
4. East Hararghe
   Treated watershed
5. Southern Region, Alaba Wereda
   Water harvesting with semi-circular bunds and area closure
6. Central Zone Tigray, Tahitay Maychew Wereda
   Gully rehabilitation

PART 1: SECTION B
INFOTECHS ON TECHNOLOGIES FOR WATERSHED AND NATURAL RESOURCE DEVELOPMENT AND PROTECTION



Infotechs on technologies for watershed and natural resource development and protection

Introduction

The following infotechs (information on techniques and technologies) or information kits are IEC (Information, Extension and Communication) materials prepared to assist development agents and various experts at *wereda* level with minimum practical information on work norms and technical standards required to undertake various works related to soil conservation, water harvesting and some basic community infrastructure like feeder roads. The main purpose of Infotechs is to guide field staff to follow correct and quality oriented technical standards in respect of local conditions of soils, slopes, vegetation, and rainfall patterns. Infotechs attempt to summarize several aspects related to the proposed interventions, providing information on key design features of the measures and their implementation requirements. Infotechs are action-oriented summaries of different measures and technologies commonly applied in various parts of the country. Infotechs can be used within the context of ongoing projects and programmes on natural resources and watershed development supported by the government and various organizations (MERET, NGOs, GTZ, etc), self-help efforts and for the national safety nets public works programme.

Most Infotechs also suggest various integration requirements and modifications to standard design necessary to accommodate various local conditions. In this regards, flexibility in design is essential to provide sufficient adaptability to local conditions within the quality standards proposed.

Infotechs are developed to be as brief and descriptive as possible. In this regard they should not be seen as comprehensive and sufficient for all situations. They are simple guidance notes on major activities based on national work norms. Accordingly, additional technical references and materials (and expertise) should be consulted whenever necessary.

The infotechs are based upon the work undertaken by various stake holders, particularly MoARD, WFP, GTZ, ILRI and WB.

The formats proposed are not in a definitive form and can be adapted and further modified and improved by regions and *wereda*s based upon local conditions and provided national norms are maintained and followed. Suggestion is also being made for each region to develop additional infotechs on single measures or combined set of measures proven successful and adapted to specific conditions.

At *wereda* level infotechs can be used during field work and training as quick references. They need to be explained to DAs by professional natural resources conservation experts and other experts (road authority, water resources, etc) and/or used during on-the-job or in-service training.

Main features of the infotechs:

Size: Summarized in either one or two pages in a single sheet.

Information: They contain both written and visual information in the form of drawings.

Ready to use (user friendly): As much as possible, a clear explanation on basic design features is provided. In several infotechs, ready-made tables with specifications are also provided together with several drawings. Most infotechs can also be explained to farmers using by enlarging and using the drawings.

Linkages: Several infotechs contain information related to other measures and recommend various combinations of technologies. The section on "Integration opportunities/ requirements" needs to be always studied carefully.

Flexibility: Most infotechs contain information on "Modifications/adaptations to standard design". This box often contains different possible adaptations that could fit within specific situations within the standards set by the work norm.

Productivity and environmental issues: Each measure should be intended as to serve both environmental and production issues. In this regard, specific references are made regarding potential and opportunities to increase/sustain productivity and environmental protection. Furthermore, most infotechs contain information on management and upgrading using various complementary measures. For example, upgrading and productivity enhancement of bunds and terraces is repeatedly associated with compost making and smart applications of compost. This aspect is deliberately repeated in several infotechs.

Adaptability: The infotechs can be further refined and expanded (or contracted) to accommodate region and *wereda* specific realities. Therefore they should be seen as guidance for further improvements.

Measures specific: This set of infotechs focuses mainly on single activities although specific references on integration with other measures is often made. In this regard, they should be seen as basic infotechs on the main interventions. However, other infotechs related to a variety of combination of measures or set of measures can also be developed to reflect specific technological approaches for different areas. Some of these infotechs are currently under preparation.

Physical Soil and Water Conservation

1. Level Soil Bunds
2. Stone Bunds
3. Stone Faced Soil Bunds
4. Level Fanya Juu
5. Bench Terracing
6. Conservation Tillage using Maresha and Broad Bed and Farrows Maker (BBM)
7. Hillside Terraces
8. Hillside Terrace with Trenches

TECHNICAL INFORMATION KIT

LEVEL SOIL BUNDS

(1) Period/phases for implementation

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

(2) Objectives/remarks

. The bund reduces and stops the velocity of runoff and consequently reduces soil erosion and the steady decline of crop yields (fig1-2).

. They are impermeable structures, unless provided with spillways, intended to retain all rainfall, and hence, increase the moisture retention capacity of the soil profile and water availability to plants, and increase the efficiency of fertilizer applications if any.

. Through their water retention effect, the bunds may allow some crop yield even in drought years.

. Soil bunds are entry points for further stabilisation and application of organic residues or compost (especially if applied in the first meters behind the bund where soil is deeper).

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

. Suitable mostly in semi-arid and arid parts of the country but also in medium rainfall areas with well drained soils. Commonly practiced in dry and moist weyna dega areas under traditional systems. Several areas also show introduced bunds adapted or adopted from past conservation activities. Local experience is very relevant to assess performance of past activities and suggest modifications as required. Improved designs can be integrated with local ones to add strength to bunds (grass, stones, etc)

(4) Main land use

. Applied generally on cultivated lands with slopes above 3% and below 15% gradient. Can be applied on grazing lands with gentle slopes at wider intervals (up to 5%). Can be applied also within sloping homestead areas combined with cash crops.

(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

. High in moisture stressed areas as without physical structures limited biological options are available, particularly for already eroded and shallow soils.
. Able to retain and accumulate water in trenches dug behind bunds for periods long enough to allow water to infiltrate, reduce runoff and erosion.

(7) Minimum surveying and tools requirements

Layout: One water line level, two range poles graduated in cm and 10 meters of string (a team of three people layout approx 2-3 ha/day).

Work: shovels, pick axes and wooden compactors (the proportion of shovels and pick axes depend on type of soil).

(8) Min. technical standards (fig 1)

. Height: min. 60 cm after compaction.
. Base width: 1-1.2m in stable soils (1 horiz: 2 vertical) and 1.2-1.5m in unstable soils (1 horiz: 1 vertical).
.Top width: 30 cm (stable soil) - 50 cm (unstable soil).
. Channel: shape, depth and width vary with soil, climate and farming system.
. Ties (if appropriate): tie width dimension as required, placed every 3-6 m interval along channel.
. Length of bund: 30-60 m in most cases, higher (max 80m) on slopes 3-5% - need to be spaced staggered for animals to cross.

(9) Layout and vertical intervals (VI)

. **Vertical intervals**: follow a flexible and quality oriented approach:
. Slope 3-8% VI = 1-1.5 m
. Slope 8-15% VI = 1-2 m
. Slope 15-20% VI = 1.5-2.5 m (only exceptional cases - reinforced)
(**Caution**: soil bunds > 15% to max 20% only if space reduced and with trench, short bunds - above 15% better apply stone faced or stone bunds).
Layout along the coutours using line level - discuss spacing with farmers and in case of lateral slopes try to maintain lines as straight as possible by applying reinforcements on depression points (to avoid curving a lot or cutting the plough line. Make bund length max 50-80m (the > the slope the < the length).

(10) Work norm

. Precise layout along contours (level) or gradient (graded) using line level.
. Scratching or removal of grasses from where embankment is constructed for better merging & stability.
. Excavation of trench or channel, and ties along channel (as necessary).
. Embankment building, shaping and compaction (essential).
. Compacting the top of bund and checking level with an A-frame (level bunds).

WORK NORM: 150 PDs/Km

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

1.**Integration with bund stabilisation**: using grasses (indigenous such as "sembelete", "dasho", others, etc.) + legume shrubs (pigeon peas, sebania, acacia saligna, etc.) in dense rows by direct sowing (15-30 cm). Pigeon peas can also be planted annually.

2. **Agronomic practices**: contour plowing and compost (start 1st year applying 2-3 m strips above the bunds - where soil is deeper and moisture is higher).

3. **Grow cash crops along bunds** (especially after 1-2yrs of composting) in single or wider strips as required. In addition to cash crops plant specific seasonal crops along bunds to use residual moisture (sunflowers, gourd, tomatoes, cucumbers, etc.).

4. **Control grazing** - avoid animals to graze between bunds for at least 1 year.

(12) Modifications/adaptation to standard design

1. Bunds that cross depression points without following exact contour lines: Reinforcements at depression points + keys (fig 3).

2. Bunds following farm boundaries: "corner bunds"+reinforcement + keys + cut&fill (fig 4) - applicable only in areas with slope < 5%.

3. In slopes < 3-5% and without lateral slopes bunds can be provided with spillways (lateral, side-checkdam, gated, etc.) - (see figures 5,6,7,8). Test measure first.

4. Ditchira bunds (traditional bunds in SNNP) - (fig 9).

6. Upgrading soil bunds and application of COMPOST (fig 10).

(13) 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 together to increase efficiency (layout, excavation, shaping, compaction, level check).

(14) Management requirements

. Soil bunds need to be upgraded to bench - the upgrading can be undertaken by using soil from the lower part of bund (apply fanya juu principle to avoid fertile deposited soil to be used for the embankment).
. Grow legumes on bunds and apply cut&carry for grass/legumes growing on bunds (do not pull the plants and let the nodulated roots to decay inside the bund - this will encourage grass to grow).

(15) Limitations

. Bunds can create temporary waterlogging if not integrated with fertility management.
. Limited stability if not integrated with revegetation - requires regular light maintenance.

(16) Institutional responsibility

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

Fig 1 Design of soil bunds (different soil types)

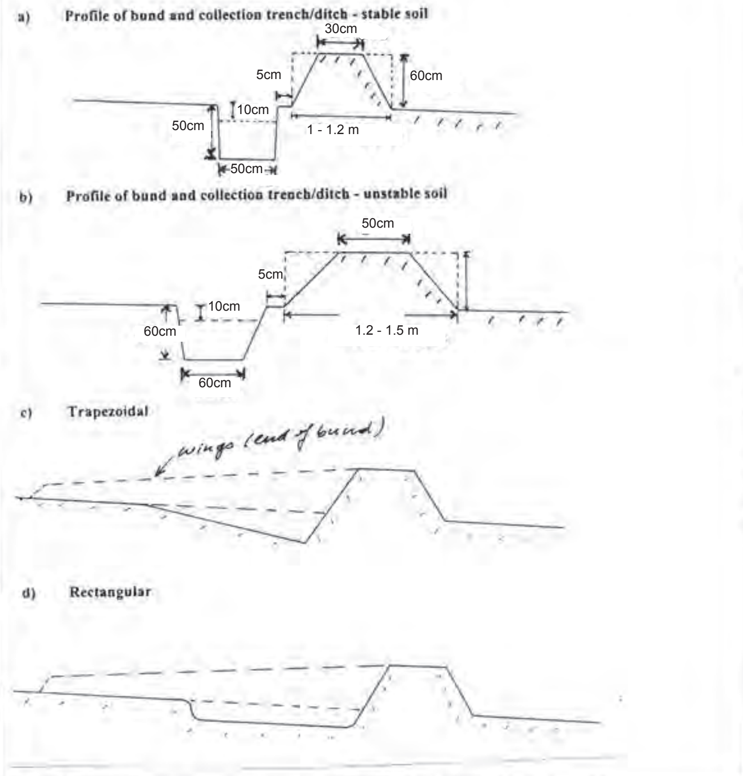


Fig 2 Example of soil bunds (along the contours)

Fig 3 Reinforcement of bunds in slight depression points (lateral slopes within plot)

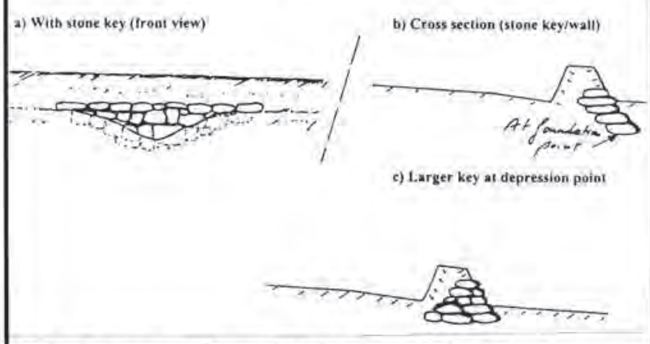


Fig 4 "Corner" or lateral stone reinforced soil bund

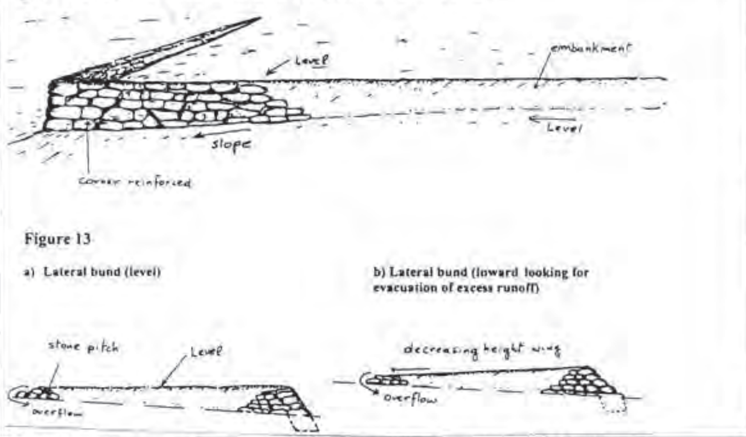


Fig 5 Bund with spillway placed at the end of the bund bund (drains laterally into stabilized waterway)

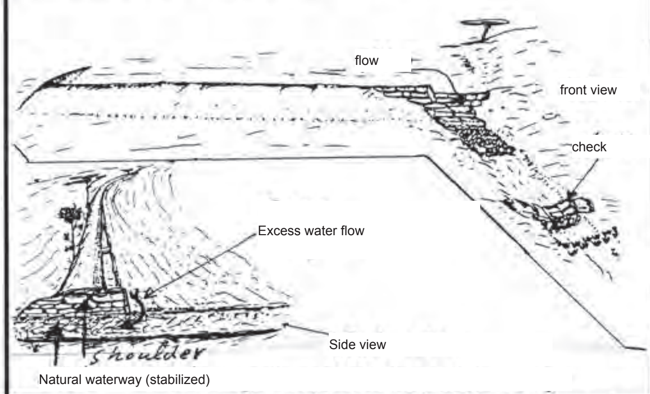


Fig 6 Checkdam spillways on one side of the bunds (<3-5% slopes)

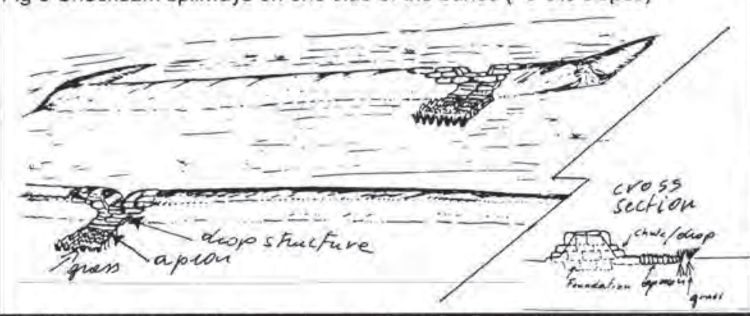


Fig 7 "Gated" spillway (only on slopes <3% or leveled terrace)

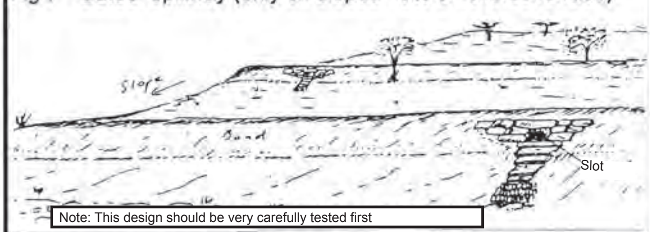


Fig 8 Lateral wings and spillways between bunds

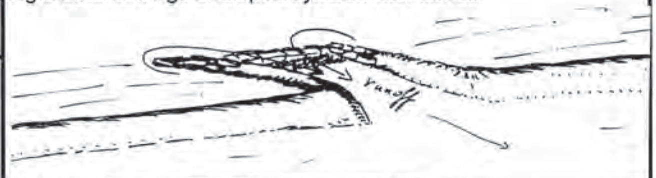


Fig 10 Upgrading soil bunds using the "fanya juu" principle + compost

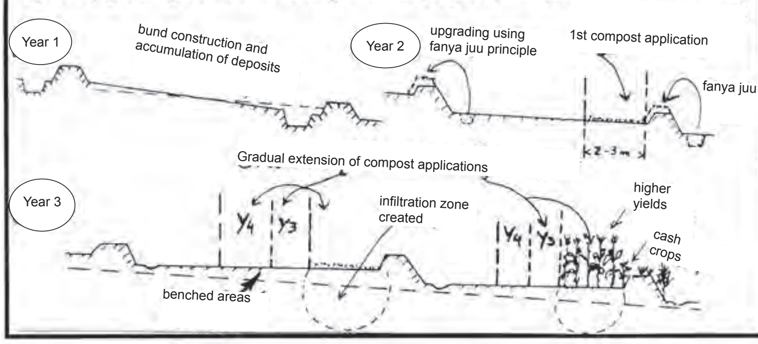
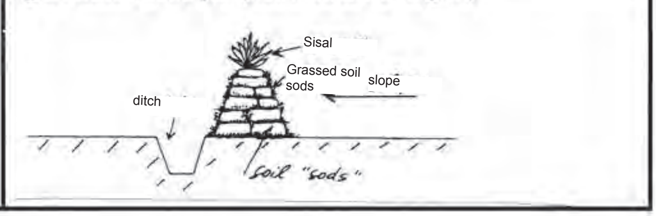


Fig 9 Ditchira Bund (adapted from SNNP region)



TECHNICAL INFORMATION KIT

STONE BUNDS

(1) Period/phases for implementation

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

(2) Objectives/remarks

. The stone bund (fig. 1) reduces and stops the velocity of runoff and consequently reduces soil erosion and the steady decline in fertility and crop yields.

. They are semi-permeable structures unless sealed with soil in their upper side. They increase the moisture retention capacity of the soil profile and water availability to plants, and increase the efficiency of fertilizer applications if any.

. Through their water retention effect the stone bunds may allow some crop yield even in drought years.

. Stone bunds are entry points for application of organic residues or compost, especially in the first 2-3 meters behind the bund where soil is deeper (see fig. 5).

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

. Suitable mostly in semi-arid and arid parts of the country but also in medium rainfall areas with deep and well drained soils. Commonly practiced in dry and moist weyna dega areas under traditional systems.Several areas also show introduced bunds adapted or adopted from past conservation activities. Local experience is very relevant to assess performance of past activities and suggest modifications.as required. Improved designs can be integrated with local ones to add strength to bunds (plants, etc).

(4) Main land use and agro-ecology

.Applicable in a broad range of land uses in all agro-climatic areas, particularly in cultivated lands with some level of stoniness. Also common in treatment of degraded hillsides. Stone bunds also possible in large gully networks combined with vegetative stabilization and tree planting.

(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

. High in moisture stressed areas as without physical structures limited biological options are available, particularly for already eroded and stony shallow soils.
. Able to retain and accumulate water in ditches dug behind the bund if necessary.
. Allows for higher stability than soil bunds in slopes > 15%.

(7) Minimum surveying and tools requirements

Layout: One water line level, two range poles graduated in cm and 10 meters of string (a team of three people layout approx 2-3 ha/day)

Work: crow bars, sledge hammers, shovels, and pick axes of shovels and pick axes depend on type of soil)

(8) Min. technical standards (fig 1)

· Height: 60-70cm up to100 cm (lower side).
· Total Base width: (height/2) + (0.3-0.5 m).
· Top width: 30-40 cm.
· Foundation: 0.3 m width x 0.3 m depth.
· Grade of stone face downside: 1 horiz : 3 vert.
· Grade of stone face upper side: 1 horiz : 4 vert.
· Grade of soil bank (seal) on upper side: 1 horiz :1.5-2 vert.
. Bunds need to be spaced staggered for animals to cross.
. Max bund length 60-80 meters.

(9) Layout and vertical intervals (VI)

Ground slope %	Height of bund (m)	Vertical Interval (m)	Distance apart (m)
5	0,50	1,00	20
10	0,50	1,50	15
15	0,75	2,20	12
20	0,75	2,40	10
25	1,00	2,50	8
30	1,00	2,60	8
35	1,00	2,80	6
40	1,00	2,80	5
50	1,15	2,80	4

(**Caution**: although the table shows the possibility to build stone bunds up to 50% slope they should not be constructed above 35% slope under Ethiopian conditions). Discuss spacing with farmers and in case of lateral slopes try to maintain lines as straight as possible by applying reinforcements on depression points (to avoid excess curving or cutting of the plough line - see figure 2).

(10) Work norm

. Precise layout along the contours (level) or gradient (graded) using line level,
. Collection of stones,
. Excavation of foundation,
. Placement and building of stone walls (larger stones for foundation),
· Filling of voids between walls with smaller stones,
· Filling of voids between walls with smaller stones and sealing of upper side with soil as required,
· Small stone ties every 5 m (optional),
. Reinforcement in depression points.

WORK NORM: 250 PDs/Km

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

1. Integration with bund stabilisation: using grasses (indigenous such as “sembelete”, “dasho”, others, etc.) + legume shrubs (pigeon peas, sebania, acacia saligna, etc.) in dense rows by direct sowing (15-30 cm) on sealed soil. Pigeon peas can also be planted annually. Stone bunds can be stabilized further by planting drought resistant plants such as sisal, Aloes and Euphorbia placed on the low and/or upper side of the stone bund.

2. Agronomic practices: contour plowing and compost (start first year applying 2-3 m strips above the bunds - where soil is deeper and moisture is higher).

3. Grow cash crops along bunds (especially after 1-2 years of composting) in single or wider strips as required. Plant specific crops along bunds to use residual moisture (sunflowers, gourd, tomatoes, cucumbers, etc.).

4. Control grazing - avoid animals to graze between bunds for at least 1 year and place bunds in staggered position and do not end a bund in a depression point.

(12) Modifications/adaptation to standard design

a) Bunds that cross depression points without following exact contour lines: Reinforcements at depression points + keys (figure 2)

b) Stone bunds with spillways (lateral, side-checkdam - figure 3)

c) Stone bunds provided with trenches (figure 4)

d) Stabilization of stone bunds and application of COMPOST (figure 5)

(13) Planning and implementation arrangements

. Planning follows community/groups and individual owners’ discussions/agreementon layout, spacing and management requirements. Groups of 5-20 households work together to increase efficiency (layout, excavation, stone collection, placement, stability).

(14) Management requirements

. Stone bunds can be upgraded to become stone walled level terraces - the upgrading occurs through raising the stone wall after 1-2 years. In this case it is essential that the foundation and the stone walls are well constructed.
. Apply cut&carry for any grass growing on bunds (sealed with soil side).

(15) Limitations

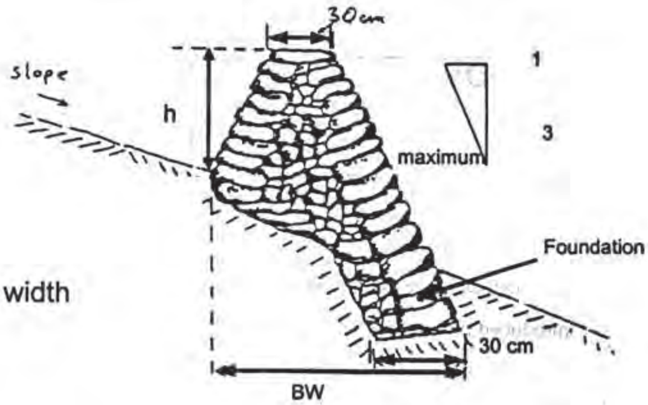
. Bunds can create temporary waterlogging if not integrated with fertility management.
. If too narrow spaced can take unnecessary space out of production + some rodents.

(16) Institutional responsibility

. Fully on individuals/groups +/- community (commitment to mgt.)

. DAs and wda experts - technical support and follow-up/management.

Fig 1. Design of stone bunds



BW = Base width

BW = **Base width**

$$= \frac{h}{2} + 30\text{-}50\text{cm (minimum)}$$

Fig 2. Bunds that cross depression points without following exact contour lines: Reinforcements at depression points + keys

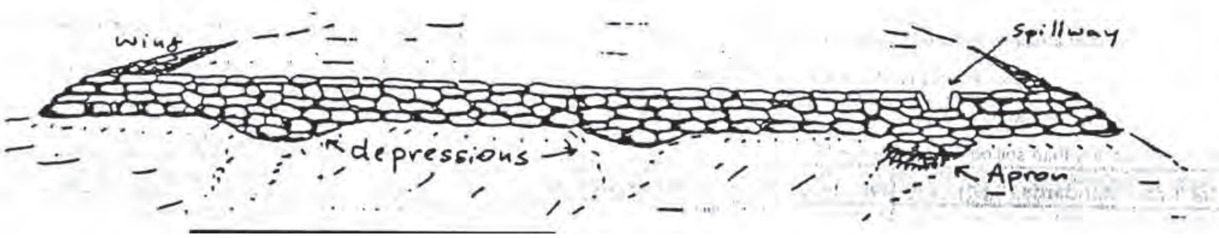


Fig 4 Stone bunds provided with trenches

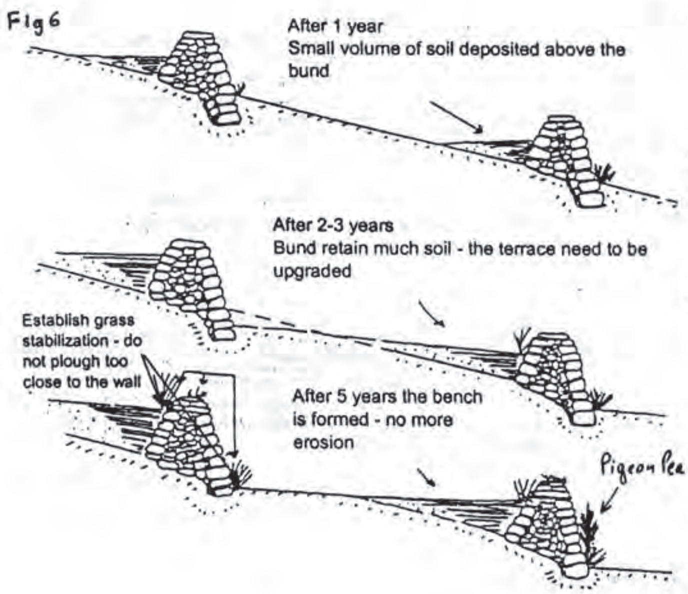


Fig 3. Stone bunds provided with spillways

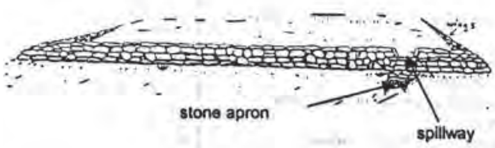
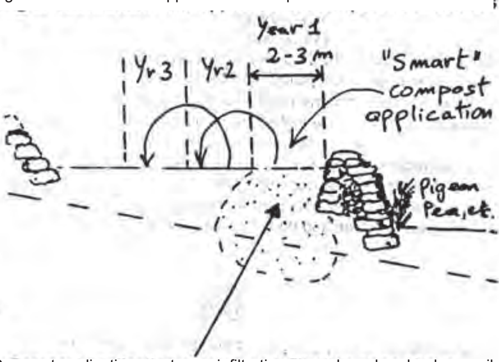


Fig 5. Stabilization and application of compost above bunds



Compost application creates an infiltration zone above bunds where soil is (1) deeprer and (2) moisture is higher. This area becomes the "butter" of the land and suitable for cash crops or high producing varieties. See infotechs on compost making for detail.

TECHNICAL INFORMATION KIT	(1) Period/phases for implementation	(2) Objectives/remarks
STONE FACED SOIL BUNDS	. Only during the dry season and period not interfering with land preparation	. The stone faced bunds are reinforced soil bunds in one or both their sides. It has the same objectives of soil and stone bunds (figure 1). . Provided they are well constructed stone faced soil bunds offer strong resistance against runoff. Stone faced bunds are suitable in areas with high stoniness and stable soils, combined with trenches and vegetative stabilization. . Suitable for dry areas and combined with other moisture conservation measures like tie-ridging and compost applications above bund or benched area.

(3) Suitability, agro-ecology and adaptability based upon local knowledge

. As per the soil bunds but more suitable in drier areas and terrains with slight lateral slopes to strengthen soil bunds. The stone faced preferred on lower side of bunds as more stable than double faced stone faced.Stone faced bunds largely applied both in traditional and new introduced systems.

NOTE: A common mistake observed in many areas are stone risers placed almost vertically on both sides of bunds. This results in poor stability and collapse of structures.

(4) Main land use	(5) Technical preparedness
Applicable in a broad range of land uses, particularly in cultivated lands with some level of stoniness.	. Land use, soil and topography assessed. . Discuss/agree with farmers on design and layout + provide on-the-job training. Skills in using and placing stones required. . Precise layout and follow-up/adaptations.

(6) Potential to increase/sustain productivity and environmental protection	(7) Minimum surveying and tools requirements
. High in moisture stressed areas as without physical structures limited biological options are available, particularly for already eroded and stony shallow soils. . Able to retain and accumulate water in ditches dug behind the bund if necessary . Allows for higher stability in slopes between15% and 35% max (single faced only).	**Layout**: One water line level, two range poles graduated in cm and 10 meters of string (a team of three people layout approx 3-5 ha/day) **Work:** crow bars, sledge hammers shovels, and pick axes of shovels and pick axes depend on type of soil)

(8) Min. technical standards (fig 1)	(9) Layout and vertical intervals (VI)	(10) Work norm
· Grade of lower stone face: 1 horiz. to 3 vertical; · Grade of upper stone face (if any): based on soil embankment grade; · Grade of soil: 1 horiz. to 1.5 vertical on stable soils and 1 horiz. to 2 vertical on unstable soil; · Lower stone face riser foundation: 0.3 depth x 0.2-0.3 width; · Upper stone face riser foundation: 0.2 x 0.2 m; · Stone size: 20 cm x 20 cm stones (small and round shape stones not suitable); · Top width: 0,4-0,5m; · Height: min. 0,7 and max. 1 m (lower stone face); . Channel or trench along bund; · Ties required every 3-6 m along trench/channel.	a) Slope range: 3-35% max b) Follow VI from soil bunds. Between slopes 5-15% add 10% to distance between bunds as stability of stone faced bunds is higher than soil bunds. . Slope 3-8% VI = 1-1,5 m . Slope 8-15% VI = 1-2 m . Slope 15-30% VI = 1.5-2.5 m Above 30% slope only in very stable soils or shift to stone bunds. c) Soil depth 50-100 cm d) Use line levels and follow contours. In gentle slopes (< 8%) avoid sharp curving along depression points and fill by plowing.	. Precise layout along contours (level) or gradient (graded) using line level. . Collection of stones for stone wall. . Excavation of stone riser foundation. . Building of stone walls (larger stones for foundation). . Excavation of soil and building of bund along stone riser construction. . Reinforcement in depression points. . Compaction and check of level. **WORK NORM: 250 PDs/Km**

(11) Integration opportunities/requirements (see also WHSC guideline)	(12) Modifications/adaptation to standard design
1. Integration with bund stabilisation: using grasses (indigenous such as “sembelete”, “dasho”, others, etc.) + legume shrubs (Pigeon peas, Sebania, Acacia saligna, etc.) in dense rows by direct sowing (15-30 cm) on upper side of bund and berm. Pigeon peas also planted annually. Lower part of the stone wall can also be stabilized by planting drought resistant plants such as Sisal, Aloes and Euphorbia in thick rows. **2. Agronomic practices:** contour plowing and compost (start first year applying 2-3 m strips above the bunds - where soil is deeper and moisture is higher). **3. Grow cash crops along bunds** (especially after 1-2 years of composting) in single or wider strips as required. Plant specific crops along bunds to use residual moisture (sunflowers, gourd, tomatoes, cucumbers, etc.). **4. Control grazing** - avoid animals to graze between bunds for at least 1 year and place bunds in staggered position and do not end a bund in a depression point.	a) Double stone faced bunds with and without stone key (relevant for reinforcements at depression points (figure 2) b) Double faced stone/soil bunds without collection trench suitable in sandy soils and uniform terrains. They should not be longer than 50 meters and then provided with lateral spillways (figure 3) c) Stabilization of stone faced bunds + compost application (figure 4)

(13) Planning and implementation arrangements	(14) Management requirements
. Planning follows community/groups and individual owners’ discussions/agreementon layout, spacing and management requirements. Groups of 5-20 households work together to increase efficiency (layout, excavation, stone collection, placement, stability).	. Stone faced bunds can be upgraded like soil bunds to become level terraces provided with a retention wall - the upgrading occurs through raising the stone raiser after 1-2 years. In this case it is essential that the foundation and the lower stone wall are well constructed. . Apply cut&carry for grass/legumes growing on bunds (not uprooted), composting and check on stability of stone raiser every 6 months/apply repairs as damage may occur.

(15) Limitations	(16) Institutional responsibility
. Same as bunds. If stone wall not well constructed require continuous maintenance.	. Fully on individuals/groups +/- community (commitment to mgt.) . DAs and wda experts - technical support and follow-up/mgt.

Fig 1. Design of stone faced soil bunds

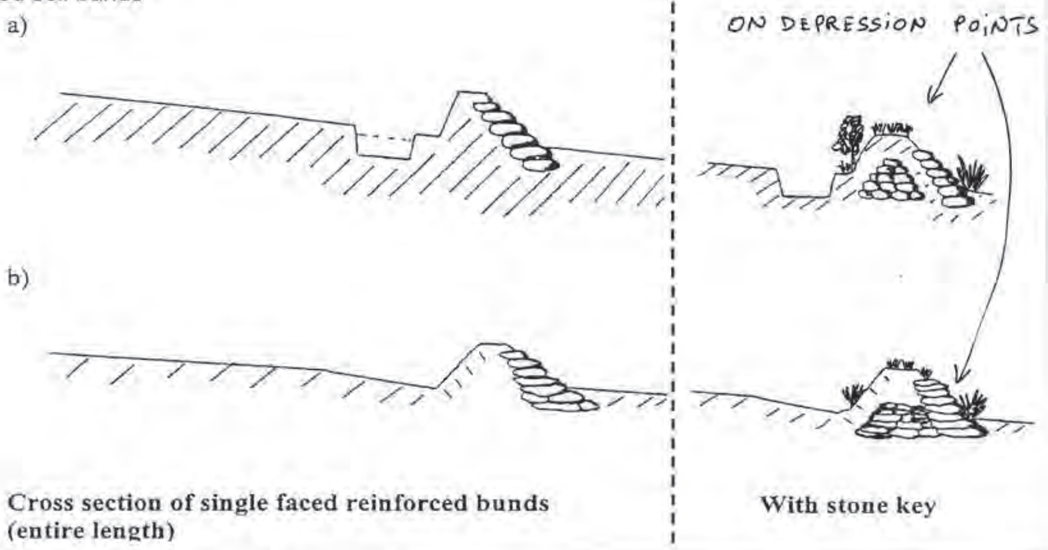


Fig 2. Double stone faced bunds with and without stone key (relevant for reinforcements at depression points)

This type of reinforcement which includes a core of stones and two stone risers is suitable in those points along bunds were there are small depressions

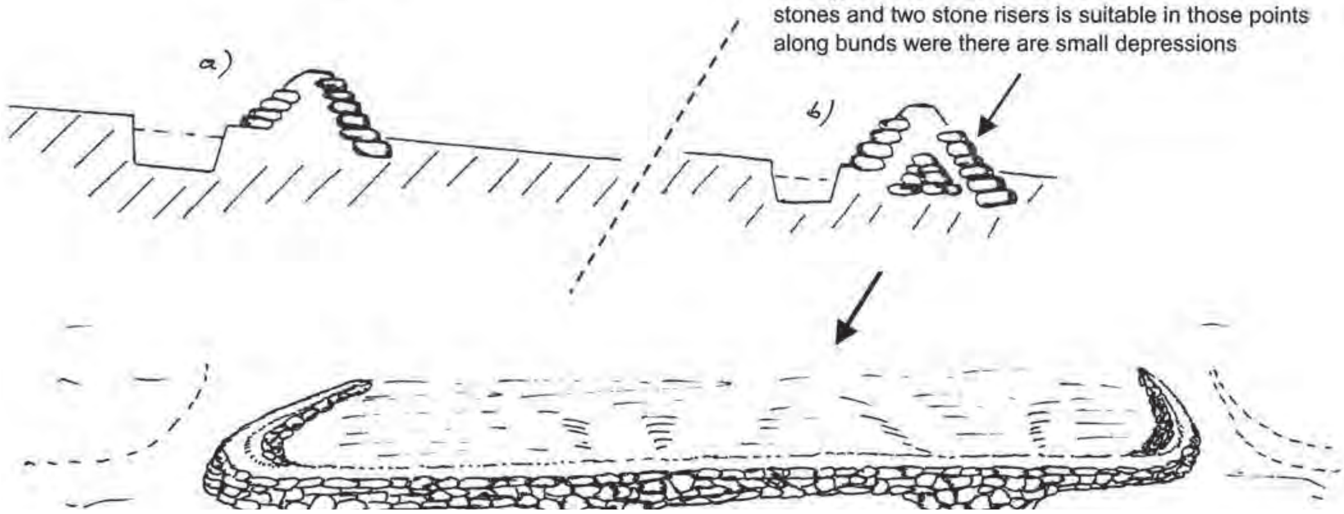


Fig 4. Stabilization and application of compost above bunds

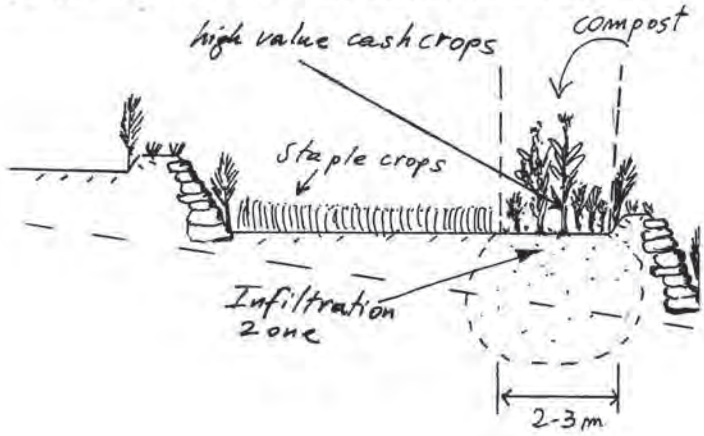


Fig 3. Double faced stone/soil bunds without collection trench suitable in sandy soils and uniform terrains (<8% slope)

TECHNICAL INFORMATION KIT	(1) Period/phases for implementation	(2) Objectives/remarks
LEVEL FANYA JUU (FJ)	. Only during the dry season and period not interfering with land preparation	. The FJ reduces and stops the velocity of runoff and consequently reduces soil erosion and the steady decline of crop yields (figures 1-2). . They are impermeable structures intended to retain rainfall, and hence, increase s.oil moisture, water availability to plants, and increase the efficiency of fertilizer application if any. . Fanya juus bench quicker than soil bunds but are not as efficient in moisture conservation and more prone to breakages/ overtopping.

(3) Suitability, agro-ecology and adaptability based upon local knowledge

Suitable mostly in moist weyna dega/medium rainfall areas with deep and well drained soils. Can also be practiced in upper ranges of semi-arid conditions, particularly on gentle slopes and well drained soils. Fanya juus are commonly practiced in Ethiopia in several areas following its introduction over 2 decades ago. Local experience very relevant to assess performance of past activities and suggest modifications. A major opportunity is the application of the fanya juu principle after standard soil bunds are constructed for not disturbing the upper ditch filled with fertile soil (see modification to design below).

(4) Main land use	(5) Technical preparedness
Applied generally on cultivated lands with slopes above 3% and below 15% gradient. Fanya juus are best constructed in uniform terrains with deep soils that do not have traverse slopes (depressions). Can be applied on grazing lands with gentle slopes at wider intervals (up to 5%). Can be applied also within sloping homestead areas combined with cash crops.	. 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	(7) Minimum surveying and tools requirements
. The main advantages of fanya juu derive from its capacity to become a bench terrace in a short number of years. However, fanya juus contribute to increase productivity only if well managed and integrated with soil fertility improvement practices, particularly vegetative stabilization and composting.	**Layout:** One water line level, two range poles graduated in cm and 10m of string (a team of three people layout approx 2-3 ha/day). **Work:** shovels, pick axes and wooden compactors (the proportion of shovels and pick axes depend on type of soil).

(8) Min. technical standards (fig 1)	(9) Layout and vertical intervals (VI)	(10) Work norm
. <u>Height</u>: min. 60 cm after compaction. **. <u>Base width</u>**: 1-1.2m in stable soils (1 horiz: 2 vertical) and 1.2-1.5m in unstable soils (1 horiz: 1 vertical). .**<u>Top width</u>**: 30 cm (stable soil) - 50 cm (unstable soil). . **<u>Collection ditch</u>**: 60cm W x 50cm D. . Ties: placed every 3-6 m interval along channel. . **<u>Length of bund</u>**: up to 60 m in most cases, max 80 m. FJ need to be staggered to allow animals to cross fields as required.	. **Vertical intervals:** flexible and quality oriented approach. . Slope 3-8% VI = 1-1,5 m . Slope 8-15% VI = 1-2 m . Layout along the coutours using line level - discuss spacing with farmers and in case of lateral slopes shift to soil bunds for higher water accumulation and apply reinforcements and keys. **Note: Shift to soil bunds in areas with slight traverse slopes and apply stone keys and reinforcements.**	. Precise layout along contours (level) or gradient (graded) using line level; . Scratching or removal of grasses from where embankment is constructed for better merging & stability; . Excavation of dowstream ditch or channel, and ties along channel; . Embankment building, shaping and compaction (essential); . Leveling of top of bund with an A-frame (level bunds). **WORK NORM: 200 PDs/Km**

(11) Integration opportunities/requirements (see also WHSC guideline)	(12) Modifications/adaptation to standard design
1. **Integration with bund stabilisation:** Fanya Juus need the embankment stabilised in the upper side to allow excess water to overtop without creating damage. Grass planted with other shrubs is most suitable. Plants like aloes and sisal combined with more productive shrubs (pigeon peas, etc.) are also recommended on upper and lower side of fanya juu. 2. **Agronomic practices:** contour plowing and compost (start first year applying 2-3 m strips above fanya juu - where soil is deeper and moisture is higher). 3. **Grow cash crops along bunds** (especially after 1-2 years of composting) in single or wider strips as required. Plant specific crops along bunds to use residual moisture inside ditches (sunflowers, gourd, tomatoes, cucumbers, etc.). 4. **Control grazing**, staggered position of fanya juus + same as soil bunds.	a) Combination of Fanya juus and soil bunds and reinforcements within the same contour line (figure 2) to address the problem of slight traverse slopes/depression points. b) Combination of Fanya juus alternated with soil bunds along the slope. This method is to allow some excess runoff not captured by the fanya juu to get trapped by the upper trench of the soil bund (figure 3). c) Upgrading of soil bunds using the fanya juu principle (figure 4) after 1-2 years (see also soil bunds).

(13) Planning and implementation arrangements	(14) Management requirements
. Planning follows community/groups and individual owners' discussions/agreement on layout, spacing and management requirements. Groups of 5-20 households work together to increase efficiency (layout, excavation, shaping, compaction, level check).	. Fanya juus need to be upgraded to become level terraces - the upgrading should use soil accumulated in the ditch below the bund. . Apply cut&carry for grass/legumes growing on bunds (not uprooted). . Repair breakages immediately after showers, especially the 1st year.

(15) Limitations	(16) Institutional responsibility
. Can create temporary waterlogging if not integrated with fertility management. . If too narrow spaced can take unnecessary space out of production.	. Fully on individuals/groups +/- community (commitment to mgt.). . DAs and wda experts - technical support and follow-up/mgt.

Fig 1. Design of Fanya Juul bunds

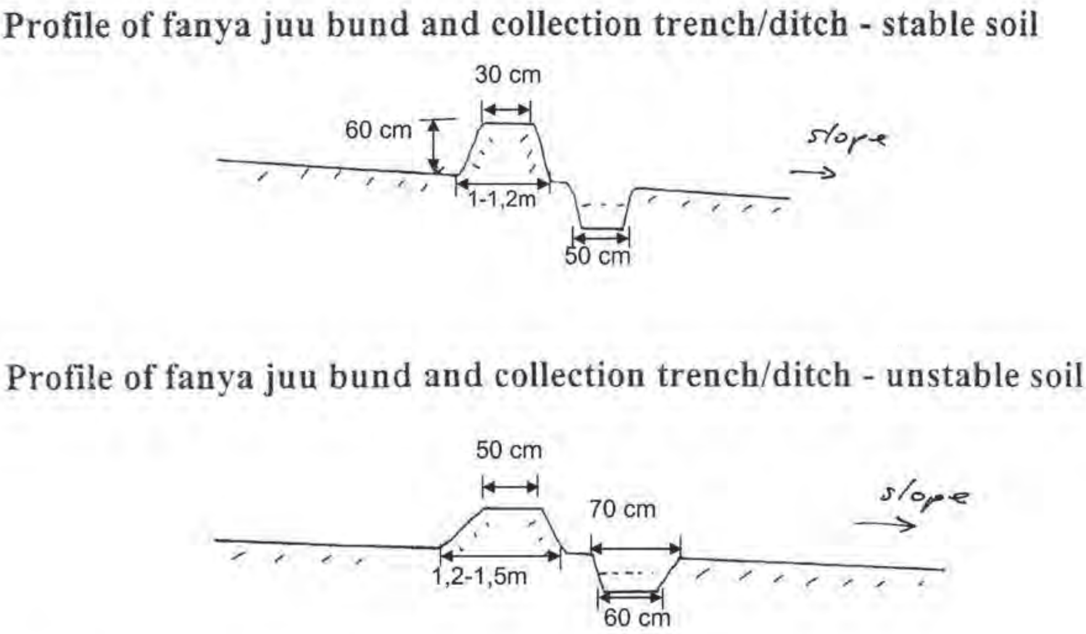


Fig. 2 Combination of Fanya juus and soil bunds and reinforcements within the same contour line to address slight traverse slopes/depression points

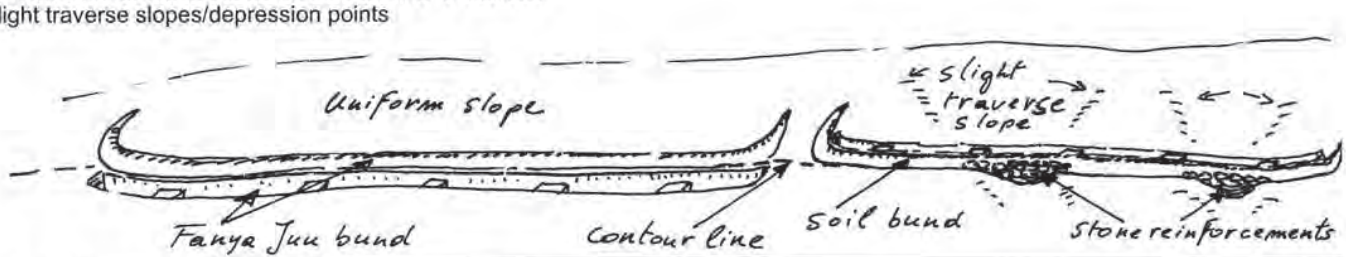


Fig. 3 Combination of Fanya juus alternated with soil bunds along the slope. This method is to allow some excess runoff not captured by the fanya juu to get trapped by the tupper trench of the soil bund

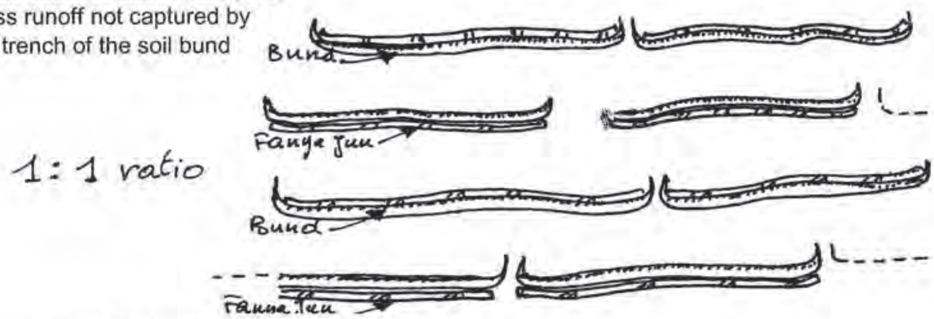


Fig 4 Upgrading of soil bunds using the fanya juu principle after 1-2 years from construction

- First Year

- Second Year

TECHNICAL INFORMATION KIT	(1) Period/phases for implementation	(2) Objectives/remarks
BENCH TERRACE (BT)	. Only during the dry season and period not interfering with land preparation	. The terrace in most cases converts a steep slope into a series of steps, with nearly horizonal benches to reduce velocity of runoff, reduce the soil erosion and the decline in crop yields (Figure 1).

(3) Suitability, agro-ecology and adaptability based upon local knowledge

Suitable mostly in moist weyna dega/medium rainfall areas with deep and well drained soils. Can also be practiced in upper ranges of semi-arid conditions, particularly on gentle slopes and well drained soils. Fanya juus are commonly practiced in Ethiopia in several areas following its introduction over 2 decades ago. Local experience very relevant to assess performance of past activities and suggest modifications. A major opportunity is the application of the fanya juu principle after standard soil bunds are constructed for not disturbing the upper ditch filled with fertile soil (see modification to design below).

(4) Main land use

. Applied generally on cultivated lands and unused steep hillsides of slopes of average 12 to 58% considering the various land use types (cereal, fruits,etc.).

(5) Minimum surveying and tools requirements

Layout: One water line level, two range poles graduated in cm and 10 meters of string (a team of three people layout approx 1-2 ha/day)

Work: shovels, pick axes and wooden compactors (the proportion of shovels and pick axes depend on type of soil).

(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

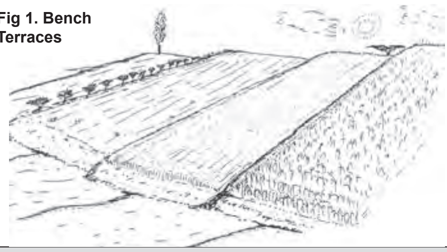
. High in moisture stressed areas and ease plowing operations.
. Need to properly balance the distribution of top soil on the bench to sustain yield.
. Able to retain/store water on the benchs and provide sufficient time to infiltrate into the soil. Allows stabilization and optimize use of compost and fertilizers.

(7) Work norm

- Use stones to support the riser from below;
- If stones are not available sow the riser with grasses to prevent collapse. Can also apply continuous brushwoods along benches (see brushwood infotech).
-Construction starts with removal of top soil and put aside before proper cut and fill process.
- Once you decide the width and determine the vertical interval (height of riser), divide boundaries between cut and peg along the contour.
-Cut from the upslope above the peg line and start filling the strip below the peg line.

WORK NORM: 500 PDs/Km

Fig 1. Bench Terraces



(8) Min. technical standards (fig 1)

Width: For areas of cultivation by hand: 2-5m is suitable. For animal driven cultivation: more than this is desirable. The more the depth of soil and the less the slope, the wider the bench terrace.

Height : The height of the riser(terrace) is the vertical interval (for a reverse slope the change in elevation across the terrace is subtracted).

A Riser has a slope expressed as a ratio of horizontal distance to vertical rise. Can be stone faced, vegetated or grassed. Brushwoods can also be applied along BTs.

(9) Layout and vertical intervals (VI)

Vertical interval is calculated as follows:

- VI (meters) = S x W / 100-SU
Where S is the land slope(%)
W is the bench width(meters)
U is the slope of the riser, expressed as the ratio of horizontal distance to vertical rise

- Precise layout along contours using line levels.

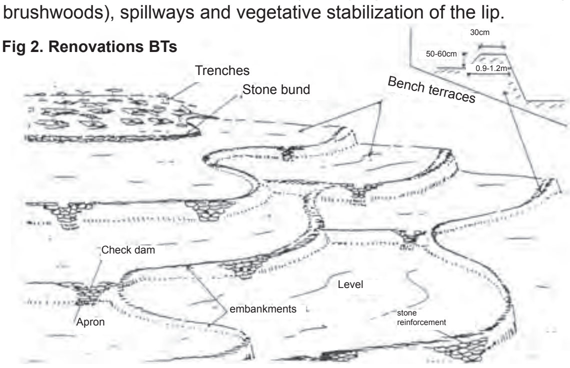
10) Integration opportunities/requirements (see also WHSC guideline)

(1) A Bench Terrace should be integrated with waterways to dispose off excess run-off from bench surfaces.
(2) Stones or brushwoods should be used to support/reinforce the riser.
(3) Apply compost starting from 2-3 meters above terrace lip (deeper soil and higher moisture) - see compost infotech.
(4) Stabilize embankment with grass and legumes (pigeon peas, treelucerne, etc.).

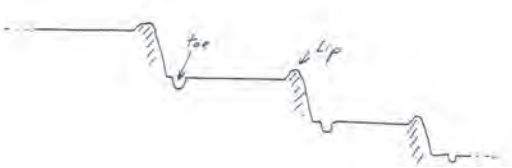
(11) Renovation of existing bench terraces

Bench terraces can be renovated by applying reinforcements (usings stones or brushwoods), spillways and vegetative stabilization of the lip.

Fig 2. Renovations BTs



12) Standard shape



(13) 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 together to increase efficiency (layout, excavation, shaping, compaction, level check).

(14) Management requirements

Requires attention and maintenance for proper management of the water on the bench. Needs stabilization with grass, legumes and brushwood checks on fragile soils. Need proper distribution of top soil unifomly over the bench surface.

(15) Limitations

Oxen access may be difficult in narrow spacings.
It is exclusively appropriate where there is sufficent soil depth and proper drainage.

(16) Institutional responsibility

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

TECHNICAL INFORMATION KIT

CONSERVATION TILLAGE USING THE MARESHA AND BROAD BED AND FURROWS MAKER (BBM)

(1) Period/phases for implementation

1.If using 'maresha' one or two 'maresha' passes for weed control only before planting. In case of using BBM on Vertisols, one blade harrow pass before planting.

2. In all cases plant early to mid-June.

3. During harvest leave at least 20 percent crop residue to cover soil surface.

(2) Main objective/purpose

. Undisturbed soil that is permanently protected by vegetative cover improves in the manner that occur in the native ecosystems, including maintenance of porous and soft soil layers through litter accumulation, intense biological activity, movement of soil fauna, and root growth. These functions improve efficient water, heat, and gas transfers within the entire soil profile.

. The presence of crop residues on the soil surface minimizes soil evaporation, and in regions of low rainfall can conserve water and increase crop water use efficiency thus improving crop yields.

(3) Suitability and adaptability to local knowledge

Conservation tillage, including reduced and zero tillage practices, is proposed as one of the most promising means of reducing soil erosion and stabilizing crop yields in the rainfed farming systems of sub-Saharan Africa.

(4) Main land use and agroecology

Conservation tillage entails a reduction in soil manipulation, thereby minimizing the energy required for tillage and the retention of some crop residues on the soil surface even during seeding operations. The ultimate goal is to reduce soil nutrient and moisture losses. It has also been found that the straw enhances the formation of organic matter, which can store water better but also improves the nutrient availability for crops to be grown on that land. It can be used for different soils and various agro-ecological zones.

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

In the Chefe Donsa district of Ethiopia, following a two years of on-station evaluation of the technical performance of the newly-developed BBM attachments, a farmer participatory trial of the broadbed and furrow (BBF) minimum tillage technology package was conducted during the 1999 and 2000 cropping seasons. In both years, passes with the ox-drawn broadbed maker (BBM) with the blade and/or tine harrow attachment and a pass with the BBM with the funnel planter (fig 2.) were required to maintain and sow wheat on the permanent BBFs. This conservation tillage package utilized a similar oxen time in both seasons; however, the total oxen time used in maintaining and sowing wheat on the permanent BBFs averaged 24 hrs/ ha and was one-third of the total oxen time required for either the newly constructed BBFs or the traditional seedbed preparation.

In 1999 and 2000 the labor requirement for in-crop weeding of the minimum tillage plots, which primarily involved harvesting the weeds growing in the furrows with a sickle, was 10 person-days per ha and did not differ significantly from the mean weeding time for the traditional plots. A traditional practice of Chefe Donsa farmers-applying ash from their homesteads to their fields to enable early-sown crops to withstand frost—led to the verification of the yield-enhancing effect of inorganic potassium fertilizer on wheat. Farmer testing the minimum tillage production system (farmers were using quarter of a hectare) increased the gross margin of wheat production by 1100 birr per hectare relative to the traditional flat seedbed system.

(6) Description of the technology and steps

Reduced tillage entails the minimum manipulation of the soil, about 3-4 cm soil depth, for planting crops while zero tillage uses direct planting without any soil disturbance with herbicides use. Leaving at least a fifth of the crop residue at harvest for soil cover will be required in both the minimum as well as the zero till systems. The soil cover not only reduces evaporation from the soil but will also protect the soil from wind and water erosion.

For acheiving these the soil manupulation on the Vertisols and soils with vertic properties, the broadbed maker (BBM) and attachment to the BBM have been used as the function in this case is to create broadbeds and furrows (BBFs) for evacuting the excess water from the fields as well as maintain the BBFs in semi-permanent basis (fig 1). The pictures below show the modified funnel planter from the Afar Region and wheat fields sown using this modified funnel planter . On other types of soils where drainage might not be as critical as in the case of Vertisols and soils with vertic properties, the issue is to deal with reducing the manipulation of the soil. This could be done easily by reducing the numberof 'maresha' passes to the minimum, say rather than ploughing five passes go for two passes, and use the Afar funnel planter for planting cereals and beans except for teff. In all cases there is a need to leave at least 20 percent of the crop residue in the fields for soil cover. The crop residue left on the surface of the land should be protected from grazing animals if it is hoped to bring the benefits intended.

Remarks in using conservation tillage technology package:

1. Cultural practice of ploughing several times with the traditional 'maresha' is established and would not easily change.

2. The work presented here is on vertisols. Community/researchers/development agents should also develop conservation tillage techniques together for the different agro-ecological zones/crops (which will include 'teff') and test it on-farm. This activity might take two to three years.

3. During the development stage of conservation technology, intensified training to the community, development agents and researchers (not many know) on conservation tillage will improve the knowledge base and adoptability of the new technology.

4. One of the major strategies of conservation tillage is sowing of crops during the start of the rains to capture even the early rains by the crops. In most cases this could not be done because farmers' fields are not protected from the grazing animals. In most cases, the bylaws by the community sets the days of controlling animal grazing starting in the mid of the main rainy season. Introduction of conservation tillage will require revisiting this sort of bylaws in place.

5. The adoption of conservation tillage would mean substantial reduction of draft power. This should lead to less animal feed requirement and pressure on the land.

Fig 1. Funnel planter being used on semi-permanent broadbedsbeds

Fig 2. Wheat sown by funnel planter

TECHNICAL INFORMATION KIT

HILLSIDE TERRACES (HTs)

(1) Period/phases for implementation

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

(2) Objectives/remarks

. Hillside terraces are physical structures constructed along the contours, generally suitable in steep degraded slopes and shallow soils (although common in other type of soils), suitable for tree planting and rather effective in controlling runoff and erosion.

. Common in most parts of Ethiopia, generally in dry areas to support area closure plantation and protect downstream fields.

(3) Suitability, agro-ecology and adaptability based upon local knowledge

. Suitable mostly in semi-arid and arid parts of the country but also in medium rainfall areas with deep and well drained soils. Commonly practiced in dry and moist weyna dega areas for the growth of trees and support of area closure. Design can change based on dryness conditions.

(4) Main land use

Applicable in steep hillsides - community closures with steep slopes (max 50%). In dry areas and shallow soils need to be combined with other measures (eyebrow basins, etc).

(5) Minimum surveying and tools requirements

. Land use, 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.
. Preparation of follow-up plan.

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

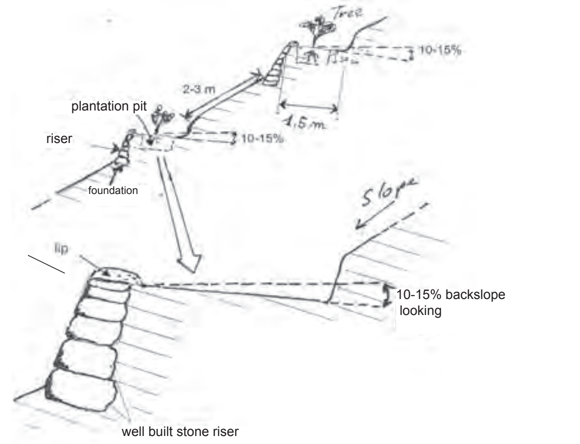
. Good potential to improve degraded hillsides - mostly for area closure and multi-purpose tree and fodder tree plantations. When combined with sound moisture conservation (trenches,etc.) and proper management it can significantly improve watershed rehabilitation, biomass production and recharging of water tables.

(7) Work norm

Layout: One water line level, two range poles graduated in cm and 10 meters of string (a team of 3 people layout approx 1ha/day).

Work: crow bars, sledge hammers shovels, and pick axes. Ratio of shovels and pick axes depend on type of soil)

Fig 1. Inward looking HT (for moisture stressed areas)



(8) Min. technical standards (fig 1)

· **Slope range:** 20-50%
. **Vertical Interval (VI)**: 2-3 meters
. Height or stone riser: min 0,5 m (range 0,5-0,75 m)
· **Width of terrace:** min 1,5 m (range 1,5-2m)
· **Foundation:** 0,3m depth x 0,3 m width foundation
· **Grade of stone riser:** well placed stone wall (grade 1 horiz to 3 vert.)
· In lower rainfall areas (most cases) hillside terrace have 5-10% gradient backslope

(9) Layout and vertical intervals (VI)

· Cut and fill of the terrace area,
· Collection of stones from working site, light shaping (if necessary) of side of stones with sledgehammer for better stability & merging,
· Excavation of foundation,
· Placement and building of stone riser,
· Small stone ties every 5 m (optional),
· Leveling of top of terrace with an A-frame.

WORK NORM: 250 PDs/Km

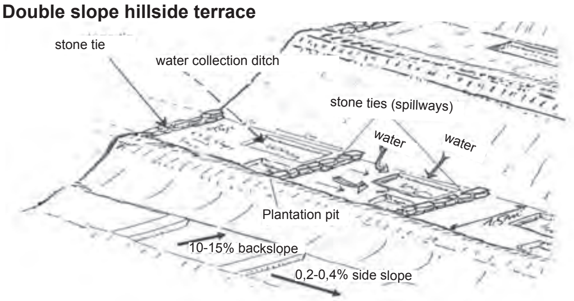
10) Integration opportunities/requirements

1. Series of trenches (2-3 lines) can be constructed in between HTs (starting 2-3 meters above the terrace. Apply soil and tree management practices. Control grazing and closure necessary.
2. Fodder, legume and cash crops can be planted at the top of the stone raiser or at its toe: using grasses (indigenous such as “sembelete”, “dasho”, others, etc.) + legume shrubs (pigeon peas, sebania, acacia saligna, trilucerne etc.) in rows by direct sowing (15-30 cm).
3. Hillside terraces, like stone bunds, can be stabilized by drought resistant plants such as Sisal, Aloes and Euphorbia placed on the lower side of the stone wall.
4. Integration with strong check dams along depresssion points and small gullies.

(11) Modifications/adaptation to standard design

a) Double slope hillside terraces in very dry areas (fig 2).
b) Hillside terraces with trenches (see related infotech)

Fig 2. Double slope hillside terrace



(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 over closures. Arrange working groups for regular maintenance.

(13) Management requirements

. Controlled grazing is a precondition for hillside terraces. Terraces should be stabilized, possibly with drought resistant species.
. Fodder and crops growing on terraces should not be uprooted but cut and carried.

(14) Limitations

. Hillside tcs. can be overtopped - need integration with trenches.
. 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

HILLSIDE TERRACES + TRENCHES (HTTs)

(1) Period/phases for implementation

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

(2) Objectives/remarks

. HTTs is highly labour intensive - combine both effects of hillsides and trenches constructed immediately above the terrace stone riser, generally suitable for steep slopes (up to 50%) and shallow-medium depth soils (although common in other type of soils). Suitable for tree/shrubs planting and very effective in controlling runoff and erosion.

. HHTs ensure protection of downstream fields, and play a significant role in replenishing water tables.

(3) Suitability, agro-ecology and adaptability based upon local knowledge

. Suitable mostly in semi-arid and arid parts of the country. Recently introduced in kolla and dry weyna dega areas for the growth of trees, catchment treatment and support to area closure. Design of trenches will change based on dryness conditions and type of plantations.

(4) Main land use

Applicable in steep hillsides with soils with low infiltration capacity and high levels of stoniness (round shaped stones not suitable). Suitable for community closures.

(5) Technical preparedness

. Land use, 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.
. Preparation of follow-up plan.

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

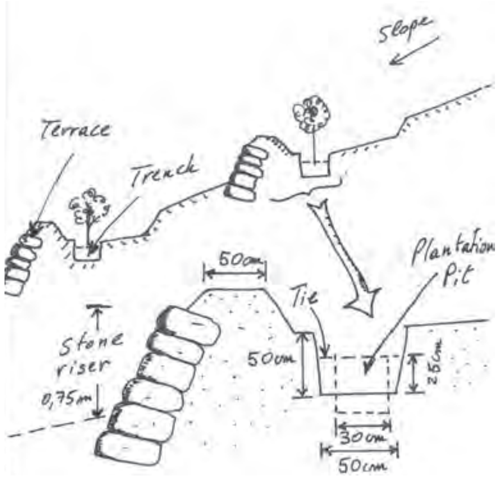
. Good potential to improve degraded and steep hillsides - mostly for area closure and multi-purpose tree and fodder tree plantations. HTTs are water harvesting structures that can increase productivitiy of area closures and convert hillsides into agroforestry systems. Good effect on raising water

(7) Minimum surveying and tools requirements

Layout: One water line level, two range poles graduated in cm and 10 meters of string (a team of 3 people layout approx 1 ha/day).

Work: crow bars, sledge hammers shovels, and pick axes. Ratio of different tools depend on type of soil/stones

Fig 1. Hillside terrace + trench (for moisture stressed areas)



(8) Min. technical standards (fig 1)

· Stone riser height: 0.75-1 m from ground level
. Stone riser foundation: 0.3-0.4 mD x 0.3 mW
. Top width: 0.5 m (0.25 m stone riser and 0.25 m soil),
· Grade of stone riser: 1 horiz: 3-4 vertical,
· Grade of soil bank: 1 horiz: 1.5 (unstable soils) to 2 vertical (stable soil),
· Base width: based upon slope,
· Size/place of trench: 50 W x 50 cm D x terrace length - placed 0,75-1m above stone wall.
· Size/place of ties: within trenches ties are placed at 2-3m intervals based upon plantation requirements and half way the depth of the trench (0.25 m) with 0.6m horiz. length x 0.5 cm width for planting seedlings.
· A 30x30x30 cm plantation pit is placed in the middle of the tie or in front of the trench (between berm and embankment) with lateral spacing depending on tree and shrubs planted (1-3 metres)·
. Max length of HTTs: 50-80m. HTTs should wing up laterally, before depression points

(9) Work norm elements

· Cut and fill of the terrace area;
· Collection of stones from working site, shaping of side of some stones with sledgehammer for better stability & merging;
· Excavation of foundation;
·Placement and building of stone riser;
· Trench excavation above stone riser and placing of excavated soil on hillside embakment;
. Pitting on ties within trenches;
· Leveling of top of the terrace embankment.

WORK NORM: 330 PDs/Km

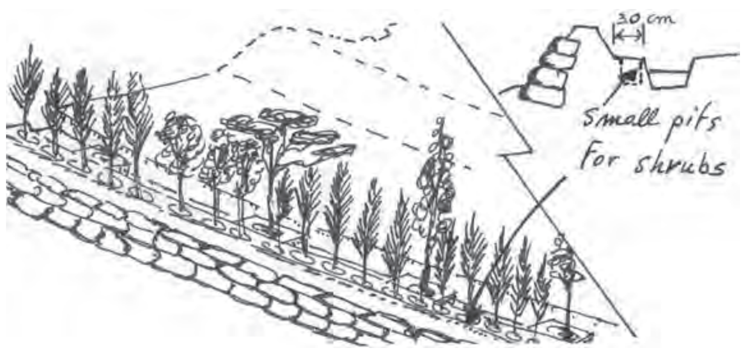
10) Integration opportunities/requirements

1. Soils and tree management practices (compost/manuring planting pits). Control grazing and closure of areas treated necessary. Mulching required.
2. Fodder, legume and cash crops can be planted on embankment and along the berm: using grasses (indigenous such as "sembelete", "dasho", others, etc.) + legume shrubs (pigeon peas, sebania, acacia saligna, trilucerne, etc) in rows by direct sowing (15-30 cm).
3. HTTs can also be stabilized by planting drought resistant plants such as Sisal, Aloes and Euphorbia placed on the lower side of the stone wall.
4. Integration with strong check dams along depresssion points and small gullies

(11) Modifications/adaptation to standard design

HTTs for mixed tree-fodder-cash crops plantation (fig 2).

Fig 2. HTTs with mixed



(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 linked to closures. Arrange working groups for regular maintenance.

(13) Management requirements

. Control grazing is a precondition for hillside terraces. Terraces should be stabilized, possibly with drought resistant species.
. Fodder and crops growing on terraces should not be uprooted but cut and carried.

(14) Limitations

. HTTs very labour intensive (trenches alone usually preferred).
. 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.

Flood Control and Improved Drainage

1. Waterways (Vegetative and Stone Paved)
2. Cut-off Drains
3. Graded Soil Bund
4. Graded Fanya Juu
5. Improved Surface Drainage for Increasing Productivity of Vertisols and Soils with Vertic Properties

TECHNICAL INFORMATION KIT	(1) Period/phases for implementation	(2) Objectives/remarks
WATERWAYS (VEGETATIVE AND STONE PAVED)	. Only during the dry season. . One or two seasons before the construction of cutoff drains.	- A waterway is a natural or artificial drainage channel constructed along the steepest slope or in a valley to receive/accommodate runoff from cut-off drains and graded terraces/bunds. The waterway carries the run-off to rivers, resevoirs or gullies safely without creating erosion. - A vegetative waterway can be constructed in areas without stones. The main advantage is that waterways can be constructed for both very small and large size catchments, thus accomodating individual or communal needs for drainage and evacuation/use of excess run-off. -Paved waterways are suitable in steeper terrains and areas with large amount of stones.

(3) Suitability, agro-ecology and adaptability based upon local knowledge

Applicable in all agro-climatic conditions, particularly in moist areas and areas prone to waterlogging. Traditional drainage and waterways common in many parts of the country. The use of grass vegetation in waterways is commonly practiced locally by farmers. Improved designs are likely to be adopted after demonstration.

(4) Main land use

. Following depressions or natural waterways and farm boundaries.
. Linked to graded bunds and cutoff drains in cultivated areas.

(5) Technical preparedness

. Land use, soil and topography assessed.
. Discuss/agree with farmers on design.

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

. Contribute to increased sustainability of production through disposing excess runoff from cultivated fields and other sources of run-off from upstream.
. Help reduce soil erosion and gully formation.

(7) Survey equipment and tools

Layout: Follow natural waterway to determine length and width. Use Pegs. **Tools:** Shovels, Hoes, Pick axe, crowbars.

(8) Min. technical standards and construction phases

(1) VEGETATIVE WATERWAYS (VW)

Most criteria set for the design of cutoff drains are valid for waterway design.
Slope: < 10%
Size: small waterways preferred (1-5 ha drainage area).
Shape: Choose parabolic cross section as this tends to resemble natural waterway.
Design steps:
1. Determine the drainage area.
2. Determine the width in meters of water way from Table 1/A having measured slope of the waterway.
3. From the table showing relationship beteen depth and width(table 1/B), determine depth in meters.
Checks-drop-aprons (CDAs): place stone or brushwood CDAs every 20m (slope <5%), 10 m (slope 5-10%) and 5 m (slopes 10-25%) (see Figure 2).

Excavation: soil piled and compacted on one or both sides of waterway (see Figure 1).
Stabilization: local grass - sods - dry straws lines dug into the ground during first year.

(2) STONE PAVED WATERWAYS (SPW)

Slope: < 20-25% slope
Size: small waterways preferred (1-5 ha drainage area)
Shape: Choose parabolic cross section as this tends to resemble natural waterway.
Design steps: same as VW (see Figure 3)
Excavation and stone paving: place flat heavy stones at the bottom - fill with smaller stone the space between large ones
Stone checks-drop-aprons (CDAs): at 1 meter vertical interval. The apron length = to height of drop. Built using stones or wooden pegs + stones. Height of CDAs 0.3-0.5m.

(9) Work norm

1. The worknorm for **vegetative waterway** is:

1 personday/1m3
which includes layout, straw lines and scour checks and outlet improvement.

2. The worknorm for stone paved waterway is:

1 personday/0.75m³
of earth/stone movement and construction of drop structures.

Table 1/A: Relationship between drainage area and width of waterway

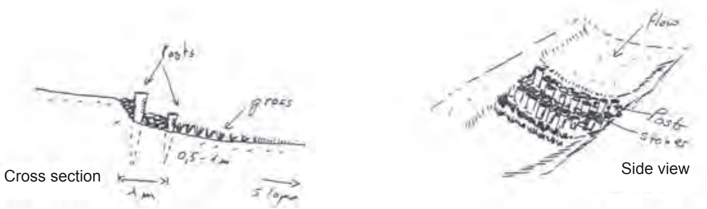
Runoff Area (Ha)	Width of the waterway(m)		
	Slope (0-5%)	Slope (6-12%)	Slope (13-25%)
1	1.5	1.5	1.5
2	1.5	2	2.5
5	2	3	4.5
10	3	6	9
15	3.5	8	12
20	4.5	12	18

Table 1/B: Relationship between depth (m) of waterway and width (m)

Width in meters	Depth in meters
0-3	0.3
4.0-6.0	0.4
more than 6	0.5

Figure 1. Vegetative Waterway

Figure 2. Check/Drop/Apron with wood posts and stones for vegetative waterways



(10) Management requirements

. Households with fields adjacent to a waterway provide proper follow-up during construction and afterwards for proper maintenance.

(11) Planning and Implementation arrangements

. Planning follows community/groups and individual owners' discussions/agreement on layout and management requirements. Groups of 5-20 households work together to increase efficiency (layout, excavation, shaping, compaction).

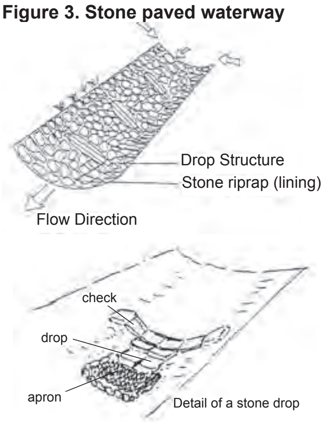
(12) Limitation

No limitation

(13) Institutional responsibility

10 - 15 households should work together during construction and after for proper maintenance of waterway channels.

Figure 3. Stone paved waterway



TECHNICAL INFORMATION KIT	(1) Period/phases for implementation	(2) Objectives/remarks
CUT-OFF DRAIN	. Only during the dry season and period not interfering with land preparation.	. A cut-off drain is a graded channel constructed to intercept and divert the surface runoff from higher ground/slopes and protect downstream cultivated land or village. This safely divert the run-off to a waterway, river, gully, etc. . In the dry lands, cut-off drains may be used mainly for the following purposes: - Divert additional water to cultivated plots; - Divert additional water to SS dams and croped areas inside gullies; - Divert additional water into reservoirs for irrigation and/or domestic use.

(3) Suitability, agro-ecology and adaptability based upon local knowledge

. Suitable mostly in moist areas of the country with medium to high rainfall. Also applicable in dry areas to protect cultivated lands and irrigation schemes, and divert runoff into reservoirs.
. Most suitable where there is proper natural waterway.
. Soils with minimum clay content to avoid swelling and cracks. Suitable on areas less than 50ha. Very steep slope site (>50%) should be avoided.

(4) Main land use	(5) Technical preparedness
. Suitable at a foot of a steep hillside under which cultivated fields are exposed. . Constructed above gully head to divert off run-off from active gullies to treated/stable ones. . This is one of the gully control measures.	. Discuss/agree with farmers on design and layout + provide on-the-job training. . Precise layout and follow-up/adaptation.

(8) Min. technical standards

The first step is to estimate a probable maximum rate of surface run-off to design a channel or ditch which will carry this amount.
Step 1: For a given area, compute the peak discharge rate Qpt by multiplying the corresponding Qp (m3/sec/ha) taken from Table 1 by the catchment area (Ca).
Qpt = Qp x Ca
Step 2: Compute the required flow cross sectional area (A) using the corresponding maximum permissible velocity (V).
A = Qpt/V
Step 3 : Decide the shape of the channel. Trapezoidal or Parabolic is recommended.
Step 4: Use Depth from Table 1/A using V and Channel gradient.
Gradient: 1-10ha =0.8-1%; 10-30ha = 0.5%; 30-50ha= 0.25%
Step 5: Find the channel discharge per unit of depth using Table 1/B attached.
Step 6: Find top width of the cut-off drain. For trapezoidal and parabolic cross-section: runoff from the catchment divided by Discharge from the cut-off drain (table 1/B).

(9) Layout of the Structure

- Make graded contour and put peges at an interval of 10 meters. Use this as the center of the channel to be excavated.
- Take additional pegs and string. O indicates the central peg. The other four pegs indicate the top dimension of the channel

```
M        N        O        P        Q
  |________|________|________|________|
```

NO + OP = Bottom depth
MNOPQ = Top Width

- Construction starts digging out NRSP first and then shaping the channel by digging MNR and PQS.

(See Figure on backside)

(10) Work norm

. Precise layout;
. Removal of grasses from place of embankment;
. Excavation of soil;
. Shaping and compaction of embankment;
. Provision of scour check (1-2% slope);
. Checking of gradient using levels (need to be very precise).

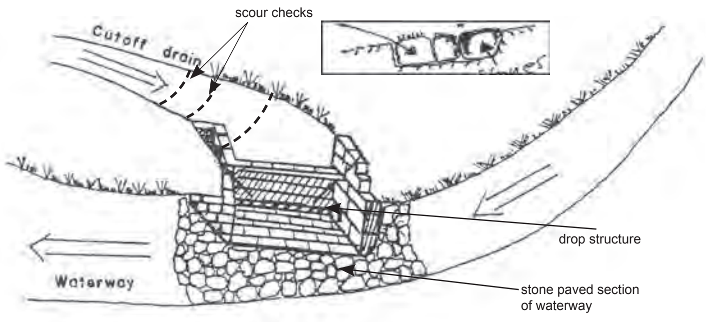
WORK NORM (Volume): 0.7 Meter cubes (M3)/Person Day

(12) Management requirements

. Requires attention and maintenance for proper management of the channel surface. Need proper distribution of top soil unifomily over the embankment.

(11) Integration opportunities/requirements

. Link to waterways (natural/artificial) to safely divert run-off.
. Construct scour checks with stones and grasses every 50 cm for 10-20 meters before the outlet to a waterway. As required construct strong drop structures to minimise the effect of water dropping into the waterway or gully, thus avoid the risk of creating additional erosion at the outlet level.



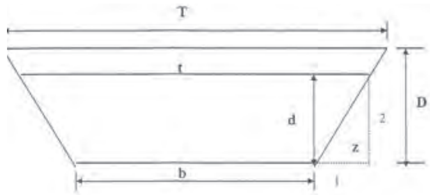
(13) Planning and implementation arrangements

. Planning follows community/groups and individual owners'agreement on layout. Groups of 5-20 households work together to increase effieciency (layout, excavation, shaping, compaction, level check).

(14) Limitations	(15) Institutional responsibility
Erosion risk at the outlet due to improper attention for provision of drop structures.	. Fully on individuals/groups +/- community (commitment to mgt.). . DAs and wda experts - technical support and follow-up/mgt.

Table 1. Values of Runoff Coefficient

Land Use/Cover	Runoff Coefficient		
	Slope (0-5%)	Slope (5-10%)	Slope (10-30%)
CULTIVATE LAND			
. Open Sandy loam	0.25-0.30	0.4	0.52
. Clay and silt loam	0.5	0.6	o.72
. Tight Clay	0.6	0.7	0.82
PASTURES			
. Dense cover	0.1	0.16	0.22
. Medium cover	0.3	0.36	0.42
. Open pastures	0.4	0.55	0.6
FOREST/WOODLAND			
. Dense cover	0.1	0.25	0.3
. Medium cover	0.3	0.35	0.5
. Scattered	0.4	0.5	0.6



Cross Section Area (A) = $bd + Zd^2$
Wetted Perimeter (P) = $b + 2d\sqrt{Z^2+1}$

Hydraulic Radius (R) = A/P = $\frac{bd + Zd^2}{b + 2d\sqrt{Z^2+1}}$

Table 2/A: Depth of a channel in meters

Channel Slope	**Maximum allowable velocity (m/sec)**					
% Slope	0.6	0.9	1.2	1.5	1.8	2.1
1					0.4	0.5
0.5				0.5	0.7	0.9
0.25	0.3	0.4	0.6	0.9		

Table 2/B: Dischrge in m3/sec/meter width

Depth of Channel	**Slope (%)**		
	0.8-1	0.5	0.25
0.3	0.6	0.4	0.25
0.4	0.9	0.65	0.45
0.5	1.3	0.95	0.65
0.6	1.8	1.3	0.95
0.7	2.25	1.7	1.2
0.8	2.8	2.15	1.5
0.9	3.4	2.65	1.8

Example: Find the size of a channel (cut-off drain) to be constructed at the foot on an hilly grassland with 20% slope. Soils of the catchment are clay. The runoff area is 6 ha. The grassland has medium cover.

Step 1: Find the corresponding run-off using rational method (table 1):
Q = K IA/36, where Q = the peak run-off rate (m3/sec); K = the run-off coefficient; I = the rainfall intensity (cm/hour); A = the run-off producing area. Thus, K= 0.82, I = 15cm/hr, A= 6 ha, then Q= 0.82 x 15 x 6 ha/36 = 2.05m3/sec.

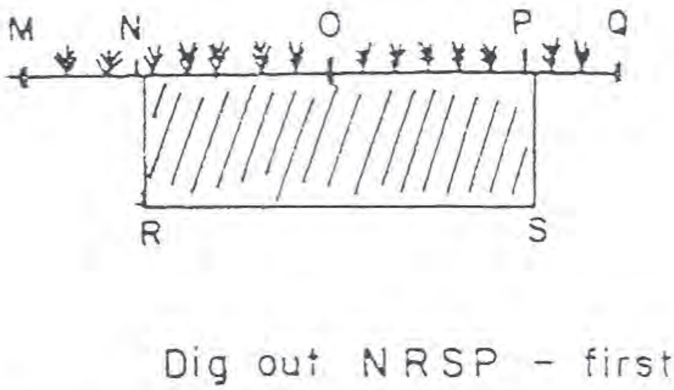
Step 2: Find the maximum allowable velocity using table 2/A above. In this case, Velocity = 1.8 m/sec for clay surface.

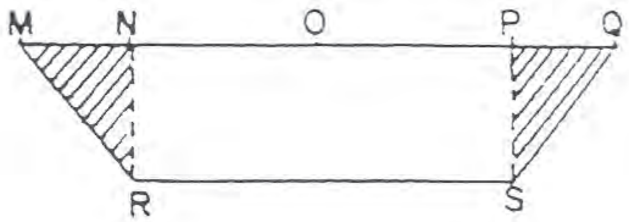
Step 3: Determine the gradient and depth of channel. For a catchment of 6 ha, a 1% slope selected. Following this determine channel depth from table 2/A against 1.8 velocity and 1% slope, which is = 0.4 m.

Step 4: Find channel discharge rate per unit width from Table 2/B. Accordingly, for gradient of 1% and depth 0.4, the discharge is 0.9m3/sec.

Find the top width of the cutoff drain by dividing the catchment run-off by the channel discharge rate per unit width = 2.05/0.9 = **2.3 m**

Steps in Cutoff drain construction





Shape the channel by digging MNR & PQS

TECHNICAL INFORMATION KIT

GRADED SOIL BUNDS

(1) Period/phases for implementation

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

(2) Objectives/remarks

. Graded soil bund is similar in description with level soil bund. However, graded soil bund is upto a maximum of 1% inclined against the contour so that excess runoff is allowed to drain to the adjoining natural or artificial waterways. It is also possible and necessary to inculde tied ridges smaller in height within the channel of the terrace. The stored water within the ties can infiltrate into the soil while any above that height is drained out.

. Graded soil bunds can be made to gradually develop in to benched type terraces through careful maintenace. Any integration of other measures such as stabilization and composting can be applied as it can be applied on level bunds.

(3) Suitability, agro-ecology and adaptability based upon local knowledge

. Suitable mostly in high rainfall and humid areas of wetter agroecologies and specially where the soil is poorly drained. Overall they can be applied in Wurch, Dega and Wet Weyna Dega areas of the traditional agroecological systems. Local experience is very relevant to assess performance of past activities and suggest modifications as required. Improved designs can be integrated with local ones to add strength to bunds (grass, legumes composting, etc).

(4) Main land use

. Applied generally on cultivated lands with slopes above 3%
. Homestead areas combined with cash crops. In case of cattle crossings bridge type crossings with stones or wooden structures are needed unlike level bunds where complete blockage is possible.

(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

. High in high rainfall, humid and water logged areas. There is high potential of integration with bilogical measures. More siutable in areas where runoff becomes excess as a result of high rainfall and poor infiltration of the soil. The tied ridges retain moisture in case of rainfall/runoff is minimum.

(7) Minimum surveying and tools requirements

Layout: One water line level, two range poles graduated in cm and 10 meters of string (a team of three people layout approx 2-3 ha/day)

Work: shovels, pick axes and wooden compactors (the proportion of shovels and pick axes depend on type of soil)

(8) Min. technical standards

. The artificial or natural waterway should be construcțied one year before the graded bund.

The channel is graded upto a maximum of 1% (10cm for every 10 meter lay out of the line level)

. Height: min. 60 cm after compaction.

. Base width: 1-1.2m in stable soils (1 horiz: 2 vertical) and 1.2-1.5m in unstable soils (1 horiz: 1 vertical). Top width: 30 cm (stable soil) - 50 cm (unstable soil). Channel: shape, depth and width vary with soil, climate and farming system.

. Channel cross section increases towards the end because of more water concentration e.g. from 25cm depth and 50cm width to 50 and 100cm, respectively. Ties (if appropriate): tie width with dimension as required, placed every 3-6 m interval along the channel.

(9) Layout and vertical intervals (VI)

. Vertical intervals: follow a flexible and quality oriented approach
. Slope 3-8% VI = 1-1.5 m
. Slope 8-15% VI = 1-2 m
. Slope 15-30% VI = 1.5-2.5 m (only exceptional cases - reinforced)

(**Caution**: soil bunds > 15% to max 20% only if space reduced and with trench, short bunds - above 15% better apply stone faced or stone bunds).

Layout along the coutours but with 1% gradient using line level. Ddiscuss spacing with farmers. Make bund length max 50-80m the > the slope the < the length. Proper link and stone pitching of the area when bund meets the waterway.

(10) Work norm

. Precise layout along contours with 1% gradient (graded) using line level,
. Scratching or removal of grasses from where embankment is constructed for better merging & stability,
. Excavation channel, and ties along channel (as necessary),
. Embankment building, shaping and compaction (essential),
. Leveling and compacting the top of bund with an A-frame.

WORK NORM: 150 PDs/Km

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

1. Integration with artificial or natural waterways and apron (in case of sharp falls) is a must.
2. Integration with **bund stabilisation**: using grasses (indigenous such as "sembelete", "dasho", others, etc.) + legume shrubs (pigeon peas, sebania, acacia saligna, etc.) in dense rows by direct sowing (15-30 cm).
3. Agronomic practices: contour plowing and **compost** (start first year applying 2-3m strips above the bunds - where soil is deeper and moisture is higher).
4. **Grow cash crops** along bunds (especially after 1-2 years of composting) in single or wider strips as required. Plant specific crops along bunds to use residual moisture (sunflowers, gourd, tomatoes, cucumbers, etc.).
5. **Control grazing** - avoid animals to graze between bunds for at least 1 year.

(12) Modifications/adaptation to standard design

1. At the out let to the waterways, in case of sharp falls, apron should be considered.
2. Upgrading graded soil bunds and application of COMPOST (Same as level soil bunds)

(14) Management requirements

. Graded soil bunds may need to be upgraded to become level terraces - the upgrading should use soil from the lower part of bund (fanya juu principle, to avoid fertile deposited soil to be used for the embankment.
. Apply cut&carry for grass/legumes growing on bunds (not uprooted).

(13) 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 together to increase efficiency (layout, excavation, shaping, compaction, level check).

(15) Limitations

. If the gradient is high scouring and if low flow blockage and overtopping is a problem.
. Limited stability if not integrated with revegetation - requires regular maintenance

(16) Institutional responsibility

. Fully on individuals/groups +/- community (commitment to mgt.)
.Common mangt. of the waterways and adjoining lands required
. DAs and wda experts - technical support and follow-up/mgt.

TECHNICAL INFORMATION KIT	(1) Period/phases for implementation	(2) Objectives/remarks
GRADED FANYA JUU (GFJ)	. Only during the dry season and period not interfering with land preparation	. The GFJ with a maximum gradient of 1% dishcarges excess runoff generated from the inter terrace spaces to the adjoining natural or artificial waterway at a non-erosive velociy. This consequently reduces runoff and soil erosion. It is also possible to inculde tied ridges smaller in height within the channel of the terrace. The stored water within the ties can infiltrate into the soil while any excess above that height is drained out. . Graded fanya juu bunds can be made to gradually develop in to benched type terraces through maintenace.
(3) Suitability, agro-ecology and adaptability based upon local knowledge		
Suitable mostly in high rainfall and humid areas of wetter agroecologies and specially where the soil is poorly drained. Local experience very relevant to assess performance of past activities and suggest modifications. A major one is the application of the fanya juu principle after standard soil bunds are constructed for not disturbing the upper ditch filled with fertile soil (see modification to design below). Improved designs can be integrated with local ones to add strength to bunds (grass, legumes, composting, etc).		

(4) Main land use	(5) Technical preparedness
Applied generally on cultivated lands with slopes above 3% and below 15% gradient. Like level fanya juus graded Fanya juus are best constructed in uniform terrains with deep soils that do not have traverse slopes (depressions), but in high rainfall areas. Can be applied also within sloping homestead areas combined with cash crops.	. Land use, soi, topography and rainfall assessed. Discuss/agree with farmers on design and layout + provide on-the-job training. Precise layout and follow-up.

(6) Potential to increase/sustain productivity and environmental protection	(7) Minimum surveying and tools requirements
. The main advantages of graded fanya juu is to divert the excess runoff and its capacity to become a bench terrace in a short number of years if frequent maintenance is applied. However, its contribution to increased productivity is assured if well managed and integrated with soil fertility improvement practices, particularly vegetative stabilization and composting. Grassing the waterway or paving is also requried.	**Layout**: One water line level, two range poles graduated in cm and 10m of string (a team of three people layout approx 2-3 ha/day) **Work**: shovels, pick axes and wooden compactors (the proportion of shovels and pick axes depend on type of soil).

(8) Min. technical standards (fig 1)	(9) Layout and vertical intervals (VI)	(10) Work norm
. **Height**: min. 60 cm after compaction. . **Base width**: 1-1,2m in stable soils (1 horiz: 2 vertical) and 1,2-1,5m in unstable soils (1 horiz: 1 vertical). . **Top width**: 30 cm (stable soil) - 50 cm (unstable soil). . **Drainage ditch**: 60cm W x 50 cm D. Ties: placed every 3-6 m interval along channel. . **Length of bund**: up to 60 m in most cases, or max 80m on gentle slopes (3-5%) . Channel cross section increases towards the end because of more water concentration e.g. from 25cm depth and 50cm width to 50 and 100cm, respectively.	.Vertical intervals: flexible and quality oriented approach . Slope 3-8% VI = 1-1,5 m . Slope 8-15% VI = 1-2 m . Layout along the coutours but with 1% gradient using line level - discuss spacing with farmers and in case of lateral slopes shift to graded soil bunds	. Precise layout along contours with 1% gradient (graded) using line level, . Scratching or removal of grasses from where embankment is constructed for better merging and stability, . Excavation of dowstream ditch or channel, and ties along channel, . Embankment building, shaping and compaction (essential), . Leveling of top of bund with an A-frame **WORK NORM: 200 PDs/Km**

(11) Integration opportunities/requirements (see also WHSC guidelines)	(12) Modifications/adaptation to standard design
1. Integration with artificial or natural waterways and apron (in case of sharp falls) is a must. Also the waterway should be grassed or paved. 2. Integration with bund stabilisation: similar ot level Fanya Juus the lower embankment of the GFJ need the embankment stabilised in the lower side to allow excess water to overtop without creating damage. Grass planted with other shrubs is most suitable. Plants like aloes and sisal combined with more productive shrubs (pigeon peas, etc.) are also recommended on upper and lower side of fanya juu. 3. Agronomic practices: contour plowing and compost (start first year applying 2-3 m strips above fanya juu - where soil is deeper and moisture is higher). 4. Grow cash crops along bunds (especially after 1-2 years of composting) in single or wider strips as required. Plant specific crops along bunds to use residual moisture inside ditches (sunflowers, gourd, tomatoes, cucumbers, etc.). 5. Control grazing, staggered position of fanya juus + same as soil bunds.	a) Combination of graded Fanya juus and graded soil bunds and reinforcements within the same contour line to address the problem of slight traverse slopes/depression points. b) At the out let to the waterways, in case of sharp falls, apron should be considered. C)Upgrading of graded soil bunds using the graded fanya juu principle after 1-2 years.
(13) Planning and implementation arrangements	**(14) Management requirements**
. Planning follows community/groups and individual owners' discussions/agreement on layout, spacing, and management of waterways required. Groups of 5-20 households work together to increase efficiency (layout, excavation, shaping, compaction, level check).	. GFJs need to be upgraded to become level terraces - the upgrading should use soil accumulated in the ditch below the bund. . Apply cut and carry for grass/legumes growing on bunds (not uprooted). . Repair breakages immediately after showers, especially the 1st year
(15) Limitations	**(16) Institutional responsibility**
. In case of cattle crossings it is impossible to apply. . If too narrow spaced can take unnecessary space out of production.	. Fully on individuals/groups +/- community (commitment to mgt.) . DAs and wda experts - technical support and follow-up/mgt.

TECHNICAL INFORMATION KIT	(1) Period/phases for implementation	(2) Objectives/remarks
Improved surface drainage for increasing productivity of Vertisols and soils with vertic properties	1) Loosen the soil during the small rains (minimum three passes). 2) Make BBMs and cover seed, mid to late June depending on rainfall.	1) Increased aeration of the soil. 2) Improved soil workability. 3) Earlier sowing date. 4) Higher and more diversified crop production, possibly double cropping. 5) Decrease in (peak) runoff flow. 6) Soil erosion decreased due to early vegetative cover. 7) Increased crop and residue yields. 8) Early harvest when there is shortage of food supply and also help farmers benefit from higher prices.

(3) Suitability, agro-ecology and adaptability based upon local knowledge

Applicable in all agro-climatic conditions, particularly in moist areas and areas prone to waterlogging. Traditional drainage and waterways common in many parts of the country. The use of grass vegetation in waterways is commonly practiced locally by farmers. Improved designs are likely to be adopted after demonstration.

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

The furrows allow excess water to drain off from the fields to the lower channels during the rainy season. This technology facilitates early sowing of crops, thereby utilizing a longer growing period and resulting in higher crop yields; soil erosion is also reduced since there is adequate vegetative cover to protect the soil during the main rains.

(5)Technology description

Clay soils, technically known as vertisols and soils with vertic properties, are prone to waterlogging, seriously reducing their productivity. These soils are mostly fertile but difficult to cultivate because of their high shrink–swell clay content, making them hard, cracking soils when dry and sticky and waterlogged soils when wet.

The BBM as shown in figure 1 is made out of two maresha beams connected in a triangular structure. The top ends of the maresha are tied together and connected to the yoke as in the traditional method. For maintaining the distance of 1.2 m between the maresha tips , a crossbeam is tied between the two poles of the mareshas at around a metre from the edges of the poles. A steel wing of mouldboard shape is then attached on each inner flat wings of the maresha to push the soil the soil inside and form the broadbed furrow maker (BBM). The chain attached at the edge of the metal wings not only shape the beds evenly but it also covers the seeds.

The BBM as shown in figure 2 should be made on less than 2 percent as slope (furrow gradient 2%<) as increasing slope could cause erosion as the speed of excess water evacuating through the furrows could be increased.

(6) Minimum tools/ requirments

1) maresha is for loosening the soil.

2) BBM for shaping the land into broadbeds and furrows and for covering the sown seeds.

(7) Integration requirements and opportunities

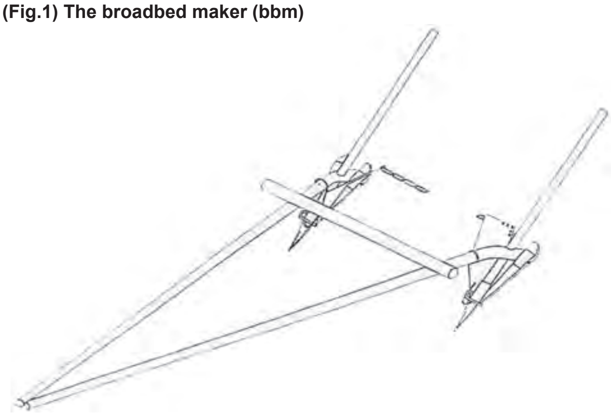
As crops on the BBm should be sown early during the start of the main rains, the crops of the BBm system can be harvested about two months earlier than those sown on traditional flat seedbeds as they are planted late in the rainy season. In some places where enough moisture is available, a second crop minly chickpes or rough peas could be planted as done by some farmers around Ginchi as these crops are generally planted to grow on residual moisture. Early harvest is beneficial for smallholder farmers since it coincides with the period of severe household food deficit and high grain prices in the local market.

(Fig. 2) The broadbed and furrow (BBmS) system

(8)The management requirements

About 7.6 million hectares (60%) of the estimated 12.7 million hectares of Vertisols are situated in the Ethiopian highlands with drainage problem. This figure of 13 million ha would increase substantially when soils with vertic properties, which have the same drainage problems, requiring field drains for improving crop productivity are consider.

(Fig.1) The broadbed maker (bbm)



(9) Constraints and limitations

1) When planted early, crops are isolated and exposed for damage by domestic animals, insect pests (crickets, grasshopper) infestation;

2) High price of BBM compared to traditional tillage tools;

3) Some farmers have an impression that using a double maresha increases draught power even though it is less or equal to the power required by the single maresha.

(13) Planning and implementation arrangements

(1) Attachments using Tine Harrow:

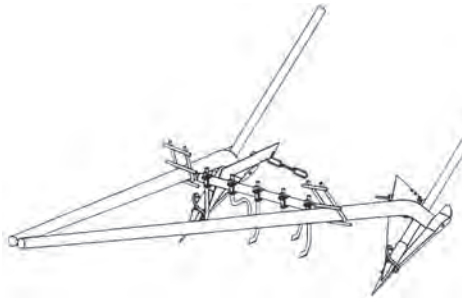
The tine attachments for the BBM were designed for reduced tillage in establishing semi-permanent BBMs system on Vertisols and soils with vertic properties. The design used 40 mm diameter metal pipe for the main bar with a simple ring and wedge fitting which is lashed to the maresha beams of the broadbed maker. The tines are made in one piece from 20 mm diameter reinforcing bar and held in place by steel clamps and wedges made from 16 mm reinforcing metal pieces and needing only a hammer to fit or adjust on the main bar. Four tines at a spacing of 20 cm would be place on the bar for the tine harrow opertation.

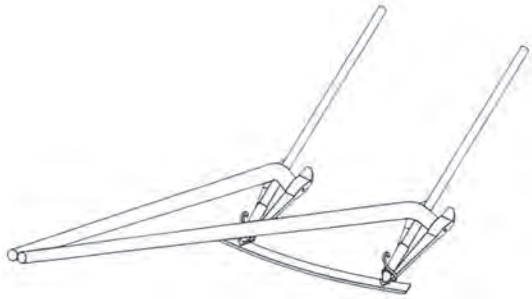
(2) Blade harrow

A blade harrow consisting of of a metal blade 4 mm thick are fixed on both sides of the maresha tines of the BBM and used for the post harvest cultivation.The blade harrow cuts the soil of the BBMs at about 4 cm depth thus also slicing the weeds that are growing at that time. At this period, the power and time requirement for this implement is drastically low for minimum soil disturbance on Vertisols and soils with vertic properties.

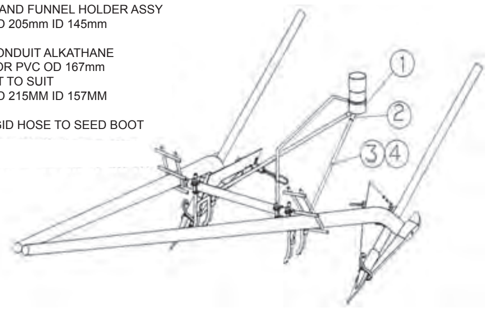
(3) Funnel planter

The planter attachment to the BBM has been developed for line seeding. This Afar system has been redesigned to be attached to the BBM with a sheet metal funnel and four connecting tubes to cover the bed of the BBFs systems which is 80 cm in width. A set of tines, tines of leading and trailing coulter units, penetrating the soil surface at 45º angle are used. The funnel consists of a circular hopper 100 mm diameter with a disked bottom drilled with four equally spaced 25 mm diameter holes to which the coulter tubes are attached. In the hopper, a centre rod supports double-layered cones above the plate with the four holes to provide better uniformity in seed distribution. The space of the lower cone to the plate is 50mm while there is 20 mm space between the two cones. The lower cone, which is nearer to the plate, has a 70 mm diameter while the upper cone has a 50 mm diameter. The holes inside the hopper could be blocked off according to the row arrangement. The funnel seeder and the planted field . The funnel planter unit is fitted to the tine bar using the same clamp and wedge system as the tines.





1. FUNNEL DIVIDER AND FUNNEL HOLDER ASSY
2. PLASTIC HOSE OD 205mm ID 145mm LENGTH 105mm
3. RIGID PLASTIC CONDUIT ALKATHANE POLYETHYLENE OR PVC OD 167mm ID 145mm LENGHT TO SUIT
4. PLASTIC HOSE OD 215MM ID 157MM LENGHT 300MM CONNECTING RIGID HOSE TO SEED BOOT



(11) Management requirements and linkage with agronomic practices and farther drainage control (outlets)

Currently the BBMs are ploughed up during general land preparation and reconstructed if the BBM package is used for the next season. The possibility of retaining the BBFs for repeated use with minimum tillage could be an option. This will save animal and human labour for various tillage operations. Along with this, the possibility of row seeding rather than broadcasting may be considered. Row planting may reduce the required seed rate by improving the crop emergence with the placement of seeds uniformly at optimum soil depth and also reduce required fertiliser rate by improving nutrient uptake by these plants. Further advantages would be better control of weeds (making weeding easier and less labour demanding) and stubble incorporation into the soil thereby partially filling the cracks thus reducing moisture loss and help the next crop.

1) Reduce animal power requirement for land preparation and constructing of BBF even without getting the small rains which would be a requirement for the traditional land preparation.

2) Early planting made feasible due to minimal land shaping requirement compared to conventional BBM or the traditional system.

3) Reduce the amounts of seed and fertilizer usage substantially (compared to the traditional broadcasting system) due to the use of funnel planter.

Cultural practice of ploughing several times and broadcasting of seeds and fertilizer established in most parts of the country would require a lot of effort to change. Therefore, as a solution to this constraint use Afar farmers to show and teach the use of funnel planter to farmers in other parts of the country. The Afar planter could be used on all soil types especially for bigger cereals (maize, sorghum) and pulses.

Water Harvesting

1. Hand-dug Wells
2. Low cost Water Lifting
3. Low Cost Micro-ponds
4. Underground Cisterns (Hemispherical, Dome cap, Bottle Shape, Sphere, Sausage shape)
5. Percolation pit
6. Percolation Pond
7. Farm Pond Construction
8. Spring Development
9. Family Drip Irrigation System
10. Roof Water Harvesting System
11. Farm Dam Construction
12. River-bed or Permeable Rack Dams
13. Small Stone Bunds with Run-on and Run-off Areas
14. Narrow Stone Lines Along the Contours (Staggered Alternatively)
15. Stone Faced/Soil or Stone Bunds with Run-off/ Run-on Areas
16. Conservation Bench Terraces (s) (CBT(s))
17. Tie Ridge (s)
18. The Zai and Planting Pit System
19. Large Half Moons (Staggered Alternatively)
20. Diversion Weir Design and Construction

TECHNICAL INFORMATION KIT

Hand dug well

(1) Period/phases for implementation

. Only during the dry season and period not interfering with Agriculture

(2) Main objective/purpose

Hand dug wells are used to irrigate small plots or to supply drinking water for human and livestock.

(3) Suitability and adaptability to local knowledge

Productive and reliable wells can be obtained in areas with permeable geologic formation and good potential for ground water recharge. High yielding wells are anticipated in alluvial deposit along the main watercourse. Areas with highly fractured geologic formation are also suitable for shallow wells.

(4) Minimum surveying and tools requirements

Layout: It should be at least 30 meters from a tream or open water hole.

Work: Hand-dug wells should be dug during the dry season when the water table is likely to be at or near its lowest point.

(5) Main land use

. Can be located on any land use, but close to the area of use.

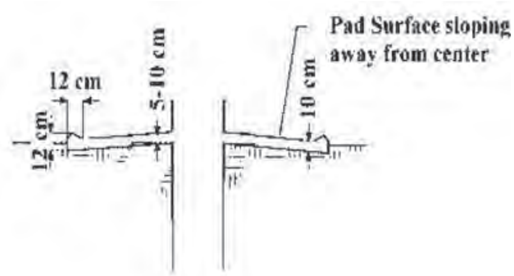
(6) Technical preparedness

. 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

Figure 2. Vertical cross-section of the well



The well site should have to be on a relatively high spot to prevent surface water from entering in to the well. See figure 2.

Figure 3. Formwork to line wells in unstable formation

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

.Additional source of water for human and livestock use and irrigation. Hand dug wells or shallow wells are more reliable water sources than surface ponds and various cisterns. Unlike surface runoff harvesting using ponds and cisterns the water for hand dug well is continously recharged through the ground. Therefore, it is more sustainable compared to other water harvesting structures. With hand dug wells there is high potential for using it over the dry season. Depending on the geology of the area recharging the ground water artificially could be required.

(8) Layout

Figure 1. Layout of hand dug well

Minimum distance of a well from water course, house, barn, etc. shall be 30 meter.

(9) Minimum technical standards

In hard formation, the diameter of open wells could be 1.5 - 3 meters. In unstable soils, the diameter could be wider (5 - 7m) at the top and 1.5 m starting from the point where hard/stable formation is encountered.

Once the water-bearing layer is reached, it should be penetrated as far as possible. Digging a well in an unstable formation requires either:

•Supporting the sides of the well and prevent them from collapsing, or

•Increasing the diameter of the well by as much as twice the depth of the well

(10) Design of the cover

.Design of Cover

.A small opening with a cover can be provided to draw water by rope and bucket in case of pump breakdown or if pumps are not affordable at all.

.Concrete aprons and drains around the well tops should be constructed to prevent spilled water and animal waste from seeping directly into the wells (see figures 2 and 4).

(11) Work norm

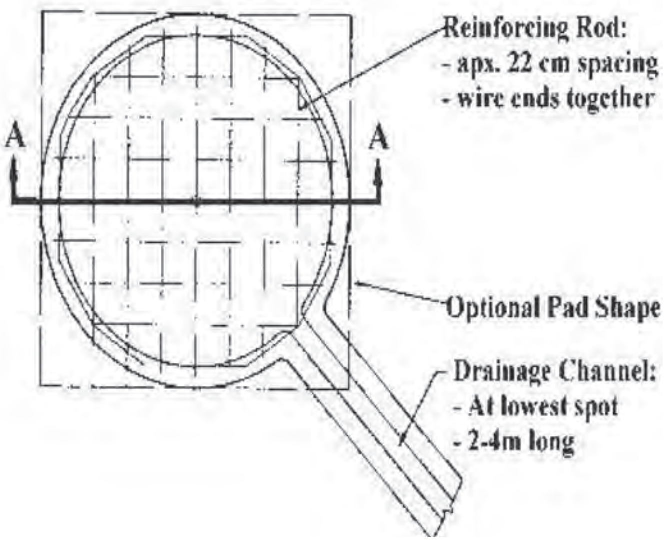
WORK NORM: 1 m3 / Personday for the first 1m depth; 0.5 m3 /PD therafter.

Stone Excavation 0.3m^3/PD.

The worknorm involves digging, disposing of spoil, excavation of diversion canal

Gravel and stone collection is 0.5 m3/ Personday

(8) Layout



(12) Planning and Implementation arrangements

. Planning follows community/groups and individual owners' iscussion/ agreement on layout, spacing and management requirements.

(13) Modifications/adaptation to standard design

Lining is required if the side walls are unstable.
Minimum Spacing between two wells shall be about 50m to avoid overexploitation of the ground water.

(14) Management requirements

Open wells should be inspected every day to ensure that no debris enters the well, while closed wells should be inspected periodically for the same reason. Cut off drains should be well maintained to prevent runoff, spilled water and animal waste from seeping or entering directly into the wells

To prevent contamination of the water, the rope and bucket used to collect the water should be suspended from the wellhead so that it cannot touch the ground.

To avoid contamination closed well with pulley or roller attached to a rope and bucket can be used. See infotech on low-cost water lifting.

(15) Limitations

Open hand dug wells are constructed in areas where there is an urgent need for a water source and the community cannot afford for the lining material and cover. The water is recommended for irrigation of small plots and not to be directly used for human consumption.

The other demerit of open wells is that they require wider space especially in unstable soils.

The sides of an unlined well may collapse when wet if adequate slope is not provided.

(16) Institutional responsibility

.To be implemented as part of an integrated watershed development intervention.
. Fully on individuals/groups +/- community (commitment to mgt.)
. DAs and wereda experts - technical support and follow-up/mgt.

TECHNICAL INFORMATION KIT

Low Cost Water Lifting

(1) Period/phases for implementation

Can be installed any time of the year.

(2) Objectives/remarks

They are instrumental in increasing the size of plot and provide the right amount of water to crops at the the right time.

The treadle pump, relative to the traditional rope and bucket system will increase irrigated surface areas and reduce irrigation labour time relative to the original irrigated surface area. Thus, resulting in increased production.

(3) Suitability, agro-ecology and adaptability based upon local knowledge

Low cost water lifting technologies are important tools for resource poor farmers.
They are mostly applicable in a condition where the lift requirement is less than 7 meters.

(4) Main land use

Can be located on any land use, but close to the area of use.

(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

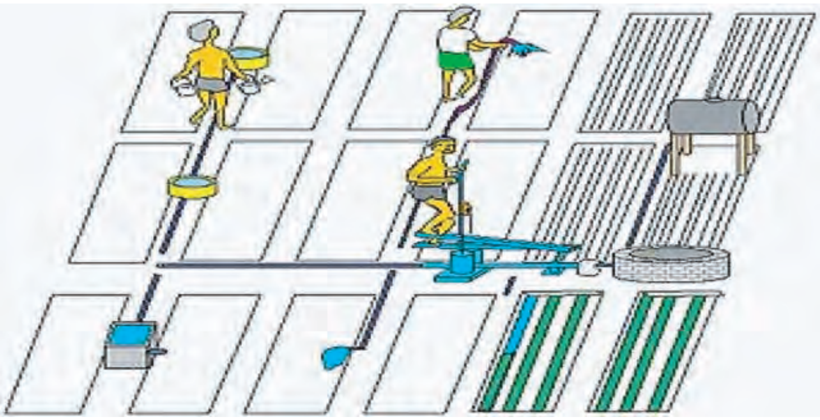
(6) Potential to increase/sustain productivity and environmental protection

. High in high rainfall, humid and water logged areas. There is high potential of integration with bilogical measures. More siutable in areas where runoff becomes excess as a result of high rainfall and poor infiltration of the soil. The tied ridges retain moisture in case of rainfall/runoff is minimum.

(7) Minimum surveying and tools requirements

The treadle pump can be located at any spot with a vertical distance of 0 - 7 meters above the water surface.

(8) The Treadle pump (as an example, see other lifting devices next page)



(9) Minimum Technical Standard (for treadle pump)

The treadle pump is a low-lift, high-capacity, human-powered pump. It can lift five to seven cubic meters of water per hour from ponds, wells and streams up to 7m deep At a lift of 4.5 metres, the treadle pump has a discharge of 1.7 1/sec and can irrigate 0.5 ha.
The pump is operated by moving two pedals while standing on the pump and can be operated for several hours as opposed to the more arduous process of hand pumping and hand watering.

Water can be extracted using low-cost human powered lifting devices such as treadle and rower pumps. Rope and washer pumps can also be used but need to be modified for the inclined position of the pond. Because the upright position is more appropriate for the vertical structures such as shallow wells. More explanation is given is diagrammatically given in subsequent figures below.

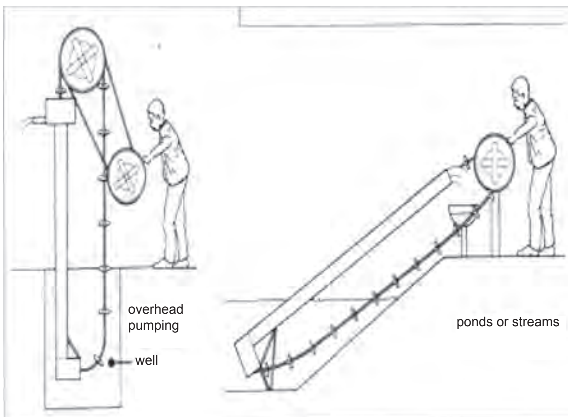
From low cost human powered pumps treadle pump is the most appropriate for extracting water from surface ponds and shallow wells as well. The treadle pump is a low-cost, human powered pump. It consists of two pistons situated inside two cylinders, which rise and fall when an operator treads on the treadles in a walking motion. This causes a vacuum allowing water to be pumped. There are two main types of treadle pumps, a suction pump and a pressure pump.

The main difference is the positioning of the valves. A suction pump can merely raise water from a source, which then spills over for gravity irrigation. The pump therefore has to be at the highest level. A pressure pump can, however suck water and then push it to a further height, creating pressure. The pumps can pump up to about 12 meters head, depending on the distance from the water source.

(10) Modifications/adaptation to standard design

The water lifted using the treadle pump can be made to flow in to furrows/basins or kept in a barrel, which is connected to a family drip irrigation system. In the absence of a treadle pump, a rope and bucket can be used to irrigate smaller plots. Also pulley, roller, and steps can be used.

Rope and Washer Overhead and Inclined Position



(11) Planning and Implementation arrangements

. Planning follows community/groups and individual owners' discussions/agreement on layout, spacing between wells, watering periods and management requirements.

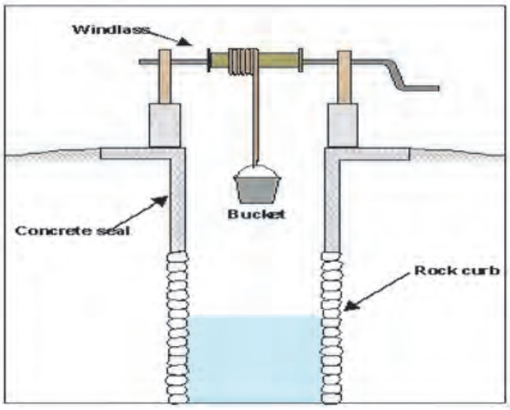
(12) Management requirements

Training in the area of irrigation agronomy, water management and operaation and maintenance of the various lifting devices

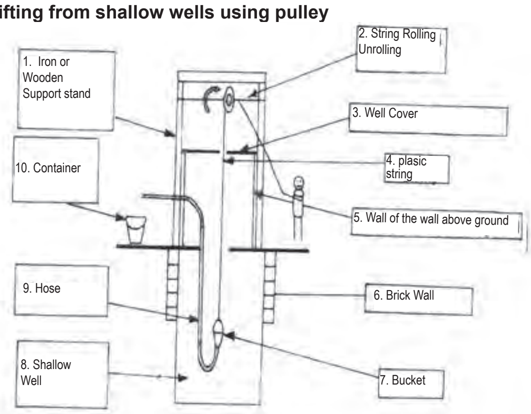
(13) Shadouf, rope and bucket, pulley, roller, treadle and steps lifting methods

Shadouf - to supply irrigation water

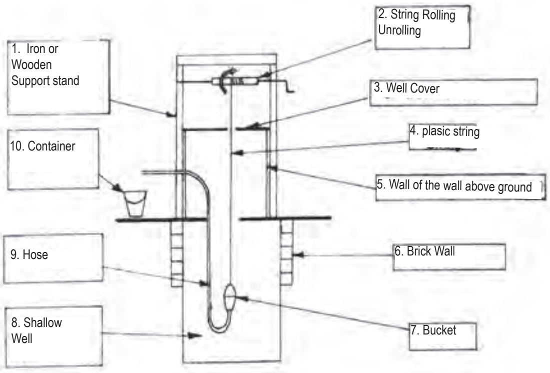
Rope and Bucket for domestic water use



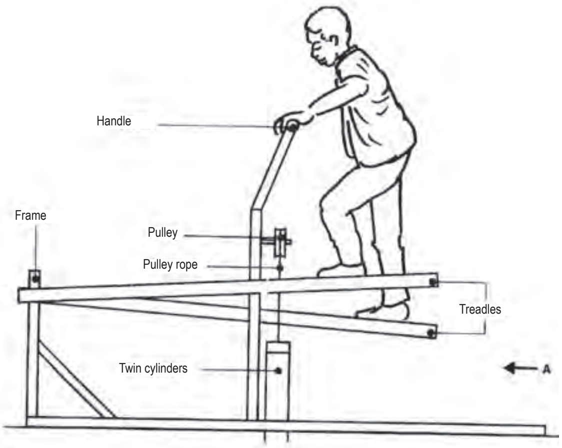
Lifting from shallow wells using pulley



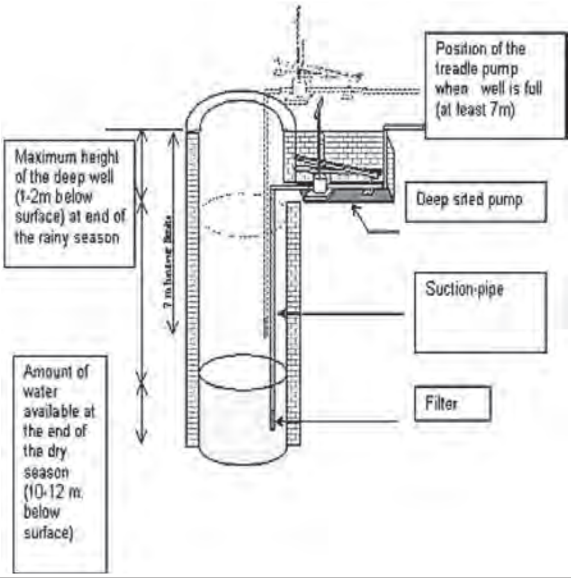
Lifting from shallow wells using rope and roller



The treadle Pump



Treadle Pump : Most effective low cost water lifting tool compared to other labor intensive tools



Thailand Water Lifting From Wells

Steps in well for water drawing

(14) Limitations

The low cost water lifting technologies are applicable to shallow water sources and irrigation of small plots upto a maximum of 0.5 ha.

(15) Institutional responsibility

.To be implemented as part of an integrated watershed development intervention.
. Fully on individuals/groups +/- community (commitment to mgt.)
. DAs and wereda experts - technical support and follow-up/mgt.

TECHNICAL INFORMATION KIT

LOW COST MICROPONDS (MP)

(1) Period/phases for implementation

. Only during dry season and min. one month before rains likely to occur.

(2) Objectives/remarks

. Supplementary irrigation to high value crops (horticulture, fruit trees, etc.).

. Water for livestock for a few months.

. Microponds allow to use surface runoff from small catchment areas within and between homesteads (foot paths, small grazing land areas, rocky areas, etc.). Can also collect water from feeder roads, graded bunds, spillways, etc.)

. Water collected can be used during the rainy season as supplementary irrigation (during dry spells) or after (1-2 months max) for additional support to horticulture crops, fruit trees, compost, small livestock, beekeeping, etc.

(3) Suitability, agro-ecology and adaptability based upon local knowledge

. Suitable in most agroclimatic zones except in areas with excessive dryness (below 400 mm rainfall) as not cost effective. They are suitable when hand-dug wells are not possible, even after watershed treatment (water tables too low). MPs need demonstration before expansion - also need support in terms of tools for increasing depth and deal with rocky subsoil, stone shaping, seepage, etc.

(4) Main land use	(5) Technical preparedness
. Mostly around homesteads. . Possible to apply on open fields to collect water from graded bunds,and waterways. . At the foot of hillsides to increase recharge of water tables. . Inside large gullies and at the foot of treated hillsides.	. Training required (DAs and farmers) . Discuss/agree with farmers on location, size, production area, catchment areas and on-the-job training. Test measures first.

(6) Potential to increase/sustain productivity and environmental protection	(7) Minimum surveying and tools requirements
. Assist grow of high value/cash crops especially high value trees in areas with low rainfall. Can support income generation activities of small land holders and assist landless with homesteads. Assists controlling runoff and can promote keeping of livestock near residences. . Can promotes better fertility management (compost, etc) and agronomic practices.	**Survey**: pegs, 10-15 meters string, measuring tape Construction: crow bars, pick axes, shovels and wooden compactors Labour group: min 5 people per micropond to increase efficiency

(8) Design & technical standards (fig 1)

Main Types:

1) Microponds (cemented): Useful for small-scale irrigation both during (supplementary) and few months after the rainy season.
2) Microponds (not cemented): Useful mostly during the rainy season as supplementary irrigation during dry spells and to recharge ground water.
Design:
A) Round shaped micro-ponds (cemented and not cemented) --> For detail design procedures consult guidelines provided by the MoARD/BoARD in each region: Usually 4-6 meters radius and 3-4 meters deep. The cone of the pond is truncated at its bottom, allowing for 2-3 meters diameter flat bottom. Volume calculated approx as fig 1-a based on small micro-catchments (400-1000m²), supply of excess runoff from feeder roads, footpaths, small closures, grazing areas, compounds, etc. Use pole and string with knots placed at different diameters based on size of pond to facilitate excavation. The bottom and sides of ponds should be tightly stone paved/faced using mortar (cement/sand 1:4), reinforced with mesh and plastered (cement/sand ratio 1:2-3). Moist the cemented wall /bottom for 2-3 weeks after construction to avoid cracks.
B) A lower cost micropond measure applicable in areas with medium textured soils is to apply clay blankets (20-30 cm) lined and compacted at the bottom to decrease vertical seepage. While applying the clay blanket moisturize and compact every 3 cm. Walls can also be stone faced and plastered using local mortar ("chika") mixed with teff straws, dung and cement (cement: soil ratio is 1: 6-8). This can only reduce lateral seepage and cracks need to be filled every year. A second option is that in addition to clay blankets side walls could be built stone stepped to facilitate access. In this case, the stone masonry work should be carefully done, and space between stones filled with mortar. Test this measures at small scale first.
C) Square or rectangular microponds: depth (2.5m to 3.5m) - may be larger in size. Side slope 1:1. Size of pond and volume as in **fig 1-b**. Rectangular ponds are usually cheaper, not cemented and used mostly to supplement water during rainy season (during dry spells). To reduce seepage a system of stone paving + a clay blanket (10-15cm layer) and/or plastic sheets can be used. Alternatively use local bricketing and seal gaps with mortar as above. Side walls (faced or stone stepped can also be built) to increase stability and reduce lateral seepage.

NOTE:All microponds need to be shaded to prevent malaria. A low cost shade is made out of a central pole placed in the middle of the pond linked to "tukul" like wooden frame covered by thatch (using straws) or mats.

(9) Integration opportunities/requirements	(10) Work norm	(11) Use of microponds from different sources of runoff
1. Construct small silt traps before water enters the MP (2mLx2mWx1mD). More than one silt trap may be required (especially for microponds collecting water from erodible soils - check first year and add one if necessary). 2. Provide each MP with a stone ladder, or a wood ladder, or hard soil hewn steps, to facilitate fetching water. 3. Microponds integrated with proper seedbed preparation for horticulture crops, compost making, beekeeping, watering of fruit trees, improved water lifting systems, etc. 4. Build the shade as indicated in (8)	(1) Excavation (1PD/0.5 m³) (2) Stone collection and shaping PD/0.5 m³) for stone stepping/facing of walls (3) Shading (thatched roof, etc) (4) Others as required (such as small cutoff drains and waterways see other infotechs).	1. Illustration of Microponds using microcatchments - figure 2. 2. Example of Microponds using overflow from springs (single or as relay structure based on amount of flow) - figure 3. 3. Example of Microponds placed as relay system along paved waterways (with drop structures and graded bunds) - figure 4. 4. Microponds receiving water from small cutoff drains (single or in series of relay cutoff drains) - figure 5.

(12) Planning and implementation arrangements	(13) Management requirements
. Planning follows groups and individual owners' agreement on location, source of runoff to exploit, purpose, type of crops and management. Groups of 3-5 households work together to increase efficiency. Skilled mason required for cemented structures.	. Removal of silt from reservoir/silt trap as required (can be used for seed beds if fine). Check the shading is effective (mats, others). Check fence for safety (aware children of hazards).

(14) Limitations	(15) Institutional responsibility
. Not suitable in unstable soils, e.g. sandy/sandy loam or very expandable soils. . Water not suitable for domestic drinking purposes. May induce water borne diseases. . Limited efficiency - only for supplementary irrigation of small plots.	. Fully on individuals/groups for management. . DAs and wda experts - technical support and follow-up/mgt.

Fig 1 Design of microponds

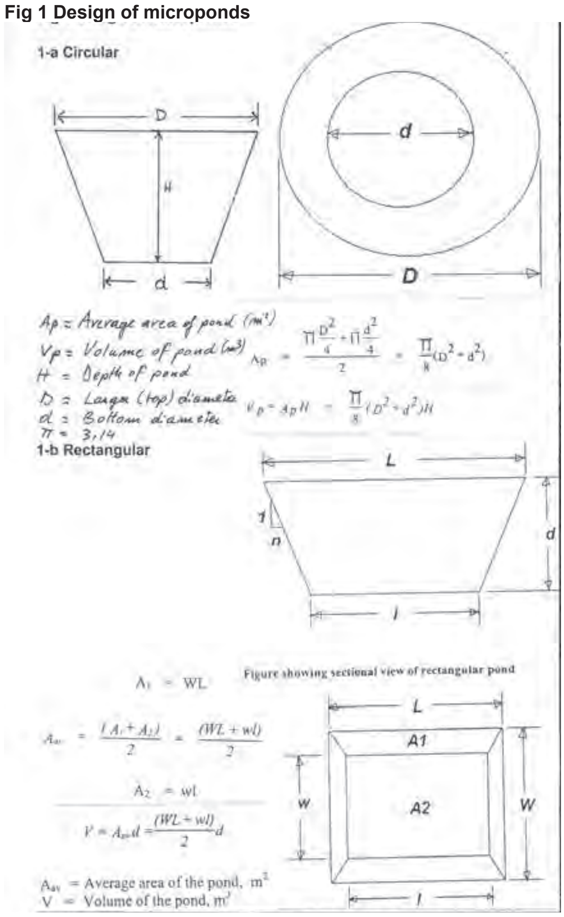


Fig 2 Example of micropond below microcatchments

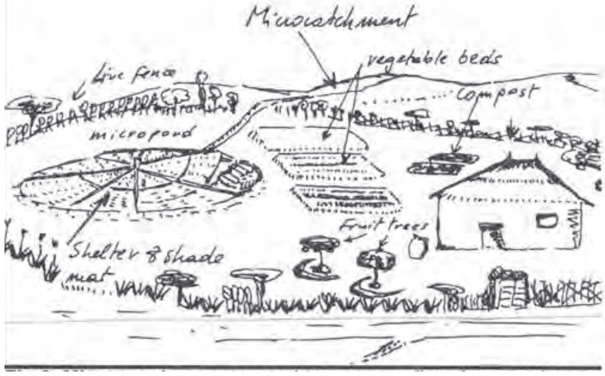
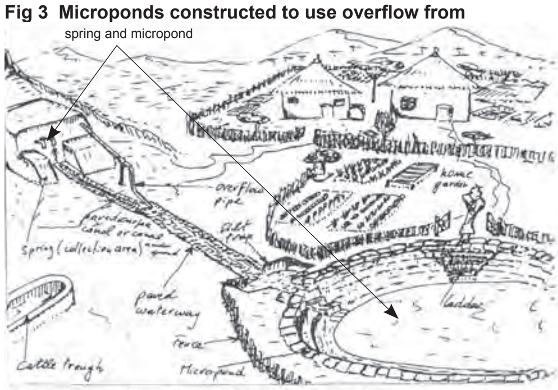
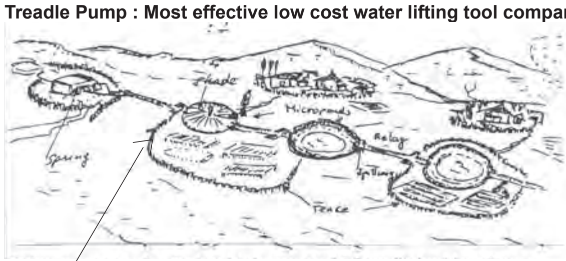


Fig 3 Microponds constructed to use overflow from



Collects overflow (especially night flow)

Treadle Pump : Most effective low cost water lifting tool compared to other



Relay microponds storing high overnight flow (linked by stone paved waterways)

Fig 4 Microponds as relay system along paved waterways (receiving water from graded bunds). Cultivation of cash crops near pond (during rainy season dry spells)

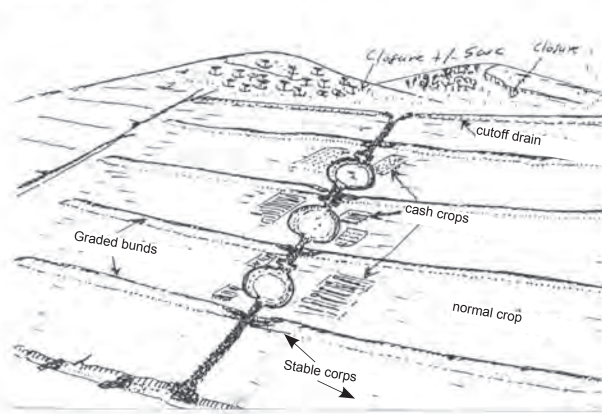
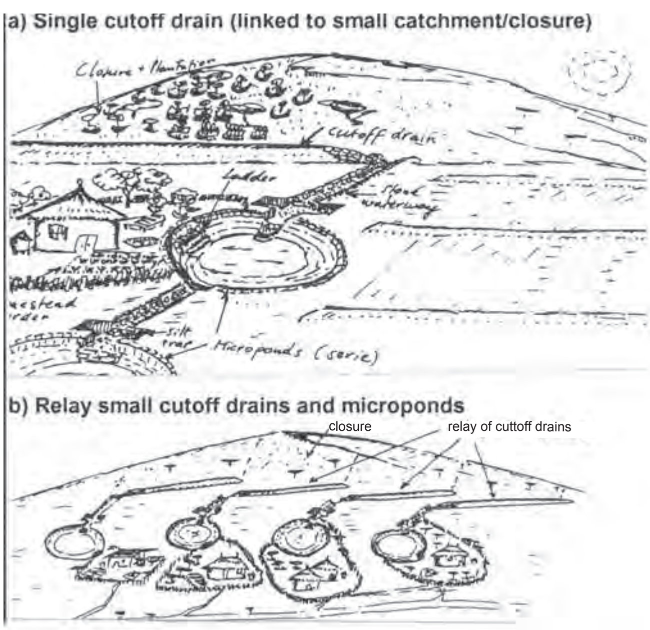


Fig 5 Microponds collecting water from small cutoff drains



TECHNICAL INFORMATION KIT	(1) Period/phases for implementation	(2) Objectives/remarks
UNDERGROUND CISTERNS (Hemispherical, Dome cap, Bottle shapephere, Sausage shape)	. Only during dry season and min. one month before rains likely to occur. But if water for mixing and curing of cement is a limitatin moist season is ok.	. Supplementary irrigation to high value crops(horticulture, fruit rees, small livestock, etc.) . Water for livestock for a few months .Water for raising seedlings in dry seasons . Microponds allow to use surface runoff from small catchment areas within and between homesteads (foot paths, small grazing land areas, rocky areas, etc.). . Water collected can be used during the rainy season as supplementary irrigation (during dry spells) or after (1-2 months max) for additional support to horticulture crops, fruit trees, compost, small livestock, beekeeping, etc.)

(3) Suitability, agro-ecology and adaptability based upon local knowledge

. Low at introduction stage - b/c could require purchased inputs (cement, chicken mesh, reinft.bars, pipes, etc.) - may need support in terms of long-term credit, skilled labor, tools, seepage and evaporation control, etc.
. Suitable to enhance horticultral production that can be used as cash crops (particularly less or non perishable crops, vegetables, fruit trees, etc.). Stable/average soils than sandy or heavy clay soils.

(4) Main land use	(5) Technical preparedness
. Mostly around homesteads. . Possible on open fields to collect water from graded bunds, and waterways. Can also collect water from feeder roads, cutoff drains, waterways, spillways, etc.	. Training required (DAs and farmers) . Discuss/agree with farmers on location, size, production area, catchment areas and on-the-job training. Technical assistance required.

(6) Potential to increase/sustain productivity and environmental protection	(7) Minimum surveying and tools requirements
. Assist grow of high value/cash crops especially high value trees in areas with low rainfall. . Can support income generation activities of small land holders and assist landless with homesteads. Assists controlling runoff and can promote keeping of livestock near residences. . Can promotes better fertility management (compost, etc) and agronomic practices.	**Survey**: pegs, 10-15 meters string, measuring tape, Construction: crow bars, pick axes, shovels, mason's hand tools, ladder, metal hack saw, barrel, plumbob, pliers, carpenter's tools, Labour group min 5 people per cistern to increase efficiency

(8) Design and technical standards (see figs 1 to 6 at the back)

Main Types by shapes: Hemishpherical, Dome cap, Bottle shape, Spherical, Sausage, etc.
1) Hemispherical: Useful to small-scale irrigation during (supplementary) and after the rainy season, easy construction, takes up space
2) Dome/Sphere/bottle/Sausage: Relatively requrie stable soils,if properly done less seepage/evaporation loss, take less space.
Design: Sizing a water tank: If the monthly rain data of an area is available , and monthly water demand for any activity in the same area is known, the required size of the tank can be estimated easily as shown below :
Step 1 Obtain average monthly rain fall of an area for a minimum of 8-10 years.
Step 2 Rank rain fall data of the months starting with the highest rainfall.
Step 3 Select the catchement type and size that will be available for use:
Step 4 Calculate the monthly runoff amount (in flow) that can be generated from the given catchement area.
Step 5 Calculate the monthly water demand (out flow) for each type of use.
Step 6 Calculate the cumulative in flow (supply) for each month.
Step 7 Calculate the cumulative out flow (demand) for each month.
Step 8 Compute the difference between total water available (inflow) and demand (outflow) for each month (step 6 minus step 7)
Step 9 Subtract the smallest negative difference from the largest posetive difference (from step 8). The value obtained will be the required water tank size for the annual water demand.
Siting conditions: 1. Locate the tanks where the largest amount of water can be stored. 2. Avoid sites near unstable ground, such as gullies, landslides or neer deep-rooted trees. Do not plant trees with deep roots near the tanks.
Under ground cisterns as compared to above ground tanks can store more water at lower cost b/c the ground supports the weight. This means walls can be thinner than for above ground tanks. Water is relatively colder, the water to be stored may come from the ground surface or from rooftops. The tank fills quickly.

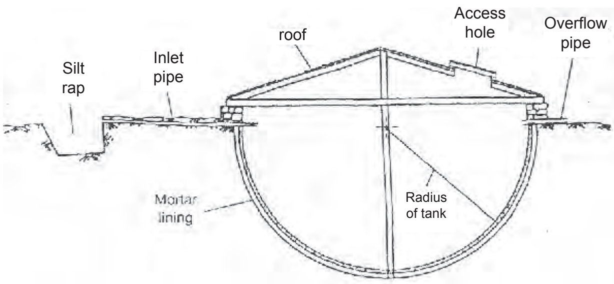
(9) Integration opportunities/requirements	(10) Work norm	(11) Use of microponds from different sources of runoff
1. Construct small silt traps before water enters the MP (2mLx2mWx1mD), see fig 6. More than one silt trap may be required (especially for microponds collecting water from erodible soils - check first year and add one if necessary). 2. Integration with low-cost lifting and drip systems to facilitate fetching water and water application to each plant. 3. Cisterns should be integrated with proper seedbed preparation for horticulture crops, compost making, beekeeping, watering of fruit trees, small livestock, etc. 4. Fencing in the case of the hemispherical and proper lid	(1) Excavation (1PD/0,5 m³) (2) Stone collection and shaping (1PD/0,5 m³) for stone pavement/facing of walls (3) Shading (thatched roof, etc) (4) Others as required (such as small cutoff drains and waterways see other infotechs)	1. Illustration of cistern hemispherical shape - fig 1 2. Sketch of emispherical cistern - fig 2 3. Illustration of cistern - dome cap - fig 3 4. Illustration of cistern - spherical - fig 4 5. Illustration of cistern - bottle shape - fig 5 6. Illustration of the silt trap - fig 6

(12) Planning and implementation arrangements	(13) Management requirements
. Planning follows groups and individual owners' agreement on location, source of runoff to exploit, purpose, type of crops and management. Groups of 3-5 households work together to increase efficiency. Skilled mason required for cemented structures.	. Removal of silt from reservoir/silt trap as required (can be used for seed beds if fine). Check the shading is effective (mats, others). Check fence for safety (aware children of hazards).

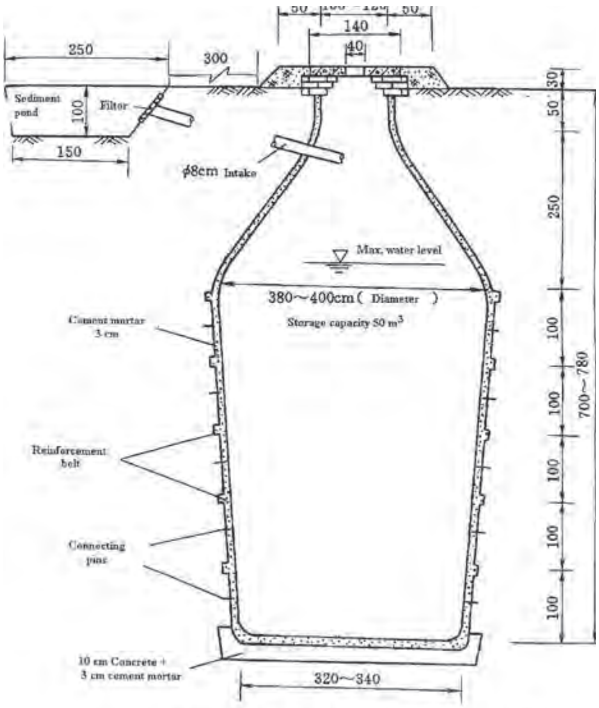
(14) Limitations	(15) Institutional responsibility
. Not suitable in unstable soils, e.g. sandy/sandy loam or very expandable soils. . Water not suitable for domestic drinking purposes. May induce water borne diseases. . Limited efficiency - only for supplementary irrigation of small plots. Credit facility required.	. Fully on individuals/groups for management . DAs and wda experts - technical support and follow-up/mgt.

1. Illustration of cistern hemispherical shape - fig 1

2. Sketch of hemispherical cistern - fig 2

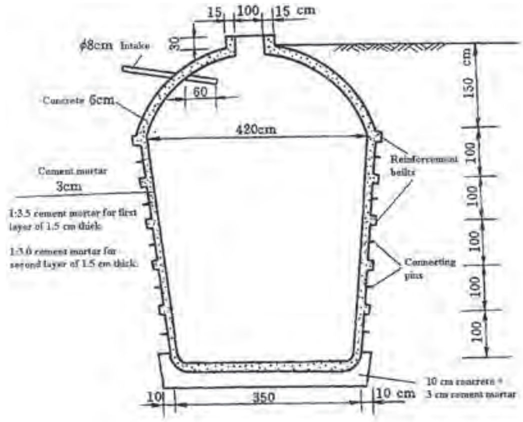


5. Illustration of cistern - bottle shape - fig 5



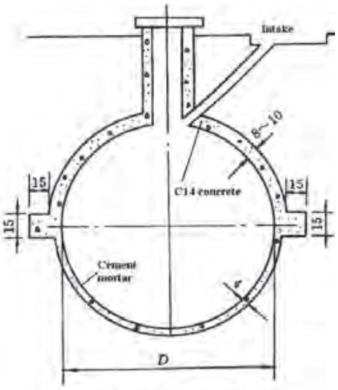
Underground tank lined with cement mortar (Unit in cm)

3. Illustration of cistern - dome cap - fig 3



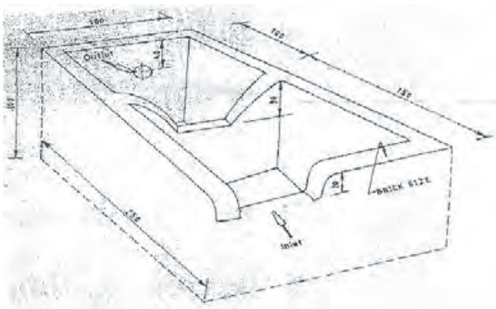
Concrete dome tank

4. Illustration of cistern - spherical - fig 4



Spherical tank (Unit in cm)

6. Illustration of the silt trap - fig 6



Competed silt trap

TECHNICAL INFORMATION KIT	(1) Period/phases for implementation	(2) Objectives/remarks
PERCOLATION PIT	. Only during the dry season and period not interfering with Agriculture	A percolation pit is a structure, constructed on any marginal land with perviouos soil, with the following objectives: 1. Recharge the ground water 2. Enhance biomass production through improved water availability in the soil profile. 3. Reduce runoff and subsequently erosion and land degradation.

(3) Suitability, agro-ecology and adaptability based upon local knowledge

. Suitable in all areas where there is no drainage problem or where the grounnd water table is deep.
. Suitable in areas where the ground is pervious
. Can be constructed on any topography with adequate runoff.
. It should be considered only as an element of an inegrated watershed development.

(4) Main land use	(5) Technical preparedness
.Marginal lands .Gullies	. 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

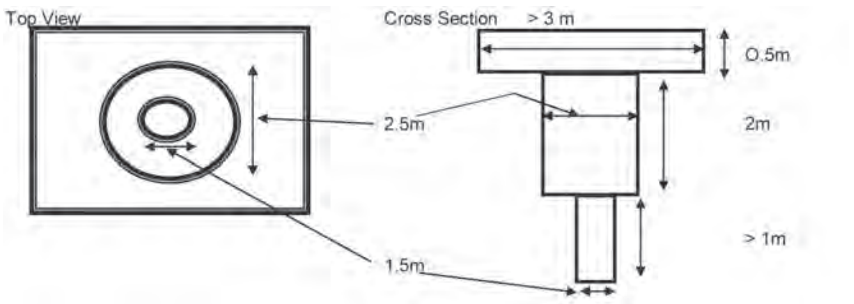
. Enhanced ground water availability for human and livestock use and irrigation.
. Water stored in the upper 1-3 m of the soil profile can sustain vegetative growth.
. Capturing the runoff by a series of ponds and related structures would retard surface runoff and subsequently avert land degradation.

(7) Minimum surveying and tools requirements

Layout: The pit can be circular or take the shape of the available land. Mark the top 0.5m deep pond and again mark the 2.5m pit.

Work: Dig the first 0.5m deep pond. Then dig the 2m deep pit. Next dig the 1.5m diameter pit. Fill the lower portion with 4cm stone.

(8) Layout



(10) Work norm

WORK NORM: 1 m3 / Personday for the first 1m depth; 0.5 m3 /PD therafter.

The worknorm involves digging, disposing of spoil, excavation of diversion canal

Gravel and stone collection

0.5 m3 / Personday

(9) Minimum Technical Standard

Percolation pits could be constructed in a wide range of conditions; (1) at any marginal land.(2) at outlets of cutoff drains/water ways (3) at abandoned quarries and depressions. There should be ample runoff that is free from pollution.

1) Excavate a 50 cm deep pond of any shape with either sides ranging from 2.5 to 10 meters.

2) Inside the o.5m pond, excavate a pit with a diameter of 2.5m and depth of 2 m.
3) Inside the pit excavate another pit with a dia. of 1.5m to a minmum depth of 1m or more.

4) The upper most portion of the pit is covered with an artificial filter to prevent suspended materials from entering in to the aquifer with recharged water.

The filter consists of 0.4m thick coarse sand, 0.5 m thick gravel (diameter 20mm) and stones of 40 mm size starting from 1m below the surface up to the bottom end.

(12) Modifications/adaptation to standard design

. The larger the pond sizes the better the recharge of the underground water.
. Spacing between two pits shall be about 50 meter.

(14) Management requirements

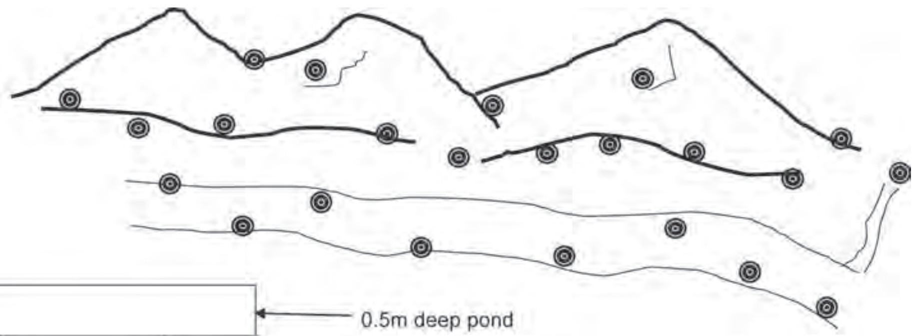
. Percolation pits require proper regular follow-up and maintenance through user groups.
. Silt deposited in the pit prevents water from percolation. Thus, it has to be removed 3 to 4 times during the rainy season.
. It is also necessary to ensure adequate runoff is diverted to the pond.

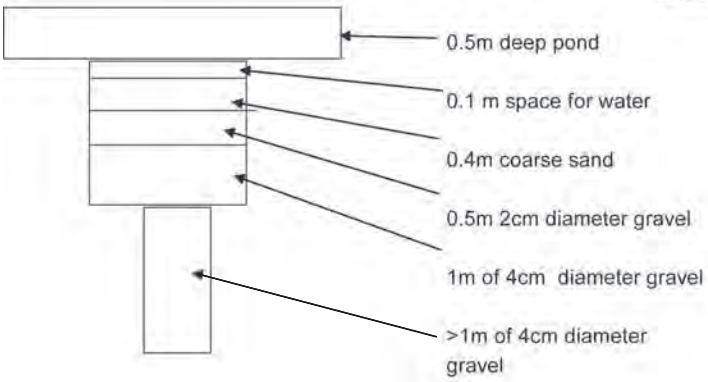
(13) Planning and Implementation arrangements

. Planning follows community/groups and individual owners' discussion/agreement on layout, spacing and management requirements.

(15) Limitations	(16) Institutional responsibility
Percolation pits shall not be excavated under the following conditions: 1) Little or no runoff 2) Weathered limestone/alkaline soils - as it would increase PH of the water; 3) Catchment with high concentration of manure or animal wastes - as it would increase the nitrate content of the groundwater; 4) Close to deep gorges - as the recharged water becomes unavailable easily; 5) Clay or impermeable geological formation - as it does not allow fast percolation of water	.To be implemented as part of an integrated watershed development intervention. . Fully on individuals/groups +/- community commitment to management. . DAs and wereda experts - technical support and follow up/ mgt.

Possible locations of a Percolation pit/pond





Excavation	Backfilling	Gravel on top of the small stones Coarse sand on top of the gravel
		

TECHNICAL INFORMATION KIT

PERCOLATION POND

(1) Period/phases for implementation

. Only during the dry season and period not interfering with Agriculture

(2) Objectives/remarks

A percolation pond is a structure, constructed on any marginal land with perviouos soil, with the following objectives:

1. Recharge the ground water
2. Enhance biomass production through improved water availability in the soil profile.
3. Reduce runoff and subsequently erosion and land degradation.

(3) Suitability, agro-ecology and adaptability based upon local knowledge

. Suitable in all areas where there is no drainage problem or where the grounnd water table is deep. Suitable in areas where the ground is pervious Can be constructed on any topography with adequate runoff.It should be considered only as an element of an inegrated watershed development.

(4) Main land use

. Marginal lands

(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

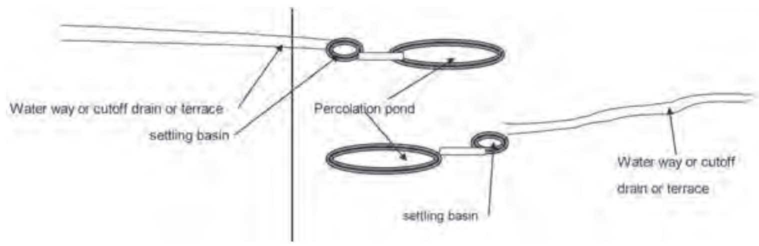
. Enhanced ground water availability for human and livestock use and irrigation.
. Water stored in the upper 1-3 m of the soil profile can sustain vegetative growth.
. Capturing the runoff by a series of ponds and related structures would retard surface runoff and subsequently avert land degradation.

(7) Minimum surveying and tools requirements

Layout: The pond can be trapezoidal or take the shape of the available land. Mark the top and bottom edges by pegs.

Work: Dig vertically following the mark of the bottom edge. Then trim the earth to join the bottom and top edges.

(8) Layout



(10) Work norm

WORK NORM: 1 m3 / Personday for the first 1m depth; 0.5 m3 /PD therafter

The worknorm involves digging, disposing of spoil, excavation of diversion canal and at a later stage removal of silt deposition from the pond surface.

(9) Minimum Technical Standard

Percolation ponds could be constructed in a wide range of conditions;

(1) at any marginal land.
(2) at outlets of cutoff drains/water ways
(3) at abandoned quaries and depressions.There should be ample runoff that is free from pollution.

(11) Modifications/adaptation to standard design

. The larger the sixe the better the recharge of the ground water
. Minimum Spacing between two percolation ponds shall be about 50 meters.

(12) Planning and Implementation arrangements

. Planning follows community/groups and individual owners' discussions/agreement on layout, spacing and management requirements.

(13) Management requirements

. Percolation ponds require proper regular follow-up and maintenance through user groups.
. Silt deposited in the pond prevents water from percolation. Thus, it has to be removed 3 to 4 times during the rain season.
. It is also necessary to ensure adequate runoff is diverted to the pond

(14) Limitations

Percolation ponds shall not be excavated under the following conditions:
1) Little or no runoff
2) Weathered limestone/alkaline soils - as it would increase PH of the water;
3) Catchment with high concentration of manure or animal wastes - as it would increase the nitrate content of the groundwater;
4) Close to deep gorges - as the recharged water becomes easily unavailable;
5) Clay or impermeable geologicalformation - as it does not allow fast percolation of water

(15) Institutional responsibility

.To be implemented as part of an integrated watershed development intervention.
. Fully on individuals/groups +/- community (commitment to mgt.)
. DAs and wereda experts - technical support and follow-up/mgt.

Percolation Pond Lined with stone riprap to prevent erosion of the sides

Percolation ponds constructed in rocky terrain may not need protection of the sides

TECHNICAL INFORMATION KIT

Farm Pond Construction

(1) Period/phases for implementation

Construction of ponds should be during, dry season before rainfall occurs

(2) Objectives/remarks

.To store surface water for use during dry seasons for the purpose of domestic use, human consumption, irrigation or for fish production.

(3) Suitability, agro-ecology and adaptability based upon local knowledge

A suitable site for a pond is where a limited amount of excavation is required to contain, or hold back a large volume of water. A valley were a dam can be constructed at a narrow pass is a good example.
The designer or expert should also think about the size of the catchment area to get enough runoff to fill the pond.
(1) Ponds should be located at a point where maximum volume of water can be collected with least digging or earth fill. (2) Ponds for livestock should be well spaced as the livestock should not travel more than one km. (3) To avoid pollution, the site should be away from farm drainage and sewage lines. (4) The drainage area should be sufficient to provide adequate runoff.

(4) Minimum tools required

(1) Wooden pegs, measuring tape or marked string.
(2) Sledge hammers, crow bars, shovels, pick axes, wheel barows and barella (to carry out soil), backets
(3) Workers or labourers

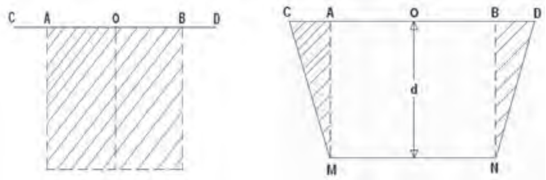
(5) Worknorms (WN)

Average worknorm is 0.5 m3/pd. The WN invloves surface clearing, digging, disposing or removal of soils and excavation works.

(6) Construction Procedures (layout)

1. Mark the pond on the ground
2. Start digging the pond
3. Keep the soil 3 m away from the edge of the pond
4. Consider point O as the center of the pond
5. If the side slopes are considered to be same in both sides, the distance of points AC and BD are equal. Similarly, distances of points OA and OB are as well equal.
6. Start excavating or digging AMNB first and then shape CAM and DBN as shown above.
7. Excavate similar dimensions on the width wise direction

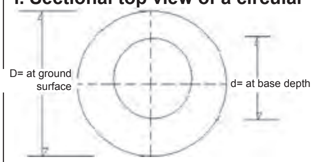
Construction procedures



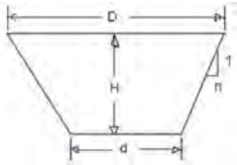
(7) Design and determination of volumes

To determine the volume of water to be stored in the pond, the volume of expected water use should be calculated.
Volume of a pond is calculated based on the shape of the pond.
(a) Volume of a **circular pond** can be calculated by multiplying the average area of the pond by its depth. (1) To avoid collapsing or sliding of the sides of ponds, it should have a certain permissible side slope. (2) The volume of the sloping sides therefore should be deducted from the total volume of the pond.

i. Sectional top view of a circular



ii. Sectional view of a circular



The average area of a circular pond is calculated using the following formula

$$A_s = \frac{\Pi D^2}{4} \qquad A_b = \frac{\Pi d^2}{4}$$

π = 22 / 7 = 3.1428.

Where, As = Area at the surface of the pond, m2
Ab = Area at the base of the pond, m2

$$A_{av} = \frac{A_s + A_b}{2} = \frac{\Pi(D^2 + d^2)}{8}$$

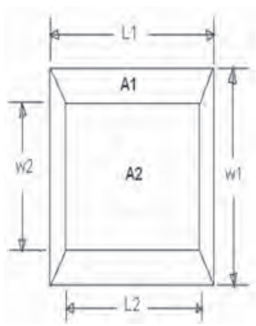
Where, Aav = Average area of the pond, m2
The average volume or capacity of a pond can be calculated by using the following formula:
Vav = =Aav x H = {π (D2+d2)/8} x H
Where,
Vav = Volume or capacity of the pond, m3
H = Depth of the pond, m.
D = Diameter of the pond at the surface, m.
d = Diameter of the pond at the bed of the pond, m.

(11) Modifications/adaptation to standard design

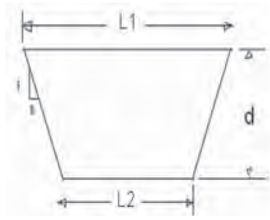
(b) Volume of a **rectangular pond** can be calculated by multiplying the average area of the pond by its depth.

The surface area (A1) and area at the bottom of the pond (A2) is calculated as follows:
A1 = W1 x L1
A2 = W2 x L2
Aav = (A1+A2)/2 =
= {(W1 x L1) + (W2 x L2)}/2
Where,
Aav = is the average area of the rectangular pond, m2
A1 = Area at the surface of the pond, m2
A2 = Area at the based of the pond, m2
W1 = Width of the pond at the surface, m
W2 = Width of the pond at the base, m
L1 = Length of the pond at the surface, m
L2 = Length of the pond at the base, m
Volume of a rectangular pond can be calculated by using the following formula,
Vav = Aav x d = {(W1 L1+W2 L2) x d}/2
Where,Vav = average volume or capacity of the rectangular pond, m3
d = Depth of the pond, m

iii. Sectional top view of a rectangular pond



iv. Sectional view of a rectangular pond



TECHNICAL INFORMATION KIT	(1) Period/phases for implementation	(2) Objectives/remarks
Spring Development	. Only during the dry season and period not interfering with land preparation	Proper spring development helps protect the water supply from contamination. The objective of spring development is to collect the flowing underground water to protect it from surface contamination, store it and avail for use.

(3) Suitability, agro-ecology and adaptability based upon local knowledge

. A spring is a place on the earth's surface where groundwater emerges naturally. The water source of most springs is rainfall that seeps into the ground uphill from the spring outlet.
. Spring water moves downhill through soil or cracks in rock until it is forced out of the ground by natural pressure. The amount, or yield of available water form springs may vary with the time of year and rainfall.
. Springs are susceptible to contamination.

(4) Main land use	(5) Technical preparedness
. In areas where groundwater emerges naturally.	. Field assessment for the presence of unprotected . springs and layout + provide on-the-job training . Precise layout and follow-up/adaptations

(6) Potential to increase/sustain productivity and environmental protection	(7) Minimum surveying and tools requirements
Springs are ideal water supply sources for drinking and irrigation if properly developed and protected.	**Layout**: Delinate the seep area using pegs. Locate the collection walls and spring box. **Work**: Insert a collector pipe low in the cutoff wall to guide water into the spring box.

(8) Layout

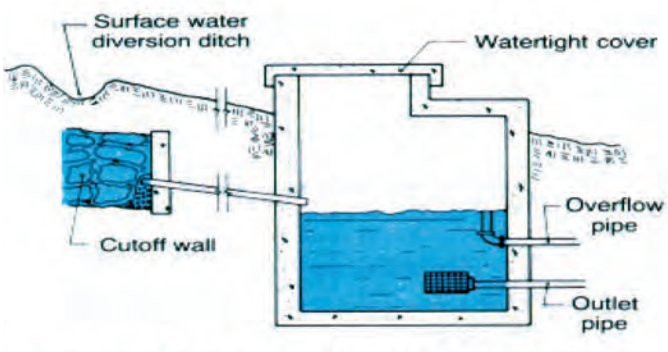


Figure 1a. Cut-away view of a concentrated spring.

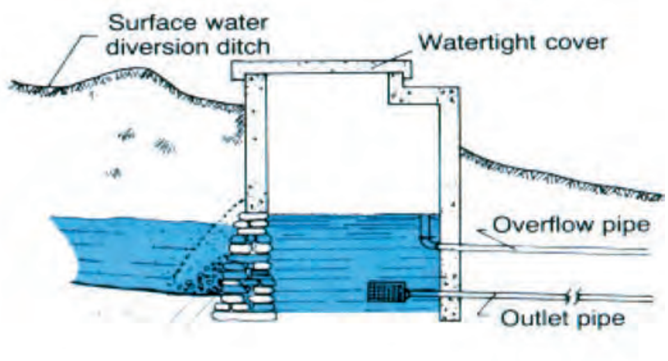


Figure 1b. Cut-away view of a low-area spring.

(10) Work norm

WORK NORM: 1 m3 / Personday

The worknorm applies for excavation, stone collection, foundations/key excavation and proper placement of checkdams and drop/aprone structures.

Masonary
WORK NORM: 0.5 m3 / Personday

(11) Modifications/adaptation to standard design

For concentrated springs intercept the water underground in its natural flowpath before it reaches the land surface (Figure 1a)

(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) Management requirements

. Springs are susceptible to contamination by surface water, especially during rainstorms.

(1) Divert all surface water away from the spring as far as possible.

(2) Do not allow flooding near the spring

(3) Fence an area at least 30m in all directions around the spring box to prevent contamination by animals and people;

(4) Avoid heavy vehicle traffic over the uphill water bearing layer to prevent compaction that may reduce water flow.

(9) Minimum Technical Standard

1. Dig test holes uphill from the seep to find a point where the impervious layer below the water-bearing layer is about 1m underground. Water flows on top of this layer in sand or gravel toward the surface seep.

2. Dig a 60cm-wide trench across the slope to a depth of 15cm below the water-bearing layer and extending 1.5 to 2m beyond the seep area on each side.Install a 10cm collector tile and completely surround the tile with gravel.

3. Connect the collector tile to a 10cm line leading to the spring box. The box inlet must be below the elevation of the collector tile.

4.The spring box should be watertight. It should be at least 1.2m high and should extend at least 30cm above ground level when buried. It should be at least 1m square.

(14) Limitations	(15) Institutional responsibility
. Springs are susceptible to contamination from surface runoff. . Springs may not be a good choice for drinking if the catchment area is used for industry and agriculture that uses chemicals, or other potential sources of pollution.	. Fully on groups +/- community (commitment to mgt.) . DAs and wda experts - technical support and follow-up/mgt.

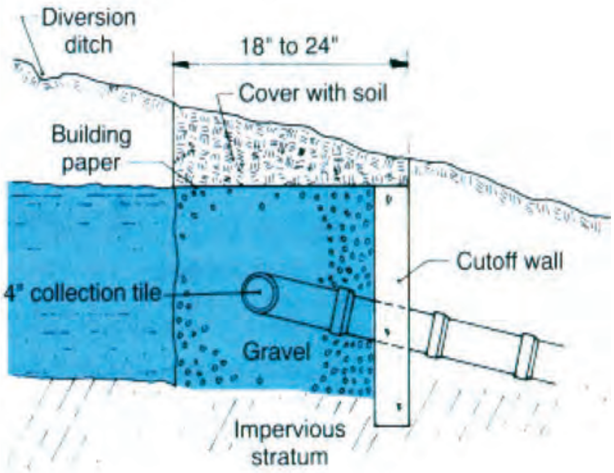
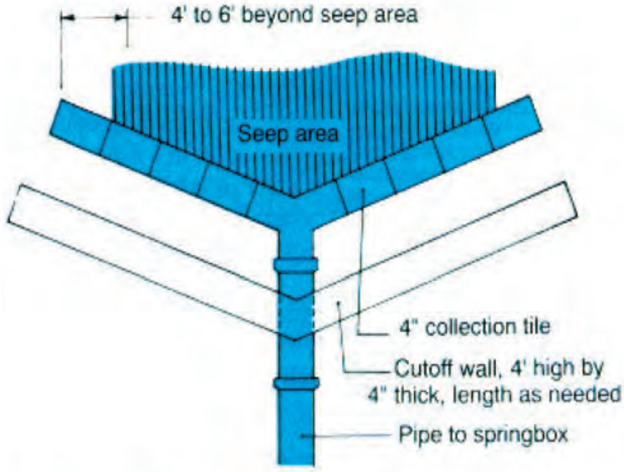


Figure 2a. Cut-away view of a seepage spring.



'igure 2b. Overhead view of a seepage spring.

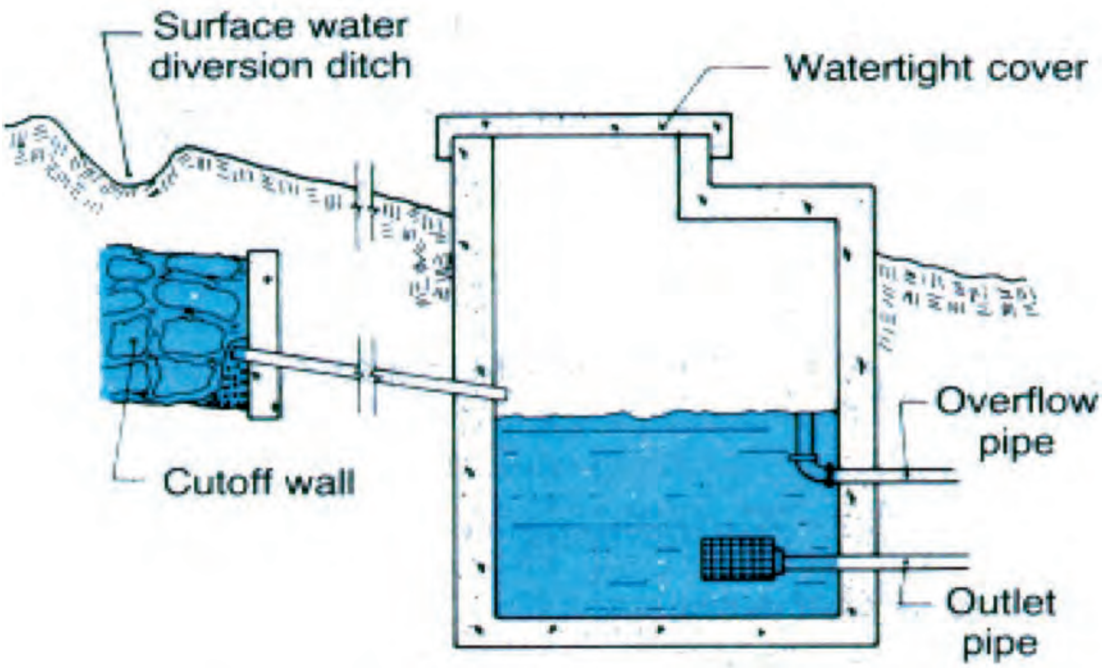


Figure 1a. Cut-away view of a concentrated spring.

TECHNICAL INFORMATION KIT	(1) Period/phases for implementation	(2) Objectives/remarks
Family Drip Irrigation System	Can be installed any time of the year.	Increased frequency and uniformity of water application plus reduced competition from weeds results in improved plant growth and yield increases of 30 to 50 percent. The system is instrumental in increasing the size of plot and provide the right amount of water to crops at the the right time. Thus, resulting in increased production.

(3) Suitability, agro-ecology and adaptability based upon local knowledge

Family drip irrigation system is an important tool for resource poor farmers.
It is best suited to arid and semi arid areas where water is very scarce.

(4) Main land use	(5) Technical preparedness
Can be located on any land use, but close to the area of use.	. 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

Crops irrigated by drip systems show water savings of up to 50 percent resulting in reduced labour and energy costs.

Controlled application of water to the plants suppresses weed growth, further reducing labour costs

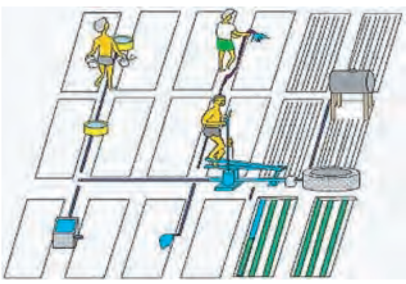
(7) Minimum surveying and tools requirements

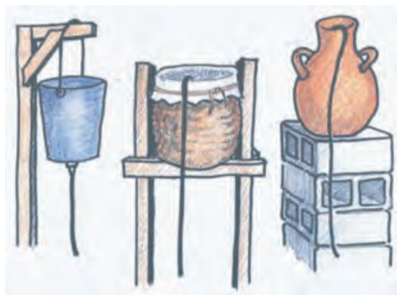
Simple strings to ensure that the rows are straight.

(10) Work norm

NA

(8) Layout





(9) Minimum Technical Standard

Drip irrigation delivers water directly to the plant through a system of plastic tubes with minimal water loss. The family drip system operates under 1 to 2 m water pressure. One family drip system can irrigate from 25m^2 to 1000 m^2 and over.The system is suitable only for row planted crops.

(11) Modifications/adaptation to standard design

A single lateral tube can be used to irrigate several rows of plants by manually shifting the line between rows. Useful where the cost of plastic tubing is high and the cost of labour is low.

(12) Planning and Implementation arrangements

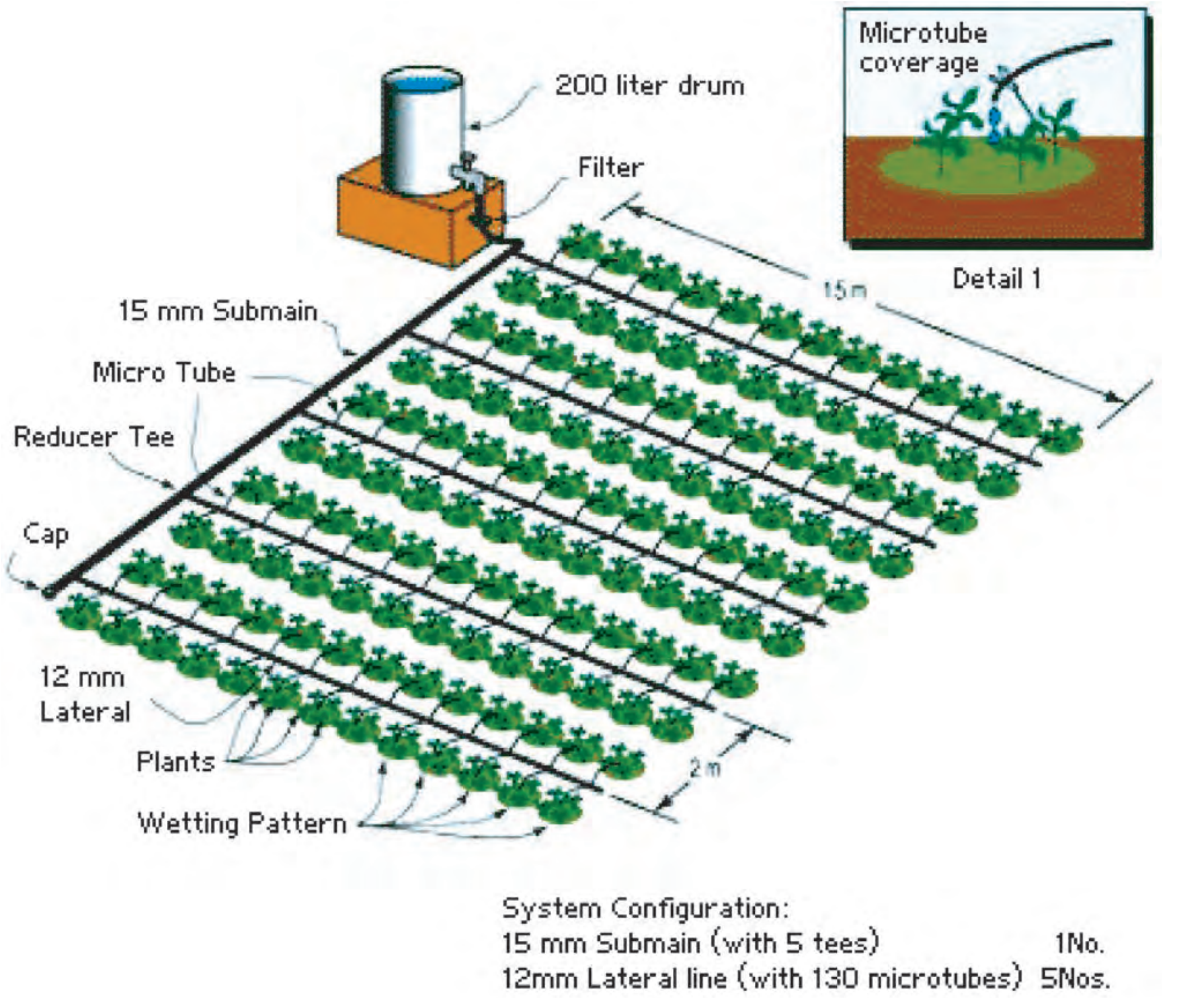
. Planning follows community/groups and individual owners' discussions/agreement on layout, spacing and management requirements.

(13) Management requirements

Training in the area of irrigation agronomy, water management and drip irrigation operation and maintenance is essential.

Ensure the water is properly filtered and the pipes are flushed once in a month.

UREA can be supplied to the crops through the drip system. But, it is not recomeneded to apply DAP using the system as it clogs the emmitters.



(14) Limitations	(15) Institutional responsibility
Emitters are liable to clogging. Applying DAP fertlizer through the system could clog emmitters. Rodents might chew the pipe causing leakage.	.To be implemented as part of an integrated watershed development intervention. . Fully on individuals/groups +/- community (commitment to mgt.) . DAs and wereda experts - technical support and follow-up/mgt.

TECHNICAL INFORMATION KIT

Roof Water Harvesting System

(1) Period/phases for implementation

. Once during the dry season, should be finished before the rainy season commences.

(2) Objectives/remarks

Roof water harvesting is a system for the collection of rainwater for domestic water supply. Roof catchments are used to collect water for individual household use, in schools and other institutions.

. Gutters and ground storage tanks are required to collect rainwater from roofs;

. Roof catchements are made of GI sheet and grass tatched materials;

. It also provides water for livestock, agricultural and fish-farming use.

(3) Suitability, agro-ecology and adaptability based upon local knowledge

. Has good potential in areas of rugged and steep terrain;
. More suitable in high rainfall areas for frequent filling of storage reservoirs;
. Suitable for arid and semi-arid areas where rainwater is the most accessible water source

(4) Technical preparedness

. Once the roof water harvesting system is constructed, the household needs to be trained on the operation and maintenance.

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

. Allows safe disposal of rain water from roofs for direct use
. Reduce workload of women by availaing water at home
. No effect on environment

(6) Minimum surveying and tools requirements

. Pipes
. Cement
. Gutters

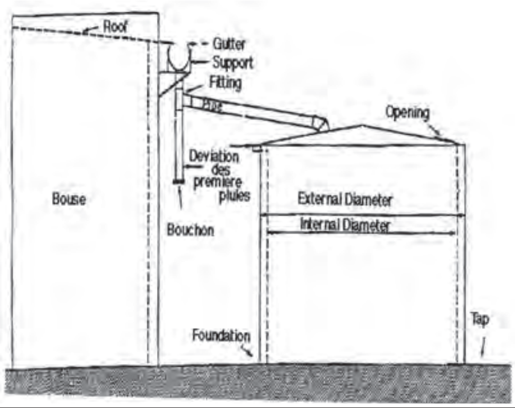
(7) Min. technical standards (fig 1)

. Calculate the area of your roof in m2
. Calculate the average yearly rainfall in mm
. Calculate the cubic meter of roof water

(area of roof, m2 x yearly rainfall, m)

. Establish the size of water tanker, which is equal to the annual volume of water from a roof.

(8) Layout



(9) Work norm

Not applicable. It requires skilled manpower in constructing the gutters, pipes and storage tanks.

(10) Integration opportunities/requirements

. This system coud be integrated with vegetable gardening and livestock rearing (small scale poultry production)

(11) Modifications/adaptation to standard design

. Storage tanker could be made of concret and placed underground.

. Plastic tanks could be used for small roof catchments.

(12) Planning and implementation arrangements

. Individual household are responsible for planning and implementation of the activity. It requires skilled manpower for installation of this system

(13) Management requirements

. Proper maintenance through cleaning the gutters and storage tanks from debris and other materials regularily.

(14) Limitations

It is costly for a rural household.

(15) Institutional responsibility

. Responsibility is at household level with support provided by water harvesting experts anddDevelopment Agents

TECHNICAL INFORMATION KIT

Farm dam Construction

A body of water created either by excavation or by earth filling across a depression or stream course. Earth fill farm dams are storage dams. All earth fill farm dams are non-over flow dams. Some of the general water sources of a farm dam are surface flow and

(1) Period/phases for implementation

Construction period for embankment or earth fill farm dams should be during dry seasons, usually January to May.

(2) Objectives/remarks

Storage farm dams are mainly to store surface runoff water and to use it when required for various uses such as for human and animal consumption, small scale or supplementary irrigation, fish production.

(3) Suitability, agro-ecology and adaptability based upon local knowledge

A suitable site for a farm dam construction is where a watercourse or river valley has a neck formation. A valley which has a large storage capacity on the upstream side of the proposed dam site is probably the best. The general paramount considerations in the choice of the dam are geology of foundations, hydrologic considerations, availability of construction materials and general know how. The geology of the foundations needs to be fully investigated before the choice is completed. The investigations are to be conducted not only at all selected alternate dam sites but also over the entire reservoir area to identify the potentially weak strata which are likely to give way under the pressure. The designer or expert should also think about the size of the catchment area to get enough runoff to fill the farm dam. Moreover, farm dams should be located at a point where maximum volume of water can be collected with least excavation or earth fill; farm dams for livestock should be well spaced as the livestock should not travel more than one km; to avoid pollution, the site should be away from farm drainage and swage lines; and the drainage area should be sufficient to provide adequate runoff.

(4) Minimum tools required

(1) Surveying equipment (such as water level, theodolite), range poles, measuring tape or marked string. (2) Sledges, crow bars, shovels, digging hoes, pick axes, wheel barrows, soil compacting tool, soil dumper, etc. (3) Workers or laborers

(5) Worknorms (WN)

The average worknorm for small farm dam is 0.40 m3/pd. The work norm for a farm dam is calculated in terms of volume of fill materials. The worknorm refers to soil and stone movement, placement of stones for a spillway rip rap, sodding of grasses on down stream face, stone riprap on upstream face, placement of sand and toe filters

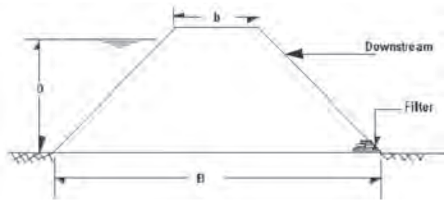
(6) Design and Construction Requirements for an earth fill farm dam

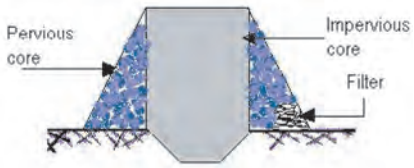
The basic requirements for earth fill farm dam are reasonable degree of imperviousness and stability under all working conditions. Purely sandy soils make the first requirement impossible while clayey soils do not satisfy the second criterion.

The most commonly used types of earth fill farm dams are homogeneous type and zoned section. The homogeneous type utilizes sandy clay soils and is presently restricted only for small dams. The entire section is made of the same type of soil unlike zoned section. The zoned section is the most popular type used nowadays in which cross sections of the farm dam is divided into zones. The outer zones are more pervious to have a free draining property while the inner zone or the core zones are made up of an almost impervious clayey soil to check seepage.

To avoid seepage through the foundation and the body of the dam, proper compacting of the soil at fixed layer is very important

Spillway:- is part of the structure which disposes the excess runoff to a safe outlet. To avoid overtopping and remove the excess water to a safe outlet, a properly designed spillway is very essential





(7) Design of small scale farm dam

The design of a farm dam is based on existing experiences and performance. For preliminary design of a farm dam, selecting suitable values of top width, height of the dam, free board, upstream and downstream slopes, drainage arrangements, etc. are required. Free board is the vertical distance between the maximum reservoir level and the top of the dam. To avoid over topping of a farm dam, there must be sufficient free board. In most cases, the recommended values of a free board for an earth fill dam are indicated in the table below.

Width :- The top width of large earth fill dams should be sufficient to keep the seepage line well within the dam, when reservoir is full. For small dams, this top width is generally governed by minimum road way width requirement. The top width (b) of the earth dam can be selected according to the following recommendations.

$$b_1 = \frac{H}{5} + 3 \qquad b_2 = 0.55\sqrt{H} + 0.2H \qquad b_3 = 1.65(H + 1.5)^{\frac{1}{3}}$$

Where:
H is the height of the dam.

Note:- Formula b1 is used for low earth fill farm dams; formula b2 is used for earth fill farm dams lower than 30 m and formula b3 is used for earth fill farm dams higher than 30 m.
The down stream and upstream side slopes depend upon various factors such as the type and nature of the dam, foundation materials, height of dam, etc.
Upstream and downstream slope ratio

Where H and V are horizontal and vertical distances, respectively

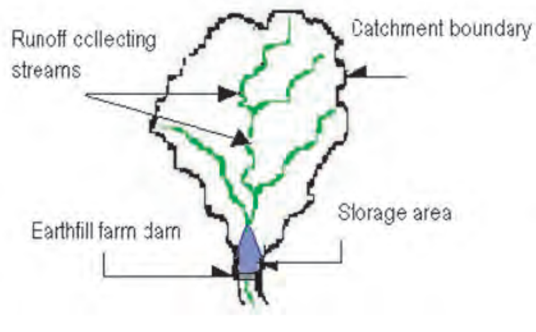
Type of construction material	Upstream slope (H:V)	Downstream slope (H:V)
Homogeneous wellgraded	2.5:1	2:1
Homogeneous Course silt	3:1	2.5:1
Homogeneous Silt clay: 1. Height less than 15 2. Height more than 15	 2.5:1 3:1	 2:1 2.5:1
Sand & gravel with a central day core	3:1	2.5:1
Sand & gravel with R.C diaphragm	2.5:1	2:1

Height of dam

The Height of a farm dam should be designed so that it is not over topped any time. Thus, after studying the wave height, wind setup, likely maximum water elevation, etc. the free board varying between 3 m to 5 m is provided depending up on the nature of the spillway and height of the farm dam, as also the degree of seismic activity at a proposed site.

Preliminary dimensions of an earth dam are given in the table below:

Height of dam, m	Max. free board m	Top width, m	Upstream slope, H:V	Downstream slope, H:V
up to 4.50	1.20 - 1.50	1.85	2 : 1	1.5 :1
4.50 - 7.50	1.50 - 1.80	1.85	2.5 : 1	1.75 : 1
7.50 - 15	1.85	2.5	3 : 1	2 : 1
15 - 22.50	2:1	3	3 : 1	2 : 1



Catchment area collecting runoff to fill the farm pond

TECHNICAL INFORMATION KIT

RIVER-BED OR PERMEABLE ROCK DAMS

(1) Period/phases for implementation

. Only during dry season and min. one month before rains likely to occur.

(2) Objectives/remarks

. River bed dams are a floodwater farming techniques where runoff waters are spread in valley bottoms of seasonal riverbeds, large gullies or natural water courses for improved crop and forage producdtion using a long, low structure, made from loose stone (occasionally some gabion baskets may be used). Developing gullies are healed at the same time. Occasionally it is required to raise the riverbed in order to guide spate floods into irrigation canals of spate irrigation schemes, or to accumulate river sediments for riverbed cultivation. In such a case, very strong dams are required that can resist powerful spate floods.

.It is a relatively low cost structure especially designed to resist heavy flooding. The structures are typically long, low dam walls across valleys. The large amount of work involved means that the technique is labor intensive and needs group approach.

(3) Suitability, agro-ecology and adaptability based upon local knowledge

River bed dams for crop production can be used under the following conditions: Rainfall: 200 – 750 mm; from arid to semi-arid areas; Soils: all agricultural soils – poorer soils will be improved by treatment;Slopes: best below 2% for most effective water spreading; Topography: wide, shallow valley beds; Traditional structures similar to river bed dams are common in several parts of Ethiopia (Dire Dawa, Tigray/Erob, Wollo, , Hararghe, etc). As the flood subsides ring planting is practiced.

(4) Main land use

. Suitable in river/valley bottoms for improved crop production. They can also be used for forage production using the residual moisture of the riverbed sediment. Is more effective in areas where villagers have some experience in spate irrigation or flood farming.

(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 cereal as well as cash 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 river bed dams collect sufficient moisture.
. Promotes 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.
. Volume of stone work per ha varies from 70 - 280m3 based on slope.

(8) Layout

A) Site Selection: site selection depends both on the beneficiaries and the technicians. Theoretically it is best to start at the top of the valley, though this may not always be people's priority. After site identification it is necessary to determine whether the structure needs a defined spillway: as a rule of thumb no spillway is required if the gully is less than one meter deep. For greater depths, a spillway is recommended. Gullies of over two meters depth poses special problems and should be only tackled with caution.

B) Catchment: Cultivated Area ratio: the calculation of the C:CA ratio is not necessary as the catchment area and the extent of the cultivated land are predetermined. However, the catchment characteristics will influence the size of structure and whether a spillway is required or not. Usually, because it is a permeable rock dam, if the depth is less than one meter then there is no need to include spillway. When required gabions are best for spillways, as loose stones easily destabilized by heavy floods. As the soils become heavier behind the bunds water logging could be a problem and selection of crop taken into account.

C) Design/size: the main part of the dam wall is usually about 70cm high although some are as low as 50cm (fig 1-4). However, the central portion of the dam including the spillway (if required) may reach a maximum height of 2m above the gully floor. The dam wall or "spreader" across the valley beds normally range from 30 to 100 meters. Sites requiring greater than this size technical assistance may be consulted. The dam wall is made from loose stone, carefully positioned, with larger boulders forming the "framework" and smaller stones packed in the middle like a "sandwich". The side slopes are usually 3:1 or 2:1 (horizontal : vertical) on the downstream side, and 1:1 or 1:2 on the upstream side. With shallower side slopes, the structure is then more stable (Fig 2). For all soil types it is recommended to set the dam wall in an excavated trench of about 10cm depth to prevent undermining by runoff waters. In erodible soils, place a layer of gravel, or at least small stones, in the trench.

D) Quantities and labor: the quantity of stone, and the labor requirement for collection, transportation and construction depends on a number of factors and vary widely. Table below gives the quantity of stone per cultivated hectare for a series of typical river bed dams under different slopes.

Land slope (%)	Spacing between dams* (m)	Volume of stone/ha cultivated (m3)
0.5	140	70
1.0	70	140
1.5	47	208
2.0	35	280

*vertical interval between adjacent dams = 0.7m, the above figures are calculated for a river bed dam with an average cross section of 0.98m2, 70cm high and base width of 2.8m and a length of 100m. The vertical interval between dams is assumed to be 0.7m, which is equal to the dam ht.

Fig1. Riverbed dam dimensions

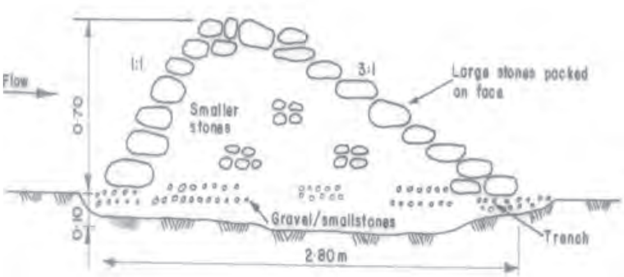
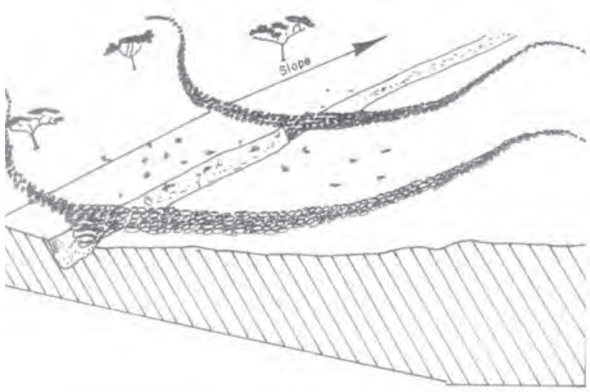


Fig2. Riverbed dam: general layout.

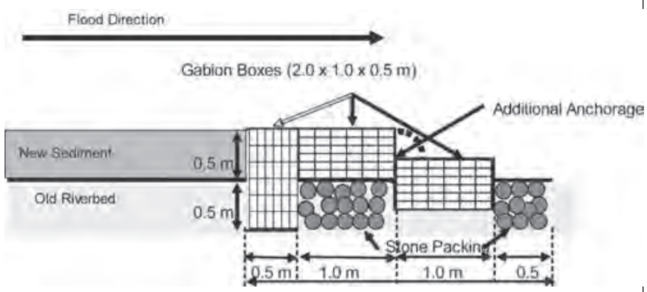


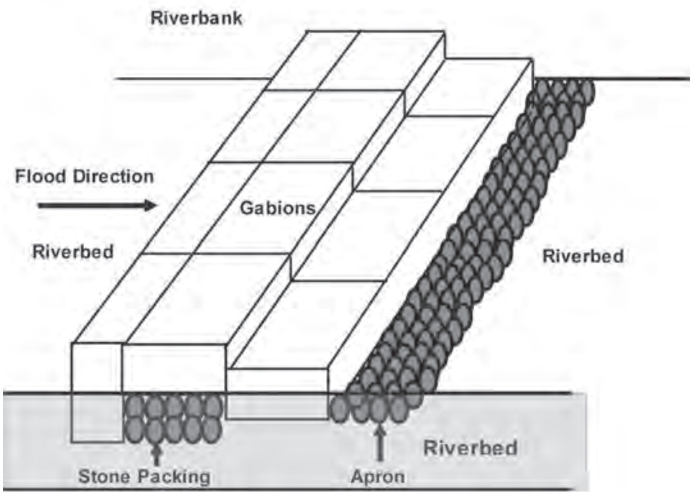
F) Example on how to determine spacing of riverbed dams:

for dams of 70cm height, the VI should theoretically be 70 cm. However in practice this may not be practicable due to the amount of stone and labor involved. As a compromise, a V.I. of 100 cm might be more realistic. Even wider spacing could be determined most easily by the use of a line-level.

The horizontal spacing between adjacent dams can be determined from the selected VI and the prevailing land slope according to the formula: HI = (VI x 100)/(% slope)

Where: HI = horizontal interval (m)
VI = vertical interval (m)
Slope in % = land gradient expressed as a percentage
For example, for a VI of 0.7 m and a 1% land slope,
HI = (0.7 x 100)/1 = 70 meters
For a VI of 0.7 m and a 2% land slope,





G) Layout and construction steps:

1) A foundation of small stones, set in a trench, is required.

2) An apron of large rocks is needed to break the erosive force of the overflow (fig1-4).

3)The downstream banks of the watercourse should be protected by stone pitching to prevent gully enlargement.

4)The alignment of the main dam walls can be marked out, starting at the center of the valley (where there may/may not be a spillway).

5)The arms end when they turn parallel to the watercourse. The contour can be laid out simply using a water tube or line level.

6)The first action after aligning the extension arms of the dam is to dig a trench at least 10 cm deep and 280 cm wide (according to the base width of the bund). The earth should be deposited up slope and the trench filled with gravel or small stones.

7)The skill of construction is in the use of large stones (preferably of 30cm diameter or more) for the casing of the wall.

8)This should be built up gradually following the required side slope, and the center packed with smaller stones and the whole length of the bund should be built simultaneously, in layers.

9) If a series of permeable rock dams is to be built, and appropriate vertical interval (VI) should be selected.Technically it is correct to: start at the top of the valley and work down; and use a VI equal to the height of the structure.

(9) Work norm

Estimate about requirements based on the following work norms:

. The work norm for the **Riverbed dam embankment** (inclusive of all elements) is estimated as 0,75 m³ of volume work (earth and stone fill) per person/day.

. The work norm for the **spillway** is **0,5 m³** of spillway excavated soil and stone work (including drop structure and rip rap if necessary) per person per day.

.More explanation is also given on the front page under design section “D). Quantities of labor”.

(10) Integration opportunities/requirements

. Riverbed dams are part of a watershed treatment. The dams improve conditions for plant growth by spreading water, where moisture availability is a limiting factor. In additon, sediment, which will build up behind the bund over seasons, is rich in nutirents, and this will further improve crop growth.

.This techniques is used exclusively for annual crops. In the sandier soils, which do not retain moisture for long, the most common crops are millet and groundnuts.

.As the soils become heavier, the crops change to sorghum and maize. Where soils are heavy and impermeable, waterlogging could be a problem and therefore, within one series of permeable rock dams, several species of crop may be grown, reflecting the variations in soil and drainage conditions.

.Gulliies leading into the main riverbed dams should be treated with check-dams or SS dams. Spillways could be necessary as required.

(11) Management requirements

. The river bed dam based on the design given above should not require any significant maintenance work provided the described construction method is carefully applied. It will tolerate some overtopping in heavy fllods.

.There may be some stones wahsed off, which will require replacing, or tunneling of water beneth the bund and need packing with small stones.

.No structure in any water harvesting system is entirely maintenance free and all damage, even small, should be repaired as soon as possible to prevent rapid deterioration.

. Agree with the land-owners/users on both sides of the dam, where to place the structure (s). If the 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.

.After 1-3 years try hand-dug well close to lower side of embankments (2-3 meters from the wall). Make sure that each households owning/using their own dams along a common dry water course/gully agree to form a group for management river bed dams (mutual help).

(12) Planning and implementation arrangements

. Large quantities of stone needed
. Outside assistance could often be necessary for transport of stones
. Siting is often determined by the people rather than the technicians
. As the structures may not be made by individual farmers, it is necessary to cooperate in construction.

(13) Limitations

.The main limitation of riverbed/permeable rock dams is that they are particularly and require considerable quantities of loose stone as well as the provision of site-specific, transport.. Labour intensive and needs thorough follow-up - difficult in areas with limited expertise. Limited number of direct beneficiaries.

Not suitable in sandy and sodic soils.

(14) Institutional responsibility

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

TECHNICAL INFORMATION KIT	(1) Period/phases for implementation	(2) Main objective/purpose
SMALL STONE BUNDS WITH RUNON-RUNOFF AREAS	During the dry season.	. The main objective is to considerably increase the biomass production of forage grass and legumes pastures and fodder crops and/or allow the introduction of species having higher water requirements in abandoned, marginal and eroded dry areas. The principle of the system and its application is the same as for runoff/runon systems suggested for the cultivated areas. Rainfall multiplier systems for grazing land can also rehabilite fertility (decay of grass and increased moisture). In this respect, a few years pasture improvement and soil fertility restoration may allow the area to be cropped again. . The main difference between this measure and the one described for the cultivated land is that instead of food crops fodder plants are grown. The system is less demanding in terms of size of structures and management of the plots as fodder species require less water than food crops.

(3) Suitability and adaptability to local knowledge

. The system as designed is not practiced in Ethiopia but of significant importance in parts of the Sahel. It can be adapted under Ethiopian conditions as runoff/runon systems are known and used for different purposes in several dry areas. This measure needs proper technical follow up at introduction stage.

(4) Main land use and agro-ecology

In dry areas with depleted soils and gentle slopes, crusted and shallow soils and marginal lands used for temporary grazing (kolla areas). It can be used to improve long fallows in dry weyna dega where such areas exist and can be reclaimed. A number of marginal lands, left fallow for years, may also be suitable for this measure, in combination with agronomic measures such as ley cropping and other measures such as ripping and bunds.

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

1. In settled agriculture small farmers having difficulties to feed their draught animals or herds are likely to be interested in this measure and take care of the reclaimed areas.
2. This technique may allow to develop large extension of pastures in pastoral and agro-pastoral areas, creating "grazing reserves or fodder banks" to use during drought events and/or to restore cattle conditions before selling them to markets. This activity combined with multipurpose trees planting (aerial pasture, gums, fruits and dyes) such as Zyziphus, Acacia senegal, Neem, etc, can ensure excellent environmental protection and income generation.

(6) Description of the technology and steps

. The system is suitable for shallow soils (<50 cm) and located in marginal areas, with low rainfall (< 400 mm). Most areas used by pastoralists fit this range.

. In slightly higher rainfall ranges (400-600 mm), they are also suitable for marginal areas with soils either shallow and/or with low infiltration rates, or adjacent to gullies.

. In all circumstances they are suitable in areas with slopes ranging from 1 to 5%.

. The minimum area for the construction of a single rainfall multiplier unit should be sufficient to allow the construction of bunds with its planted area and the runoff (catchment area). If the area include small depressions or gullies, the bunds should wing up before crossing such points. Before the construction of the bunds, the cropped area may be preferably ripped to increase infiltration and encourage biological life.

. Concerning the ratio between runoff area and planted area, it should be estimated according to the amount of rainfall (mean seasonal). The planted area should not exceed 5-10 meters width. Runoff/runon ratios range from 2:1 to 5:1 depending on rainfall and vegetation.

. Since the type of soils are usually shallow, with structural problems (crusts, etc) and limited water storage capacity, excess runoff is expected to occur. For this purpose, bunds should be provided with lateral wings of decreasing height to evacuate excess water and/or side spillways. The bunds wing up laterally for the entire length of the cropped area. Spillway construction follow the same criteria as indicated for soil/stone bunds but often of smaller size due to the smaller size of bunds.

. Suggested dimensions are: height of the bund is 45-60 cm, length 10-50 meters and base width 1-1.5 meters. The bunds have to be staggered alternatively with lateral spacing between bunds of 2 meters to allow overflow.

. The bunds are made out of soil (stable soil, slopes < 3% and rainfall >400 mm) or stone faced (slopes 1-5%, rainfall < 400 mm or above). In case of stone bunds, structures should be sealed with soil on their upper side.

Figure 1. Small stone-faced soil bunds using runoff-runon systems

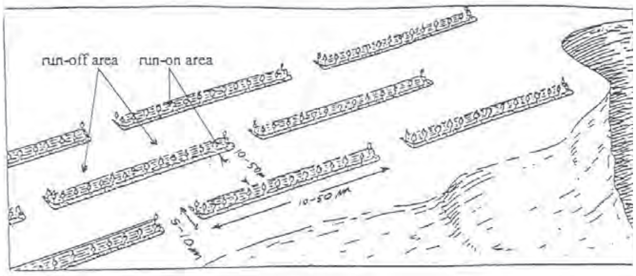
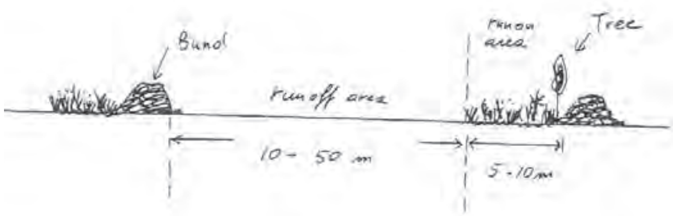


Figure 2. Cross section



(7) Integration requirements and opportunities

1. In areas developed for fodder crops, first year crop stocks should be cut half their height and the stubble mulched.
2. In case of grass/legume pastures, first year reseeding should be allowed and grass cut after grass seeds reach maturity.
3. To improve water holding capacity of the area and encourage fast growth of pasture ripping is recommended (one passage every 1m) followed by 1 ploughing operation.
4. Sowing of drought resistant legume fodder.

(8) Constraints and limitations

. Main limitations refer to the labour inputs available for this activity. Others would be the control grazing arrangements, always difficult to maintain in case of marginal areas, particularly if other areas in the surroundings are still grazed freely.

TECHNICAL INFORMATION KIT	(1) Period/phases for implementation	(2) Main objective/purpose
NARROW STONE LINES ALONG THE CONTOURS (STAGGERED ALTERNATIVELY)	. During the dry season.	. Stone lines are semi-permeable or permeable structures, intended to capture some moisture and thus allow the growth of spontaneous grass. By slowing down runoff they also decrease erosion, although not completely. . This is a soil and moisture conservation measure suitable for rangelands and degraded grazing lands in dry areas. The measure is less labour intensive and material demanding than small stone faced soil bunds but less efficient. . The principle is rainfall multiplier system but the measure is applicable only if stones are available.

(3) Suitability and adaptability to local knowledge

. Can be easily adapted in moisture stressed areas and agropastoral settings. Some of these practices are common in West Africa and can be easily adopted under Ethiopian conditions.

(4) Main land use and agro-ecology

. Dry areas with extended degraded grazing lands or rangelands with low productivity and that can be converted into grazing areas. Can be suitable for pastoral and agropastoral areas to induce better growth of natural grass.

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

. Productivity of grass can improve considerably in areas with stones and with gentle slopes (max 3-5%). If applied over large areas it can control erosion quite significantly and slow down water runoff. Being a semi-permeable or permeable system it is not considered as efficient as other systems in similar conditions but cheap.

(6) Description of the technology and steps

. Layout is along the contours, in successive semi-circular lines staggered alternatively.

. Slope should not exceed 3-5%. The soils should be permeable enough to allow sufficient infiltration although this measure is often implemented in areas with crusted and shallow soils, paved with stones. In this respect, stone lines can be easily overtopped by excess runoff. However, it is a cheap method but it is neither an effective erosion control nor an optimal water retention system.

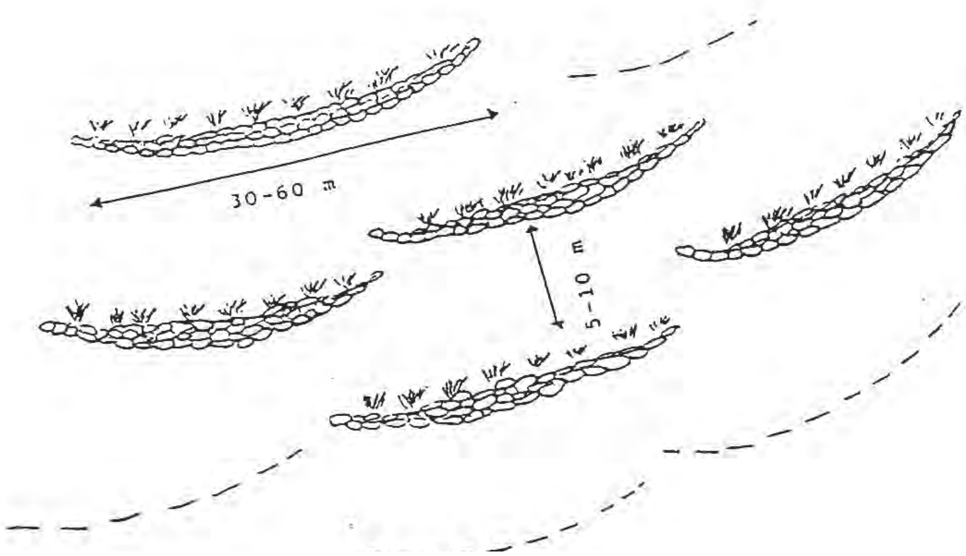
. Stones lines are built with a 30-40 cm height, piled in a piramidal way and are usually 10-40 meters long. Normally, for maximum water retention the two lines are spaced apart 5 to 10 meters.

. If improved grass/legume are planted they should be drought resistant and withstand low fertility levels (fertility building pasture or legume crops). Other biological measures can be applied but farmers may not be willing to invest many resources for a low productivity device.

. Control grazing and cut and carry are required.

. Work norm is same as for soil bunds.

Figure 1. Narrow stone lines staggered alternatively



(7) Integration requirements and opportunities	(8) Constraints and limitations
1. Integration is with plantation of drought resistant plants and trees (Acacia sp, Parkinsonia aculeata, etc) at specific intervals (2 m) along the stone lines. 2. Cut and carry and control grazing.	. Limited water harvesting capacity. Stone lines can be easily damaged.

TECHNICAL INFORMATION KIT

STONE FACED/SOIL OR STONE BUNDS WITH RUN-OFF/RUN-ON AREAS

(1) Period/phases for implementation

. During the dry season only for the construction of bunds and tie-ridges. Every year apply compost in the cropped area.

(2) Main objective/purpose

. This is a rainfall multiplier system for reclaiming and rehabilitating marginal areas with low productivity, shallow soils, often affected by surface crusts and low water infiltration rates, with slope ranging between 1 to 5%. Both runoff and runon areas are included within the bunds.

. The runoff area is intended to serve as a micro-catchment to supply additional water into a runon area (cultivated area) to increase production levels in one portion of the total area or to introduce crops with higher water requirements that otherwise would not grow without additional moisture.

(3) Suitability and adaptability to local knowledge

. Some traditional forms of runoff-runon system exist in most regions, especially in drylands. These systems are usually not practiced at a significant scale.

(4) Main land use and agro-ecology

. Mostly suitable in arid areas (Kolla and Berha) but also semi-arid (dry weyna dega) with shallow soils and abandoned or unused areas because of rainfall deficit.

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

. High potential in agropastoral areas and in drylands with portions of land out of cultivation. This activity may allow large portions of degraded lands to be rehabilitated where cultivation was not considered possible.

(6) Description of the technology and steps

1) Slope range and type of soils: for slopes < 3-5% and soil depth above hardpan/rocky area of 50 cm or more.

2) Runoff/runon ratio = ratio of the area yielding runoff (catchment area) and the area receiving runoff (cultivated area) range 0.5-1:1 and 1.5:1 (0.5-1.5 run-off/catchment area and 1 run-on/cultivated areas) for stone faced/soil bunds and stone bunds.

(3) Type of bunds: Stone faced/soil or stone bunds are recommended. There are cases where also soil bunds can be tried (small plots). In case of soil bunds (rare) ratio should not be higher than 0.5-1:1.

(4) Size of the area delimited by two bunds: small catchments will harvest runoff even from shorter storms. Each cultivated area may be delimited by a 20-80m long bunds provided with lateral wings of 5-15m width (see Fig.1).

(5) Layout of bunds: bunds level along the contours and wing up laterally to evacuate excess water. Depression points to be avoided and/or bunds reduced in size and oriented in different directions based on slope.

(6) Construction criteria/phases:

--> Soil bunds: only on slopes < 3% (see standard design);

--> Stone bunds: up to 5% slopes, with strong and large foundation, sealing of the stones is important to reduce the flow of runoff through the bund and facilitate the growth of grass;

--> Stone faced soil bunds: very well compacted and with stone walls placed on both sides of the bund with stable angle. The top of the bund is also planted with dry resistant grass species;

--> Height of the bunds: at least 60-75 cm, length from 25 to 100 m, bottom width 1.5-2 m and top width 30-50 cm. The bund has wings as long as the width of the cultivated area (10-15 meters in the example);

--> Distance between bunds: not exceed 15 to 20 meters within this range of slopes and staggered alternatively. Lateral distance 3-5 meters and protected with lines of stones to evacuate excess runoff (lateral wings should have a decreasing height in order to be the first to evacuate excess runoff).

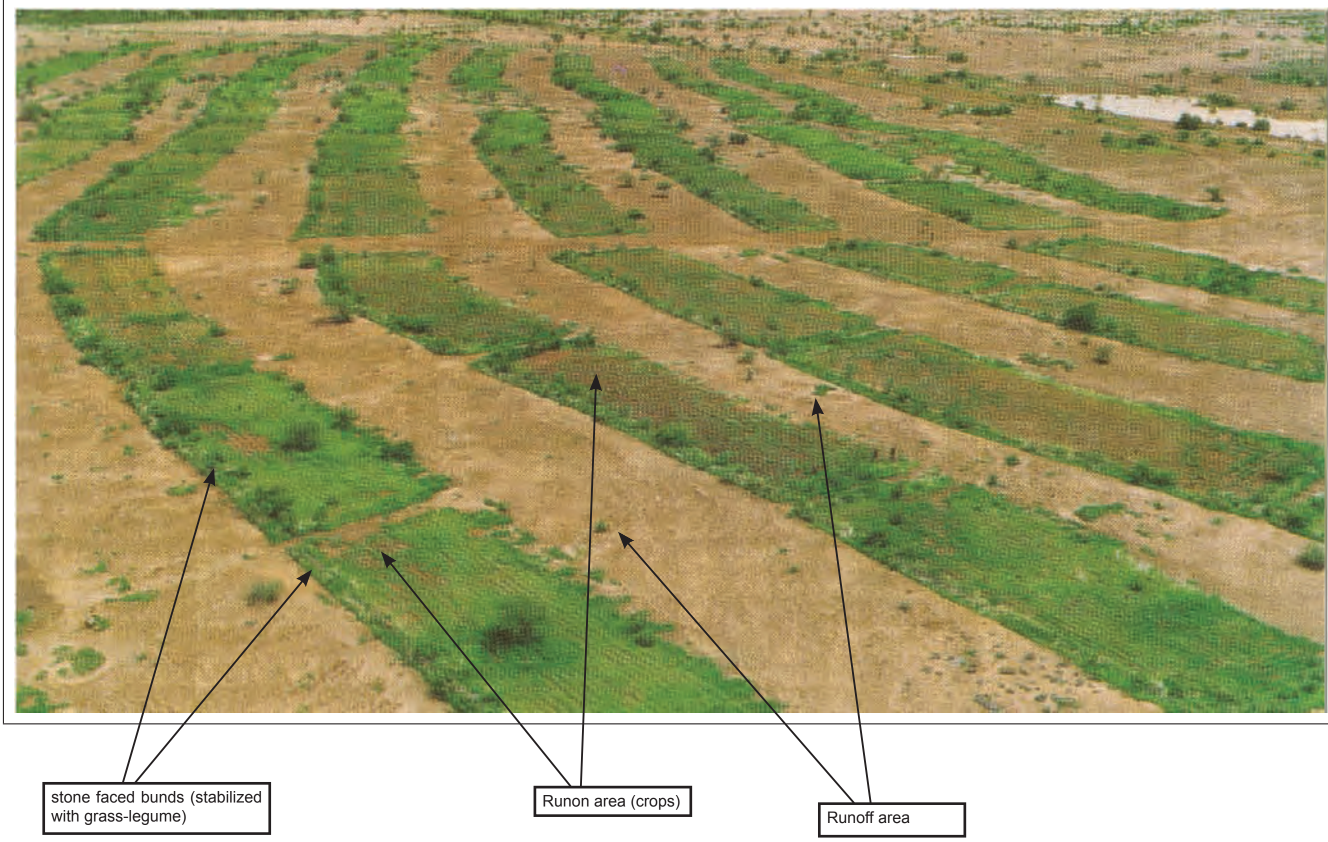
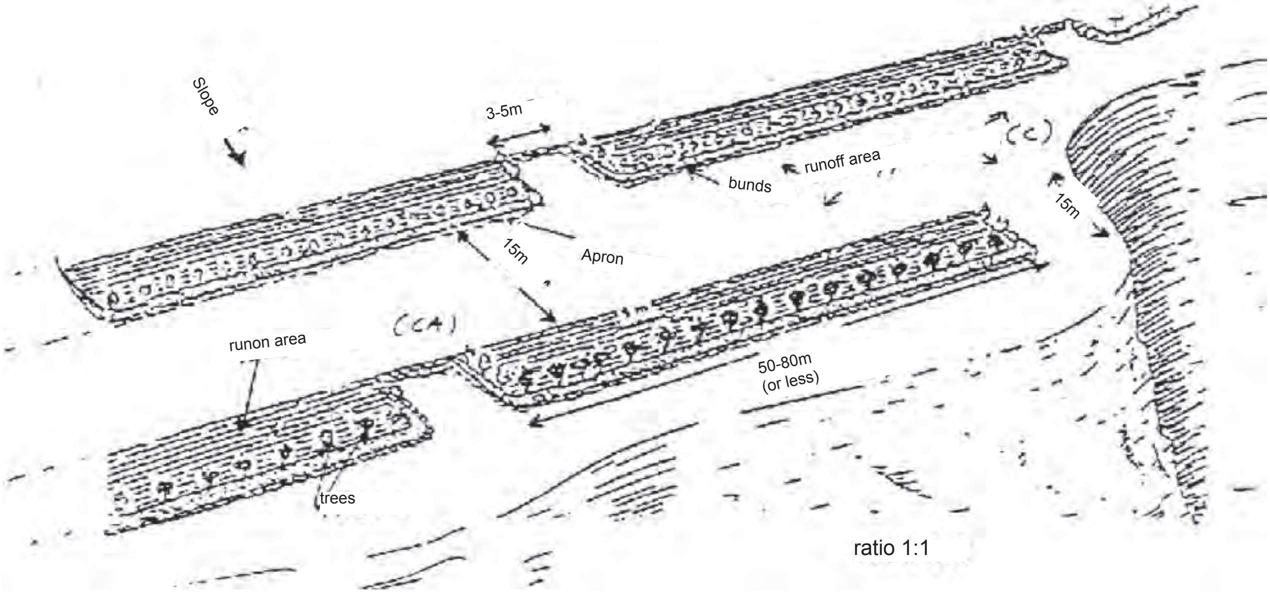


Figure 1. Example of runoff-runon system



(7) Integration requirements and opportunities

a) Provision of spillways with drop/apron may be required in addition to the side wings on bunds (for higher runon-runoff ratio, low infiltration, aggressive rainfall, etc), particularly in case of soil bunds.

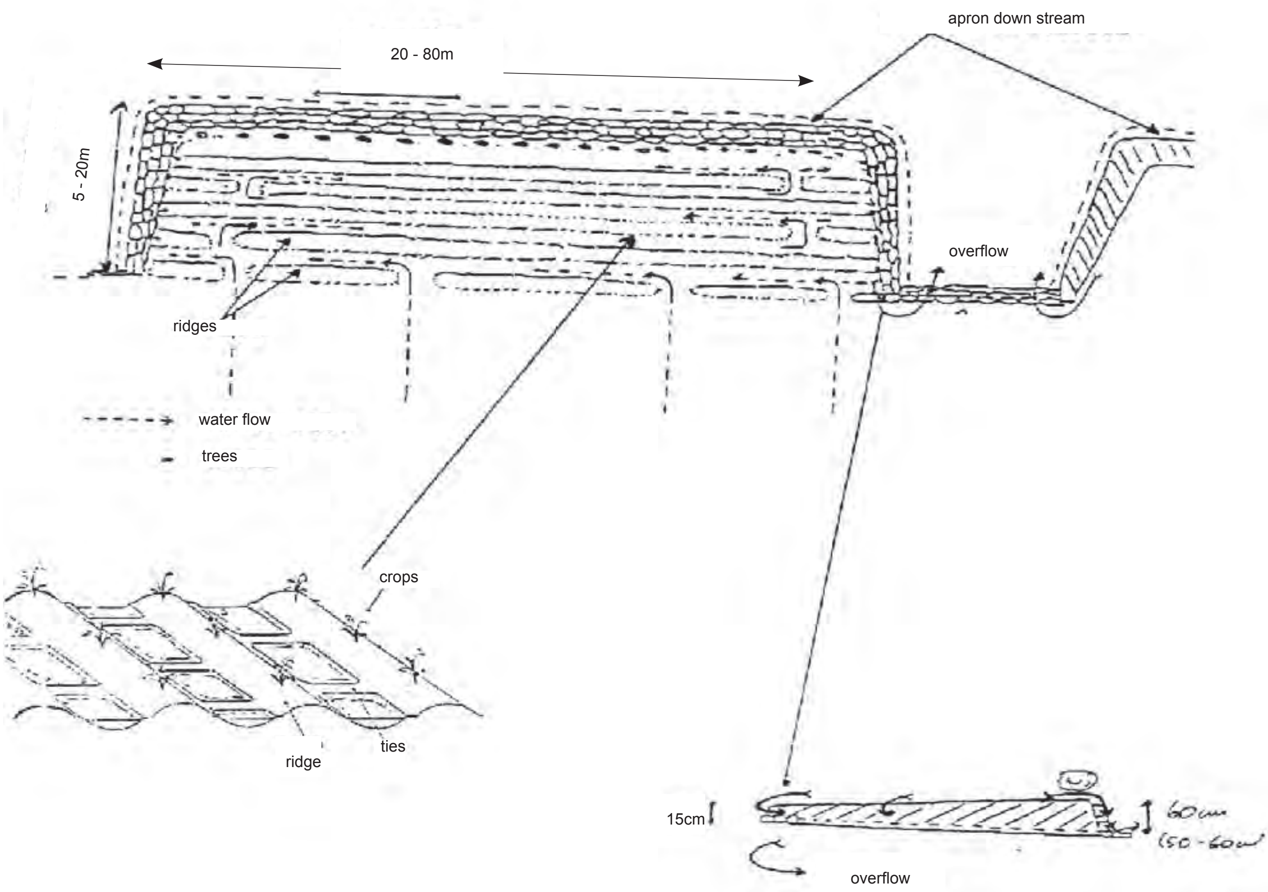
b) Tie-Ridging of the runon (cultivated areas) along the contours is essential for an even distribution of moisture. Every ridge along the contours should be interrupted to allow water to pass through into the next furrow (see Figure 2). Apply compost to increase infiltration every year.

c) Dry resistant trees/shrubs (Acacia species, Aloe sp., Agave sp. etc.) should be planted every 1-2 m along the ditch/berm.

d) Integrated with drought resistant crops (Sorghum, millet, etc) and legumes.

e) Mulching of crop residues recommended.

Figure 2. Aerial view of design of runoff-runon system



TECHNICAL INFORMATION KIT

CONSERVATION BENCH TERRACE (CBTs)

(1) Period/phases for implementation

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

(2) Objectives/remarks

.are constructed on steep slopes to combine soil and water conservation with water harvesting practices

.they control erosion and retain moisture

.suitable for food/ tree crops and are effective in controlling runoff and erosion.

. they are also water harvesting structures, the riser acts as a catchment

.Common in most parts of Ethiopia, (e.g Konso) generally in dry areas

. benching action eases cultivation operation by oxen, however, more appropriate to use

(3) Suitability, agro-ecology and adaptability based upon local knowledge

. Suitable mostly in semi-arid and arid parts of the country but also in medium rainfall areas with deep and well drained soils. Commonly practiced in dry and moist weyna dega areas for the growth of trees and support of area closure. Design change based on dryness conditions.

(4) Main land use

. cultivation of annual and perennial crops.applicable in a broad range of land uses, particularly in cultivated lands with some level of stoniness. Also possible in large gully networks combined with vegetation

(5) Technical preparedness

. Land use, depth of soil and slope assessed. Discuss and agree with farmers on crops, spacing and integration with other measures as required. The deeper the soil is the better for effective moisture conservation.Training on layout, construction and

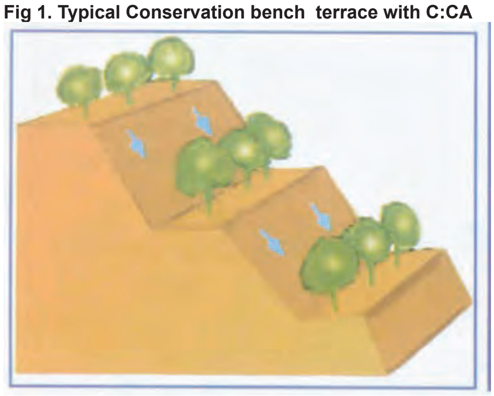
(6) Potential to increase/sustain productivity and environmental protection

. Good potential to improve cultivation of steeper slopes - mostly for annual and tree crops.The Konso people make contour bench terraces supported by stones. In fact this resembles more of in-situ moisture conservation but they also divert, in short distances, local runoff from bare lands, roads and footpaths. The lower part of the benched field is planted with perennials such as coffee and Gesho.

(7) Minimum surveying and tools requirements

Layout: One water line level, two range poles graduated in cm and 10 meters of string (a team of 3 people layout approx 1ha/day).
Work: crow bars, sledge hammers shovels, and pick axes. Ratio of shovels and pick axes depend on type of soil).

Fig 1. Typical Conservation bench terrace with C:CA



(8) Min. technical standards

The main design consists of the width of terrace and the catchment area. Typical terrace widths are 10m and up to 30m and 50m or more (on gentle slope). Mini terraces 9m wide are made with 1:1 C:CA ratio. The bench can be made either level along its length or graded at 1:400 (0.25%). Typical C:CA ratios are 1:1 or 2:1 (fig. 1). The catchment area increases as rainfall decreases. A rotation can be considered to alternate cropping in the catchment in wetter seasons and fallow in the drier ones.

(9) Work norm elements

·Cut and fill of the terrace area,

·Careful in placing back top soil .Collection of stones from working site, light shaping (if necessary) of side of stones with sledgehammer for better stability and merging,

· Excavation of foundation,

· Placement and building of stone riser, revegitating risers

· Leveling of top of terrace with an A-frame.

WORK NORM: 1PD/0.75m3 stone

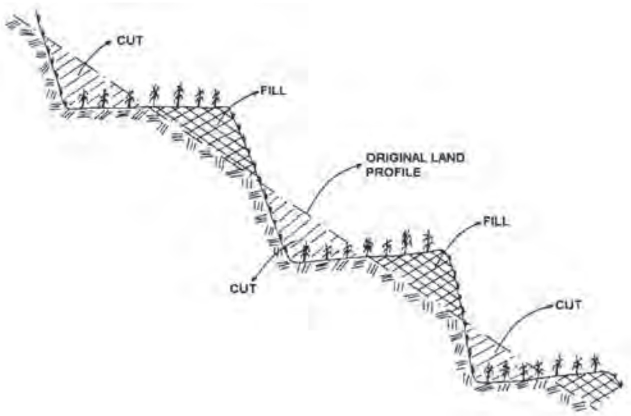
(10) Integration opportunities/requirements

1. Control grazing and closure necessary.
2. Fodder, legume and cash crops can be planted at the raiser or at its toe: On the benched field annuals such as sorghum, maize and others are cropped.
3. In Konso cassava, a root crop, is grown on the top edge of the terrace to make use of the accumulated soft soil.
4. Farmyard manure and compost is intensively applied.

(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 over closures. Arrange working groups for regular maintenance.

(11) Construction of bench terrace by cut and fill method (fig 2)



(13) Management requirements

. Control grazing is a precondition to avoid destruction of the terraces. Terraces should be stabilized, possibly with drought resistant species. Fodder crops growing on terraces should not be uprooted but cut and carried. More effective cropping pattern changed from annuals to perennial.

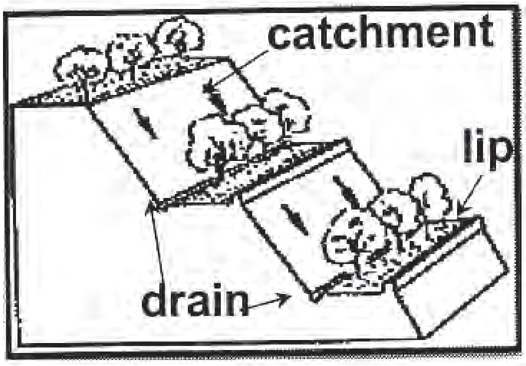
(14) Limitations

. In very high slopes hoe cultivation is a must, labor intensive
. Requires frequent maintenance if not well stabilized.

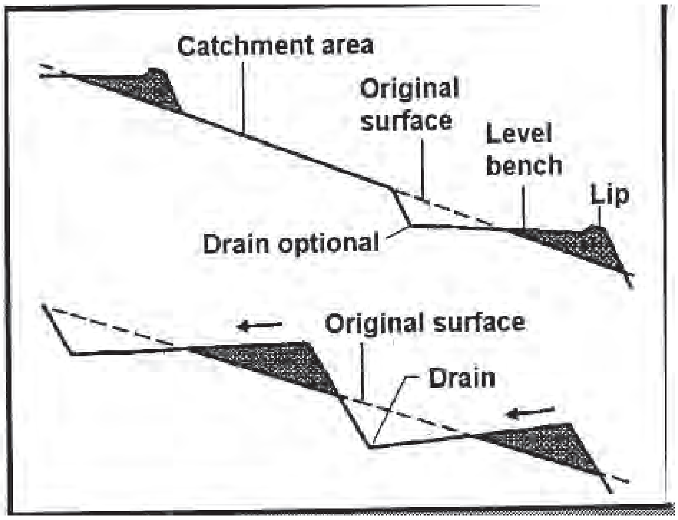
(15) Institutional responsibility

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

Microcatchment: countour bench terraces



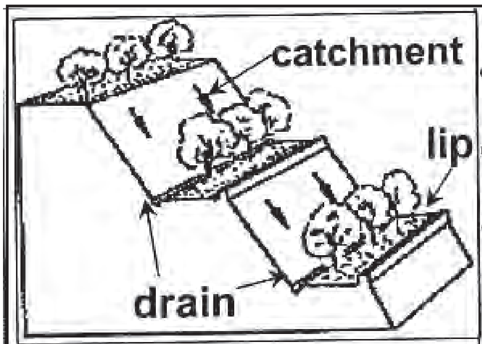
Different types of contour bench terraces



Sloping bench

Interrow WH and Contour bench terraces

Microcatchment: countour bench terraces



= 200-600 mm /yr

= 20 - 50 %

- even cropping area
- drain
- lip

- water retardation
- prevention of soil erosion

= 2 - 20 m²

= 2 - 10 m²

= 1 : 1 to 10 : 1

Trees, bushes and annual crops

Interrow WH and Contour bench terraces

TECHNICAL INFORMATION KIT

TIE RIDGE (S)

(1) Period/phases for implementation

Mostly during planting seasons and after During constrcution of physical SWC

(2) Objectives/remarks

. Tie ridges are small rectangular series of basins formed withing the furrow of cultivated fields mainly to increase surface storage and to allow more time for rainfall to infiltrate the soil. Making tied ridges manually is time and labor consuming. Therefore, there is a maresha attached ridge tier developed by Melkasa Agricultural Research Center.

(3) Suitability, agro-ecology and adaptability based upon local knowledge

. Suitable mostly in semi-arid and arid parts of the country but also in medium rainfall areas with deep and well drained soils. Commonly practiced in dry and moist weyna dega areas for the growth of trees and support of area closure. Design change based on dryness conditions.

(4) Main land use

Applicable in cultivation land with gentle slopes. Availability of various cultivation equipments and the type of soil better mechanization can be adopted to areas where the volume of rainfall is small and variable. Once made during planting it requires little maintenance, however it has to be done for every cropping season.

(5) Technical preparedness

. Tie ridges can be applied before and after planting, however, in most cases are applied after or druing planting. If applied before planting could expose the already existing soil moisture to evaporation. The slope within which they are most effective is less than 5%. Precise layout on contouring required.

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

. Good potential to improve production exists because of effective moisture conservation. It is also possible to use tied ridges for dirveted runoff directed to the cultivated fields other than for rainfall. Farmers in Raya - valley practice tied ridges along their practice of runoff farming i.e. spate irrigation. They are used for annuals, however, when changed to inter-row rainwater harvesting structures tree crops can be grown. See back page for inter-row RWH

(7) Minimum surveying and tools requirements

Layout: No need of surveying equipment as such but need perfect contoured furrows run with oxen. If tie ridges are to be made by hand then A-Frame advised.

Fig 1. Tie Ridges along the contours

(8) Min. technical standards (fig 1)

· Height of the tie ridge can be 15-20 cm within a furrow depth of 20-30cm.

· They are constructed in staggered position along neigbouring furrows.

. Row spacing and tying interval could range between 1 and 10m.

. The steeper the slope, the higher the rainfall intensity and the lower the water holding capacity of the soil.

.Row spacing and tieng interval dependent on slope of the land, intesity of rainfall and water holding capacity of the soil.

. Training and demonstration is needed on how to insert into the traditional implement.

(9) Work norm elements

WORK NORM:

·tie ridging is usually an activity to be performed as a normal cultivation operation. If it has to be done by hand it will take 20 person days per ha. Maresha attached tie ridging can be carried out by 2 person days per person each having pair of oxen. Staggering along neighbouring furrows is required.

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

1.Tied ridges are more appropriate with row crops (such as maize, sorghum, beans, etc). Even broadcast crops such as teff can be practiced during planting provided rain is expected in few days after planting. Both tying interval and row spacing are dependent on the severity of runoff.

2. Tie ridging after planitng is normally for row crops

3. Manuring and mulching (decrease evaporation and enhance growth)

4. Increasing the width of cut can be applied for powerful oxen and light soils

5. Reduced frequency of tillage can be achieved

6. For harder soil and weak oxen reduce the width of furrow slice going to be cut by the plogh share - narrow furrow slice.

(12) Planning and implementation arrangements

. Tied ridges are appreciated on individual plots where use right is secured. As they are meant to maximaize moisture on cereal or row crops that are usually annuals they can even be practiced on rented land effectively. Point breakage by high intensity of rainfall can be checked and repaired during growing seasons.

(11) Modifications/adaptation to standard design

(13) Management requirements

. Control grazing is a precondition for tie ridges as even light trampling will compromise their function.

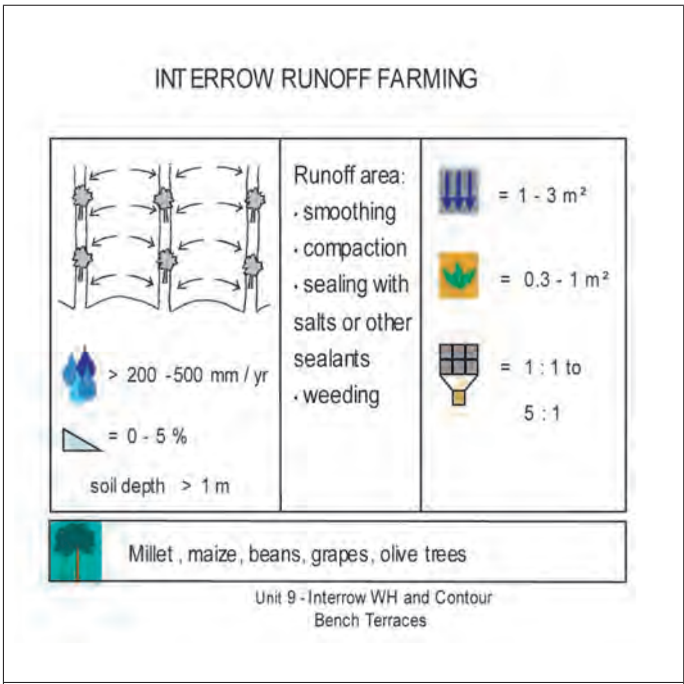
. They can also be practiced after planting similar to the traditional practice of “Shilshalo”, where tied ridges are formed during cultivation operation, especially in areas of spate irrigation.

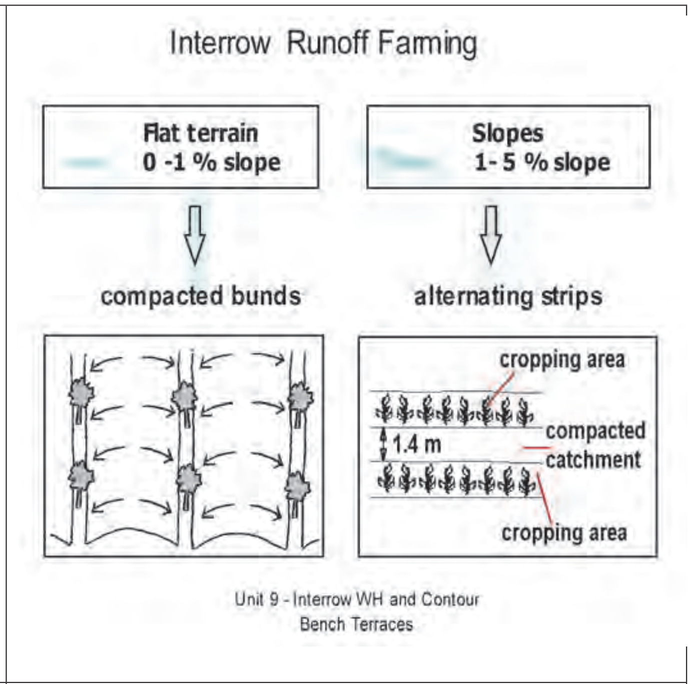
(14) Limitations

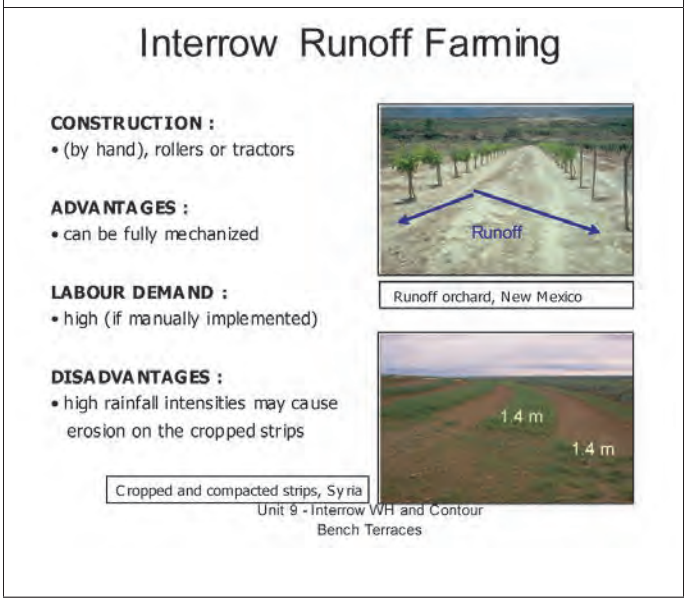
. Unless contoured can be easly overtopped.
. Used on gentle slopes and flat lands only

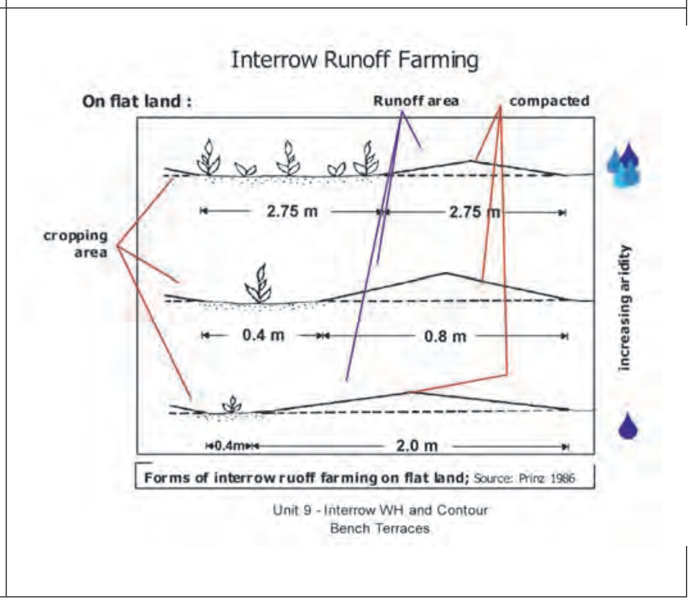
(15) Institutional responsibility

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


INTERROW RUNOFF FARMING
Runoff area:
· smoothing
· compaction
· sealing with salts or other sealants
· weeding
= 1 - 3 m²
= 0.3 - 1 m²
= 1 : 1 to 5 : 1
> 200 - 500 mm / yr
= 0 - 5 %
soil depth > 1 m
Millet , maize, beans, grapes, olive trees
Unit 9 - Interrow WH and Contour Bench Terraces


Interrow Runoff Farming
Flat terrain
0 -1 % slope
Slopes
1- 5 % slope
compacted bunds
alternating strips
cropping area
1.4 m
compacted catchment
cropping area
Unit 9 - Interrow WH and Contour Bench Terraces


Interrow Runoff Farming
CONSTRUCTION :
• (by hand), rollers or tractors
ADVANTAGES :
• can be fully mechanized
LABOUR DEMAND :
• high (if manually implemented)
DISADVANTAGES :
• high rainfall intensities may cause erosion on the cropped strips
Runoff
Runoff orchard, New Mexico
1.4 m
1.4 m
Cropped and compacted strips, Syria
Unit 9 - Interrow WH and Contour Bench Terraces


Interrow Runoff Farming
On flat land :
Runoff area
compacted
cropping area
2.75 m
2.75 m
0.4 m
0.8 m
0.4m
2.0 m
increasing aridity
Forms of interrow ruoff farming on flat land; Source: Prinz 1986
Unit 9 - Interrow WH and Contour Bench Terraces

TECHNICAL INFORMATION KIT

THE ZAÏ AND PLANTING PIT SYSTEM

(1) Period/phases for implementation

Digging Zai pits during the dry season, preferably at the end of rains. Compost applications in January. Other operations follow cropping requirements.

(2) Main objective/purpose

. Zai pits are systems of small pits dug along approximate contours allows the cultivation of crops on degraded lands.

. The zaï pits restore degraded lands (crusted, hard, compacted and poorly structured soils), thus increasing the land available for cultivation. It is a simple technique that, amongst others, landless or oxenless can practice because it requires only manual labour

(3) Suitability and adaptability to local knowledge

. Not applied in Ethiopia but suitable in most degraded gentle slopes

(4) Main land use and agro-ecology

. In Kolla and Dry Weyna dega (arid and semi-arid) areas. Suitable to restore degraded lands, particularly crusted and compacted gentle slopes with shallow soils (usually areas temporarily grazed, out of use, etc.), to rehabilitate degraded gentle sloping lands near gully sides and to make productive small plateaus on top of degraded hillsides.

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

.The zaï system improves the soil structure (organic matter content, micro-organisms activity, aeration, circulation of nutrients and water into the soil, etc.) and thus infiltration. Consequently, they protect the soil from further erosion and conserve and store water and nutrients.

(6) Description of the technology and steps

a) Type of soil and slope: on degraded hard crusted, shallow and compacted, nutrient depleted gentle sloping lands (slopes < 5%).

b) Layout, Dimensions and Construction phases:

--> Start from the top of the field.

--> The zaï are series of pits dug following approximate contours.

--> However, for better orientation mark few contour lines at regular intervals of 1m with the line level.

Fig 1. LAYOUT OF ZAÏ

--> Construction starts after the rainy season, by the end of October - November (1st cycle) when some residual moisture facilitates the workability of the soil. Use hoe, pick axe, shovel and occasionally crow bars to dig the pits.

--> Start by digging the first line of pits following approximate contours between the marked contour lines. The pit may have various sizes, 30-50cm diameter x 15-20cm deep. Spacing apart two zaï pits within each line is 30-50cm. Pile the excavated soil downwards.

--> Proceed downwards the slope and dig the second line of zaï & pits staggered against the first line. Spacing between the zaï & pit lines is 60-75cm.

--> After construction, **apply one full spade of farm yard manure** (FYM) or compost to each pit.

--> During the dry season, the wind will bring additional leaves and residues into the pits.

--> Therefore, the different micro-organisms, ants or termites will start recycling organic matter up and down into the soil profile, loosening and improving the structure all along.

--> After the first rains, zaï pits are sown with sorghum or millet (first season). Zaï pits harvest water and conserve soil. Soil moisture further improves the biological life and conditioning of the soil structure.

--> At the end of the growing season, sorghum & millet stocks are harvested by cutting them 60-90cm high from the ground level. The remaining stock is manually broken and thrown into the pit. During the second dry season the stalks will be decomposed and pulverized by the insects and other organisms.

--> During the second dry season, a second round of zaï pits can be dug in between the first year lines following the same procedures as above (2nd cycle).

--> During the second rainy season, plant legumes inside the pits dug on the 1st cycle. The second cycle pits are sown with sorghum or millet.

By the end of the second rainy season, the whole area is expected to be rehabilitated and easy to cultivate by either oxen or manually. After the two cropping seasons (cycles) using sorghum or millet you can switch to other crops (legume, sunflower) but always remember to leave some or most crop residues in the soil.

1st CYCLE				2nd CYCLE			
Oct-Nov	Nov-Dec	June-Aug	Oct-Dec	Nov-Jan	Jan	June-Aug	Oct-Dec
Dig Zaï	Apply manure & compostmulched into pits line pits	Sowing sorghum millet	Harvest + stalks mulched into pits	Dig zaï between lines	Apply compost & manure	Sowing sorghum millet	Harvest+stalks into second

Figure 2. Example of Zai pits in between soil bunds

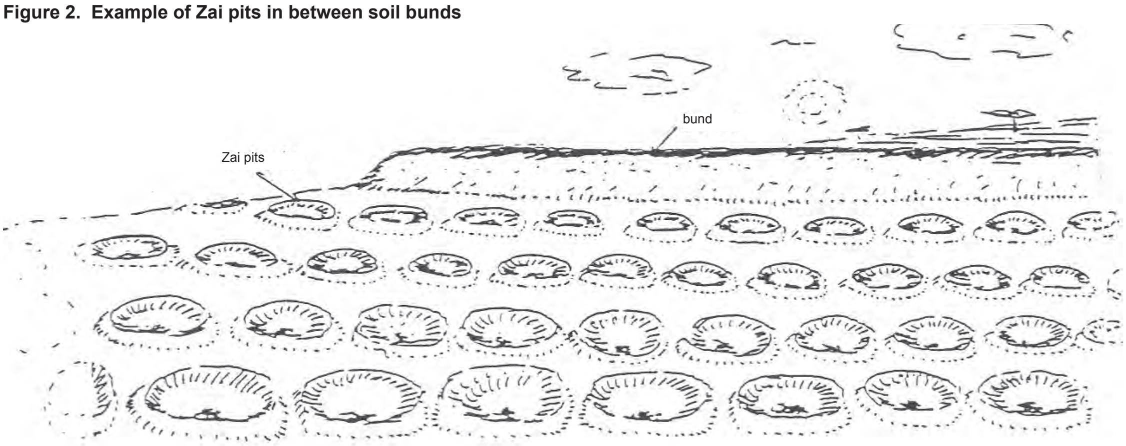
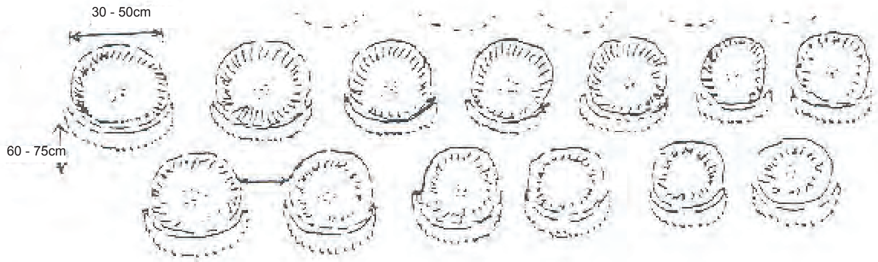
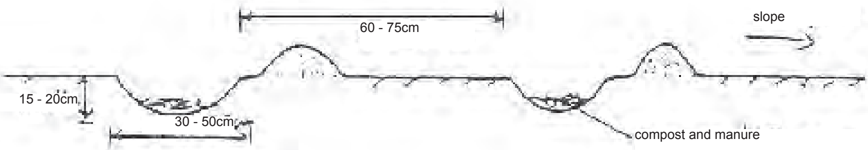


Figure 3. Zai construction

a) Arial View



b) Cross Section

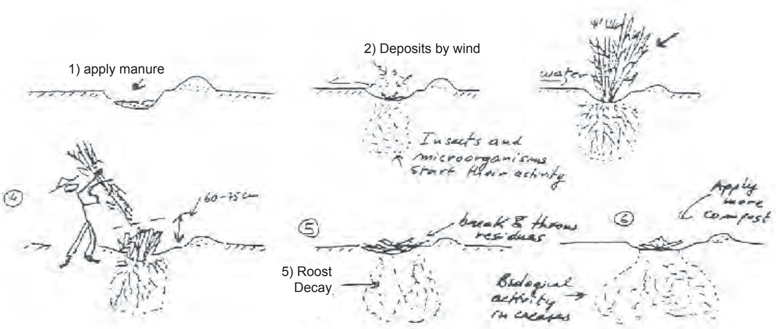


(7) Work norms

. The rough estimation of number of zaï pits per hectare range from max. 33,000 to minimum 16,000 pits based upon spacing and size. The work norm is 50 pits/day. It should be noted that the investment per hectare during 2 cycles of zaï should not only be related to the yields of sorghum or millet but also to the value of the land after the treatment.

(8) Integration requirements and opportunities	(9) Constraints and limitations
. Add contour bunds every 20-30 zaï lines to avoid risk of excess runoff breaking too many zais in case of heavy rains. . . Apply compost and control grazing. . Start with demonstration sites. . After 3-5 years of intensive care can be converted into multi-storey system of trees, crops, fruits, fodder, etc.	. The zaï system is labour intensive. It is then applicable where shortage of cropland is severe and labour is available and seen as cost effective investment. The Zaï system is not recommended on steep slopes.

Figure 4. Management of Zai pits



TECHNICAL INFORMATION KIT

LARGE HALF MOONS (STAGGERED ALTERNATIVELY)

(1) Period/phases for implementation

. During the dry season.

(2) Main objective/purpose

.The measure is a rainfall multiplier system that allow cultivation of crops in low rainfall areas. It is applied in areas with sandy and sandy loamy soils affected by low fertility levels and thin surface crusts that inhibit infiltration and increase runoff.

. Large half moons are suitable structures to enable cultivation of drought resistant crops in areas with very low rainfall.

. They intercept all runoff and stop erosion.

. It is also a measure suitable for rangelands and degraded grazing lands in dry areas (forage crops).

(3) Suitability and adaptability to local knowledge

. These structures are common in most drylands in the world since ancient times - not found in Ethiopia except for similar smaller structures for tree planting. However, principles of rainfall multiplier system is known in most Ethiopian drylands and this technology can easily expand.

(4) Main land use and agro-ecology

. This technology is applied in dry to very dry areas (below 500 mm rainfall - Kolla areas) for the cultivation of food and/or forage crops in previously abandoned terrains with gentle of almost flat slopes. These areas are common in pastoral and agropastoral setups and can be reclaimed using these and other similar techniques.

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

. If applied correctly it is a very effective technology for the reclamation and rehabilitation of shallow and crusted sandy areas - It is usually a zero-runoff system thus reduces erosion significantly.

(6) Description of the technology and steps

. Structures are semi-circular bunds 5 -15 meters large, 50-75 cm high and with a decreasing height at their tips to evacuate excess water although soils are often permeable enough. Slopes should not exceed 5% and soil depth should be not less than 30-50 cm.

. The runon-runoff ratio should be 1:1 to max 1:3 as more runoff can break the embankment. This means a 5 meter diameter half moon (has 2.5 meters width of cultivated area) will be distant from the next one 5 meters; with 1: 1 ratio (see figure 2), 7.5 m with 1:2 ratio and 10 m with 1:3 ratio. Half-moons can be placed one attached to the other (1:1 ratio) as a continuous system. However, the drier the area the higher the ratio between runoff-runon areas.

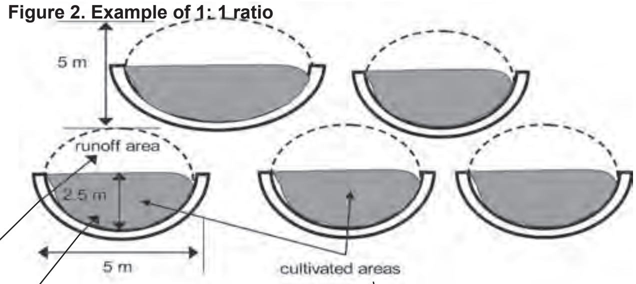
. Low moisture demanding crops should be planted such as millet and specific varieties of sorghum. Pulses such as specific drought resistant varieties of beans but also chick peas can be used.

. Half moons can also be planted with pure stands of pigeon peas and other fodder crops mixed with grasses (see ley pasture infotech)

. For work norms, apply the one for soil bund (150PD/km).

Figure 1. Half moons structures

Figure 2. Example of 1: 1 ratio



(7) Integration requirements and opportunities

. Integrated with control grazing and tree/shrubs planting on embankment (pigeon peas, etc) + manure applications.

(8) Constraints and limitations

. Not effective > 5% slope. Needs maintenance if not stabilized.