# TRAINING PACKAGE ON BIOPHYSICAL SOIL AND WATER CONSERVATION MEASURES ON HILLSIDE/DEGRADED LAND

## PART FIVE: TECHNICAL MANUAL ON BIOLOGICAL SOIL AND WATER CONSERVATION MEASURES ON HILLSIDE/DEGRADED LAND

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# MODULE 1: PLANTATION, BUND STABILIZATION, HEDGEROW AND PLANT MANAGEMENT

## 1. Introduction

Plantation refers to the practice of planting crops, flowers, grasses and legumes in small or large scale uncultivated areas. Accordingly, it refers to the biological plantation of seedlings, grass and legume crops; trees/shrubs fodder etc planted on hillside and degraded land and physical structures to be stabilized.

Plantation helps to give coverage for soil surface to protect it against the action of falling raindrops and absorbs their kinetic energy, increases degree of infiltration and maintains the roughness of the soil surface. In addition, it reduces speed of surface runoff, binds the soil mechanically, and diminishes microclimate fluctuations in the upper most layers of the soil surface. Moreover, it improves the physical, chemical and biological properties of the soil. Accordingly, hillside vegetation includes plantation, bund stabilization, hedgerow and plant management.

A dense vegetation cover is used to:

- prevents splash erosion;
- reduces the velocity of surface runoff;
- facilitates accumulation of soil particles;
- increases surface roughness which reduces runoff and increases infiltration;
- the roots and organic matter stabilise the soil aggregates and increase infiltration (Morgan 1999; Richter 1998; Hurni et al. 2003).

Hence, it is important to prepare Training Package on hillside vegetation to equip the Woreda Experts, DAs and Farmers with the concept and techniques of hillside plantation in order to improve the vegetation coverage of hillside/degraded areas.

## 2. Bund Stabilization

***Bund stabilization*** refers to the planting of crops, grass, shrubs and trees on bund embankments in different combinations in order to strengthen the resistance and stability of bunds against rain drops splash effect, runoff, wind erosion and cattle trampling.

At the same time, stabilization has the purpose of making productive the surface area occupied by the structure.

Stabilization is applicable for all land uses in which physical structures for soil conservation and water harvesting are constructed. Virtually all surfaces can be stabilized. Different species will be recommended in different agro climatic conditions. In dry areas drought resistant species are key elements for stabilization.

All physical structures including bunds, hillside terraces, ponds and cut of drains are liable to mechanical actions of rain drops, gravity, as well as human and livestock interferences. Therefore, bund needs to be stabilized:

- ♣ to ensure sustainability/stability and effectiveness of the physical structures
- ♣ to increases productivity (i.e. intensification).
- ♣ to stabilize bunds or fragile lands.

Ideally, planting on a bund should be done when the soil is sufficiently moist, well below the rooting depth of the plants. It is safe to start after the rainy season has begun properly. It is best to plant on a dull, cloudy weather, or during the cool hours of the day. Dry, sunny, windy days should be avoided.

For good survival after planting, seedlings need a balanced root: shoot ratio and an adequate root collar diameter to be sturdy/strong. The plant must support itself and the transpiring shoots have adequate moisture to prevent wilting and ultimately death.

Bund can be stabilized using grasses such as (indigenous grasses “sembelete”, “dasho”, chemo grass, herbs others, etc.), exotic grasses (dwarf elephant grass, vetiver grass) plus legume shrubs such as (pigeon peas, sesbania, acacia saligna, etc.) in dense rows by direct sowing or planting of splits or seedlings (15-30 cm).

## *2.1 Species Selection and Planting Techniques*

Bund can be stabilized by using different plants species such as: grasses, leguminous and fodder plants and with various species. It could be established followed by growing cash crop (especially 1-2yrs of composting) in single or wider strips as required. In addition, annual crops could be planted along the bunds to use residual moisture (sunflowers, gourd, tomatoes, cucumbers, etc.). These planting materials have their own agro-ecological preference for their successful establishment & effective growth. Some factors that need to be considered to carry out successful & appropriate selection of planting materials:

- ♣ specific objective to stabilized & rehabilitate the bunds,
- ♣ essential merit of the vegetation to meet multiple needs of local communities,
- ♣ commitment and willingness of local communities to protect and manage the planted vegetation covers,
- ♣ altitudinal range (including the incidence frost & drought its tolerant to such phenomena),
- ♣ rain fall (total annual rain fall, mono and bi-modal),
- ♣ length of growing season pattern (one or two wet seasons),
- ♣ soil condition (soil pH, depth, texture (clay, sand, clay-loam), water logging, salinity
- ♣ slope % variation.

In addition those species to be considered are species:

- ♣ Those do not disperse by seed, in order to avoid dispersed in farm lands.
- ♣ Those species which make good coverage of the soil
- ♣ Which form dense hedges up on growth in order to support bund formation
- ♣ Which do not form shade effect on crops?
- ♣ Those capable of forming a dense, permanent hedge, resistant to harmful effects of overgrazing, permanent hedge, resistant to harmful effects of overgrazing and fire

Some of the plant species suitable for bund stabilization are mentioned below in table 1 below.

Table 1: Suitable plant species for bund stabilization

| No | Species | Altitudinal range (m) | Min. Rainfall (mm) | Soil requirement |
|---|---|---|---|---|
| 1 | Grass species | | | |
| 1.1 | Phalaris | >3000m | 400 -650 mm | Heavy fertile soils |
| 1.2 | Elephant | 2000m asl | 1480-1620 mm | Deep, friable fertile soil |
| 1.3 | Buffel | Up to 2000m asl | 375-750mm | Light texture well drained |
| 1.4 | Rhodes | 600-2000m | 650-1200 mm | Light texture well drained |
| 1.5 | Guinea | 650-1500 | 650-1500 mm | Well drained medium textured fertile soils |
| 1.6 | Dicanthium | na | na | Suitable to most texture of coralline sand to heavy black clay |
| 1.7 | Desho | 1700-2800m | na | na |
| 1.8 | Vetiver | 3000m | 300-6000mm | versatile |
| 1.9 | Bana grass | 2500m | 800mm | Versatile |
| 1.10 | Green gold | 2500m | 800 mm | Versatile |
| 1.11 | Setaria | Up to 2000 m | 500-700 | Well-drained fertile soil |
| 1.12 | Sorghum almun | Up to 1800 mm | 400-900 | Black alluvial soils |
| 2 | Leguminous trees | | | |
| 2.1 | Desmodium | Up to 2000m asl | High rainfall (900 - 1000) mm | Well-drained sandy loam soils |
| 2.2 | Vetch | 1500-3000m asl | 400mm | Versatile |
| 2.3 | Siratro | Up to 1700m | 700-800 mm | Light textured low fertility soils |
| 2.4 | Stylo pere | Up to 2000 m | 600-2500mm | na |
| 2.5 | Lablab | Up to 2000 m | 700-2000 mm | Deep sandy to clay loam soils |
| 2.6 | Alfalfa | 500-3000m asl | 600-750 mm | Deep fertile & well drained |
| 3 | Fodder plants | | | |
| 3.1 | Tree Lucerne | Up to 3200 m | 550mm | Well-drained soil |
| 3.2 | Sesbania | 200 - 2500 m | 600 mm | Wide range |
| 3.3 | Acacia species | na | na | na |
| | A.altida | Up to 2000 | 450-800 mm | Deep sandy loam soils |
| | A.salgina | Up to 1800 | 450-800 mm | Poor rocky soils |
| 3.4 | Albizia | Up to 1800 | 150-200 | Well-drained soils |
| 3.5 | Pigeon pea | 500-1800m | 600-1000 mm | Varity of soil |
| 3.6 | Leucaena leucocephala | Up to 1800m abs | 500-2000 mm | Well-drained heavy fertile soil |
| 3.7 | Parkinsonia | na | na | na |
| 3.8 | Moringa | Up to 1800 m | 500-1100 mm | Variety of soils |
| 3.9 | Cactus | na | na | na |

na= not available

**A. Stabilization with trees and shrubs**

Tree/shrubs should be planted at close spacing: 30 to 60 cm apart on single or staggered double row (one on the berm and the other at the lower side of the embankment). Plant the trees/shrubs using seedlings instead of direct sowing because seedlings grow faster and by the end of the rainy season have a rooting system able to explore wider and deeper portions of the soil profile and thus have a better chance to withstand the long dry season. Hillside terraces and tranches can also be stabilized

by planting drought resistant plants such as Sisal, Aloes and Euphorbia placed on the lower side of the stone wall. Establishment in direct sowing is also successful and cost effective in selected tree & shrub species. Therefore, must be encouraged. E.g. Sesbania, F.albida, “Gummero”, A.abysinica etc,

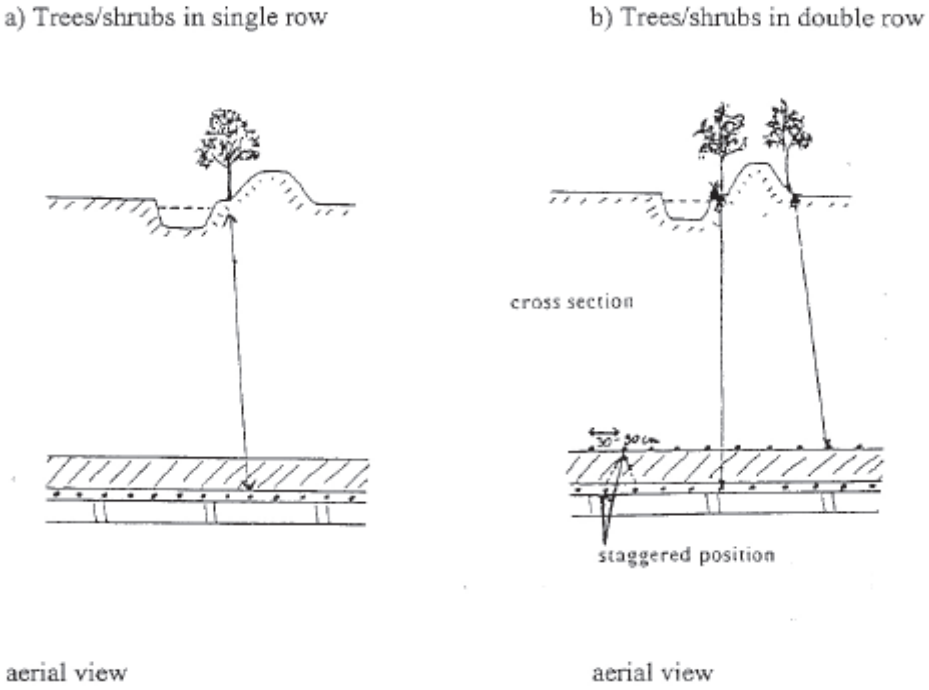
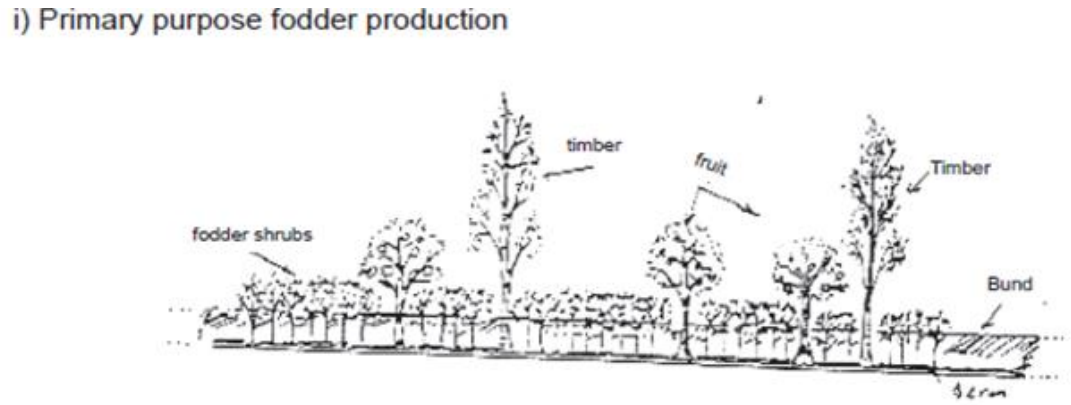



**Figure 1: Trees/shrubs for fodder production**

Trees/shrubs such as Leucaena leucocephala, Pigeon peas and Sesbania sesban, Acacia saligna planted in dense rows can also be introduced and used as forage mixed with crop residues.

**B. Stabilization with Trees and Shrubs for fuel wood**

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



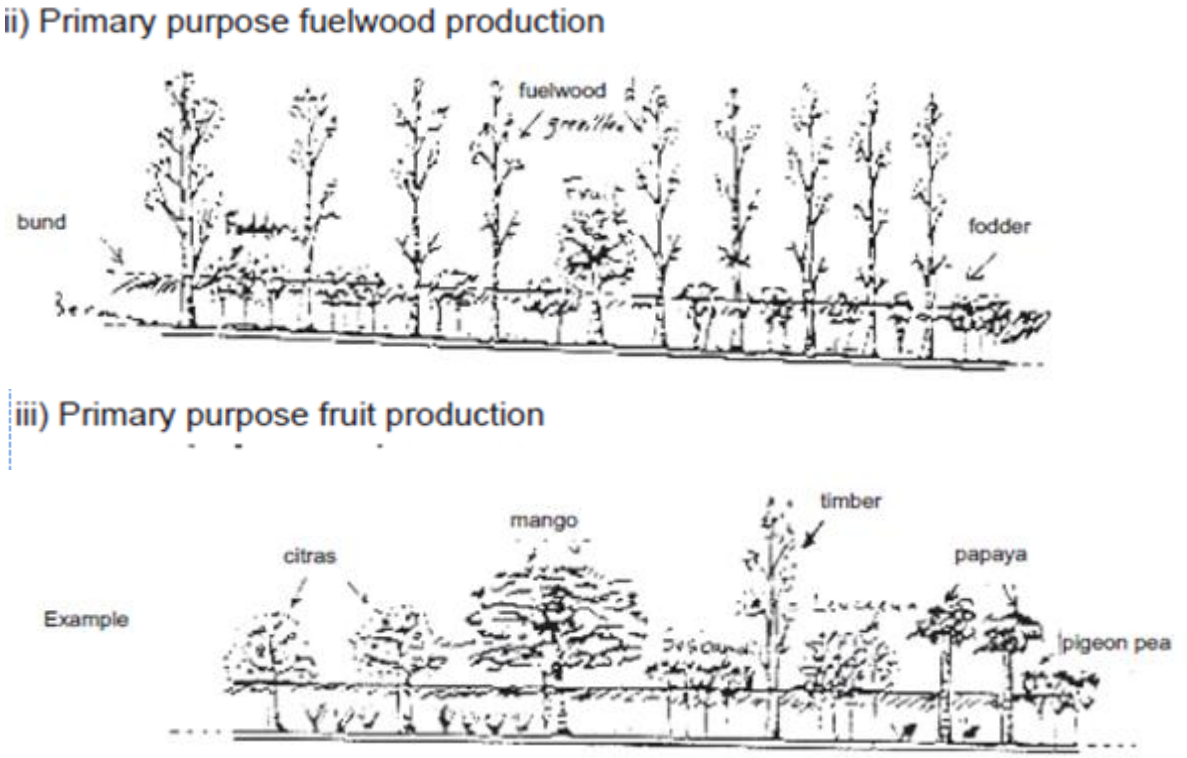



**Figure 2: Multipurpose trees/shrubs and fruit trees**

**C. Stabilization with Fruit Trees**

Fruit trees can be planted along bunds, bench terraces and in collection ditches, etc. Plantation of fruit trees is very appropriate in most conditions combined with trenches behind structures. Species include mango, guava, citrus and other species. Some other drought resistant perishable and non-perishable fruit trees species should be tried from other countries (cashew nut, custard, apple, pistachios, apricots, jackfruit, tamarind, etc.). Highland fruits such as apples, plums, and peaches can grow at higher altitudes and make bench terraces an attractive and productive option. It is recommended to plant fruit trees in combination with other multipurpose species at various intervals (for example: 1 fruit tree - 3 fodder trees, 1 fuel wood tree – 3fodder trees - 1 fruit tree, etc) (see figure 2).

**Figure 3: Fruit trees with other multipurpose species**

**D. Stabilization with Forage Grasses and Legumes**

All physical structures can be stabilised with grass and legume pasture species. Amongst these, soil and stone faced soil bunds, trenches and herring bones are most suitable for grass and legume stabilisation. Fodder grass and legume can be integrated with trees/shrubs in different combinations. Therefore they close gaps between trees/shrubs and make the bund stronger. In Ethiopia, several local drought resistant and palatable grass species are available (Dasho grass, Chemo grass, sesbania, dwarf elephant grass, pigeon pea etc.). Choose the best type of grass species based upon type of soil, water requirements, and palatability and biomass production. Fruit trees: Planting in side trench bunds must be encouraged since this is very promising in drained soils.


**Figure 4: Dasho Grass and Sesbania**

**Figure 5: Pigeon pea & Elephant grasses**

If native grass species are to be used, ask the farmers which one they suggest prefer and have sufficient seeds for planting. If new grass species are to be introduced, consult forage/livestock expert. Test germination rate of seeds (50-80% is satisfactory). If germination is lower increase the number of seeds during sowing time or look for another lot of seeds. Plant grass and legumes in

different proportions based upon needs (2 rows of grass+1 row legume, 2 rows legumes+1 row grass, etc).

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


**Figure 6: stabilization with grass and legumes**

**E. Stabilization with annual crops**

Traditionally farmers plant different crops along the bunds where moisture is higher. This practice should be encouraged and improved. In the first year, water logging tolerant crops should be planted along the berm such as millet and pigeon pea. Some other crops such as pulses, oilseeds (nug, niger, etc.), beans or vegetables (pumpkins, etc.) can be planted on top of the embankment. At the end of the rainy season, the bottom of the collection trench can also be sown at late rains stage with crops such as sunflower, chick pea or vegetables.

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

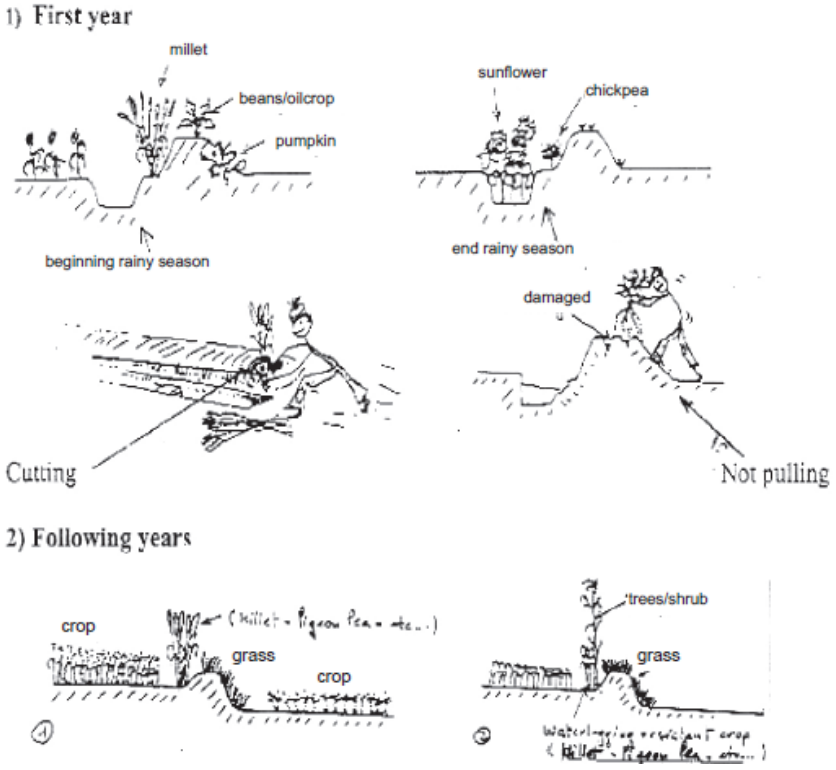



**Figure 7: Stabilization with crops**

**F. Stabilization a combination of Annual Crops/Grasses/ Trees/Shrubs**

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

## *2.2 Preparation of planting materials*

**Forms of Planting Materials**

Planting materials for bund stabilization can be either from seeds, seedlings and stem cuttings. The source can be from grasses, leguminous or fodder plants. The vegetative type includes seedlings, root splits and stems cuttings.

**Preparation of seeds**

General idea can help to give necessary technical supports to farmers for their own tree seed collection and utilization. Seeds must be collected when they are ripe and ready for collection. Seed maturity can be detected easily for fruits and cones by their colour. Most fruits turn yellow, red, brownish etc. (depending on their nature) when they are ripe enough. The following are the steps for local seed collection.

- ♣ Encouraging farmers to have well prepared plan for seed collection,
- ♣ Advising them to prepare necessary tools and equipments for seed collection (ladders, ropes, seed baskets, sacks or other containers; mats, notebooks and format seed documentation),
- ♣ Identifying for the existing of vigorous and health mother trees in the local area,
- ♣ Requesting permission to get an access to the mother trees if it is on an individual land,
- ♣ Collecting only mature seed to maximize seed viability, seed storability and good quality seedlings,
- ♣ Mixing bulky seeds from the same species of different trees thoroughly together,
- ♣ Drying the seeds to their low moisture content before they are stored,
- ♣ Storing the seeds under a consistent cool temperature, low air humidity and at low moisture contents,
- ♣ Checking and treat for dormancy problem,
- ♣ Proper documentation by using seed collection format,

**Planting with seeds**

Success in planting by seeds depends on good seed quality, planting in rows or in spots; seed is sown and not broad cast on surface. The depth of planting has to be 1-3cm depending on seed size and it has to properly placed/ buried in soil. The following are the steps for seed planting on seed bed for seedlings preparation.

1meter width X10meter length seedbed

**Seedling Preparation**

- ♣ Prepare a mixture of fine sand, forest soil and farm yard manure,
- ♣ Prepare seedbed/s with 1m width and 10m length by locating it against slope,
- ♣ If the situation forces you to have more than one seedbed, leave 0.5m space between each seedbed for appropriate management,
- ♣ Carrying out smooth and fine seedbed preparation for small sized seeds (grass seeds),
- ♣ Ensuring the avoidance of big clods and soil movement during the seedbed preparation,
- ♣ Watering the seedbed a day before planting to stabilize the seedbeds and to avoid the burying of seeds due to soil movement.
- ♣ Use small stick make a line with 30cm space and of 2cm depth against the length of the seedbed,
- ♣ Mix the seeds with filter to have uniform plant population,
- ♣ Slowly drop the seeds within the prepared line,

- ♣ Slightly cover the seeds by using leafless tree branch (see figure 2 below),
- ♣ Carry out regular watering and weeding,

**Planting with Seedlings**

Preparing Proper and large size pitting before planting and manure is applied. Bare-rooted plants and stumps can be planted in a hole or slit dug with a spade, mattock, or even opened up with a crowbar, container plants are planted in a small pit. For all planting the following general rules apply.

- ♣ Select only healthy and well grown seedling to plant
- ♣ Insert roots into the soil up to the root collar.
- ♣ Avoid damaging roots by breaking, bending, or crushing.
- ♣ Firm soil around the roots by heeling or foot pressure.
- ♣ Remove impervious containers before planting.
- ♣ On dry sites the planting position should maximize water retention, eg. Furrow bottom, base of mound.
- ♣ Stumps should not be forced into the ground. They should be placed in specially prepared holes and the soil firmed around them as with ordinary plants.
- ♣ In arid regions plants may be put in specially deep to ensure that roots reach moist soil and only a small part of the shoot is above ground and subject to transpiration stress. Deep planting of tall plants can sometimes be done to prevent them being blown over.
- ♣ Plant seedlings early in the morning or late afternoon.

**Planting of root splits**

Root splits are another means of planting materials to be prepared for bund stabilization. Some grass species such as Vetiver, Dasho, Guinea, Phalaris and Setaria are more suitable for the preparation of root splits. The following are steps for root split preparation for clumps grass:

- ♣ Cut the old clumps of grass at about 12 cm above the ground,
- ♣ Carefully uproot and transport the clumps to the planting site,
- ♣ Keep the clumps under moist/damp condition to avoid desiccation before planting,
- ♣ Cover the root part of the clumps with moist mulches and storing them under shade,
- ♣ Carefully separate the clumps into splits with 2 - 3 tillers in a set of each split,
- ♣ Use simple hand tools sharp knife to separate apart the splits, without damaging the roots and growing points,
- ♣ Preferably planting the seedlings on a cloudy day.

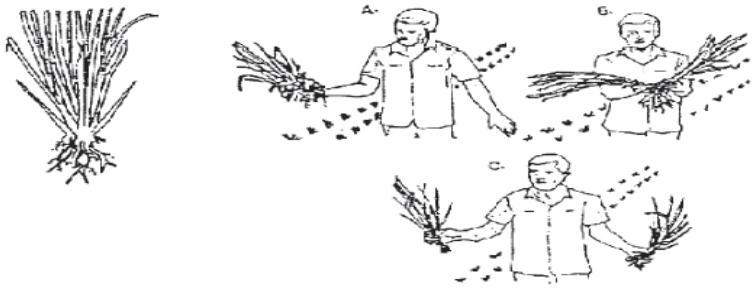


**Figure 8: Splitting grass from clumps**

**Steam Cuttings**

A well-grown stand of mature stems from Elephant grass with three nodes can be cut and planted in furrows or surface broadcast/scattering and covered with soil. Two nodes are buried in the soil while one of the planting materials is expected to remain above the soil. The stem should be cut in sliced form and planted at $45^{o}$ to protect the entrance of rainfall after plantation. Thus cutting and planting of vegetative planting materials should not be in a perpendicular position.

**Grass Strips**

Grass strips are vegetative barriers made out of grass planted in narrow strips of 0.5 to 1.5 meters width laid out along the contour. They are made up of live vegetations (shrubs & grasses). Grass strips control erosion rather effectively in gentle slopes. While they contributing to protect soils against erosion they also provide valuable biomass meant to increase animal feed or used for different purposes (eg. roofing, etc.). Grass strips are suitable for cultivated land, mostly in medium and high rainfall areas (moist weyna dega and dega). Within the context of moisture deficit areas grass strips can be applied in semi-arid areas and but not for arid areas. Grass strips can replace physical structures effectively usually up to 8% slopes. Exceptions are possible above those ranges but not as effective and/or combined with physical structures and or trees/shrubs hedgerows. The following are the steps in planting grass strips:

- ♣ Make (0.5-1.5 cm) depth is the optimum for most species.
- ♣ When planted manually, rows are opened with a stick at the desired spacing and seed is drilled in the row.
- ♣ Seeds are covered with a thin layer of soil and pressed hard to the soil.
- ♣ Before planting, seeds should be checked for their germination.
- ♣ Alternatively and for improved efficiency and rapid cover use splits and/or grass cuttings or seedlings planted in lines/rows without discontinuity.
- ♣ Spacing between the seedlings/splits should not be wider than 5 cm to guarantee effective grass strip.

**Layout**: grass strips are established along the contours. Grass strips are established on a 1m vertical interval, i.e. at 3% slope the distance apart two strips is 33 meter and decrease to 7 meter at 15% slope. In dry areas, grass strips should not be established on slopes > 8%. For slopes up to 15% they may be planted alternatively with bunds (one grass strip/one bund). The width varies from 0.5 m to 1 meter, depending on the density of the plants in the strip. For conservation purposes a width of 0.8-1 meter is recommended (See Figure 6).

The grass strip is established by broadcasting or sowing/planting seeds/splits/cuttings in two or three lines. The middle row can be sown with a legume to improve the nutritive value of grasses. If the broadcasting method is used, grass seeds can be mixed with the legume seeds and broadcast in the strip.

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

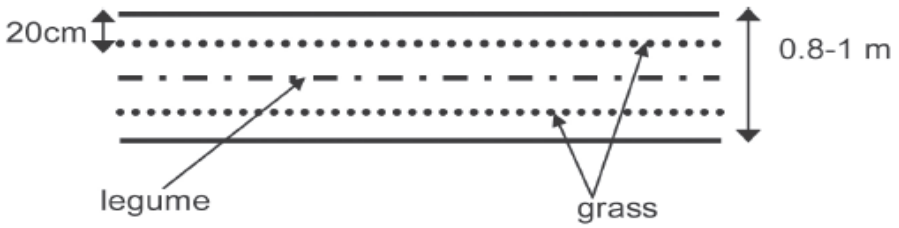



**Figure 9: Grass Strip (aerial View)**

**Figure 10: Effectiveness of Grass strip of Desho grass example from chencha**

**Figure 11: Dasho grass strip (Picture from Angacha, watershed, 2013)**

**Stabilization with Vetiver Grass**

Vetiver grass, or khus khus (*Vetiveria zizanioides L.), is native to South and South-East Asia, where it* has been used for centuries to mark boundary lines. Its roots and tops have also been harvested. The fragrant, **insect-repelling** roots yield and oil which is valuable in the perfume industry. Traditionally, these **roots were woven into mats, fans and fragrant screens**, while the tops of the grass were used **for handicraft, thatch, mulch**, fodder and animal bedding. Vetiver is still cultivated for these purposes today in South and South-East Asia, Africa, the Pacific, the Americas and the Caribbean. Vetiver grass has some Special Characteristics.

**Morphological Characteristics**

- Vetiver grass does not produce **above or underground runners**.
- The plant has a **strong and massive** root system, which is vertical in nature descending 2-3 meters in the first year, ultimately reaching some five meters under tropical conditions.
- The depth of root structure provides the plant with great **tolerance to drought**, permits excellent infiltration of soil moisture and penetrates through compacted soil layers (hard pans).
- Above ground, the shoots **can grow to two meters** and when planted close together it forms a solid vegetative barrier that retards water flow and filters and traps sediment in runoff water.
- Growth occurs from the crown, which rises relative to soil build-up.
- It is also highly **resistant to pests, diseases, fire and heavy grazing** pressure.

**Ecological Characteristics**

- ♣ Although vetiver is tolerant to extreme soil and climatic conditions, it is intolerant to heavy shade.
- ♣ Shading will reduce growth and, in extreme cases, may result in plant failure.
- ♣ It is considered as a pioneer plant.
- ♣ When the planted or invading indigenous species of trees and shrubs eventually form into a heavy canopy above vetiver, its growth will be reduced, and, if desired, it will die out under prolonged shading.
- ♣ Thus, vetiver is a valuable pioneer agent for land rehabilitation and the establishment of native plants or in the context of forestry establishment on steeply sloping lands.
- ♣ Whilst vetiver originates as a tropical grass, its adaptability permits it to thrive in climatic circumstances outside the tropical and sub-tropical zones.

**Effectiveness of Vetiver Grass for erosion control**

- ♣ When planted correctly, V. zizanioides will quickly form a dense, permanent hedge.
- ♣ It has a strong fibrous root system that penetrates and binds the soil to a depth of up to 3 meters and can withstand the effects of tunneling and cracking.
- ♣ It is perennial and requires minimal maintenance.
- ♣ It is practically **sterile**, and because it produces no **stolons or rhizomes** it will not become a weed.
- ♣ Its crown is below the surface, which protects the plant against fire and overgrazing.
- ♣ Its sharp leaves and aromatic roots repel rodents, snakes, and similar pests.
- ♣ Its leaves and roots have demonstrated a resistance to most diseases.

Once established, it is **generally unpalatable** to livestock. The **young leaves, however, are palatable** and can be used for fodder.

- ♣ Vetiver is both a **xerophyte** (adapted for life with a limited supply of water) and a **hydrophyte** (grows partly or wholly in water), and once established it can withstand drought, flood, and long periods of water logging.
- ♣ It will **not compete** with the crop plants it is used to protect.
- ♣ It will grow in **all types of soil**, **regardless of fertility, pH, or salinity.** This includes sands, shales, gravels, and even soils with aluminum toxicity.

**Methods of Propagation**

The four common ways to propagate Vetiver are:

1. Splitting mature tillers from Vetiver clump or mother plants, which yields bare root slips for immediate planting or propagating in poly bags.
2. Using various parts of a mother Vetiver plant
3. Bud multiplication or in vitro micro propagation for large scale propagation
4. Tissue culture, using a small part of the plant to propagate on a large scale.

Vetiver grass can be produced on nursery sites **bare rooted** and with **polyethylene tubes**. Vetiver can only be grown from fresh planting material (planting slips). Therefore try to establish a Vetiver nursery from where farmers can 'harvest' planting slips every year. The nursery should therefore be permanent.

**Procedure:**

The site for the nursery does not need to be fenced, unless there is a lot of livestock around.

1. When planting Vetiver grass, split a larger plant into small planting slips.
2. Then simply put the planting piece or planting slip in a small hole in the ground or into small plastic bags. Make sure all the roots are covered with soil.
3. Plant the slips with 20-30cm between each plant. Water them unless the soil is already moist
4. During the first weeks, check regularly whether the nursery is ok. The slips should start shooting within the first 2-3 weeks. Water if it does not rain

3. When the grass has grown tall, cut or trim it down to 10 cm. This will increase tillering and thus increase production in the nursery
4. When the time is right for using Vetiver in the fields, uproot as much grass as needed, but make sure that enough grass is left behind to re-establish the nursery. By doing so, enough planting material will be available for the next planting season.

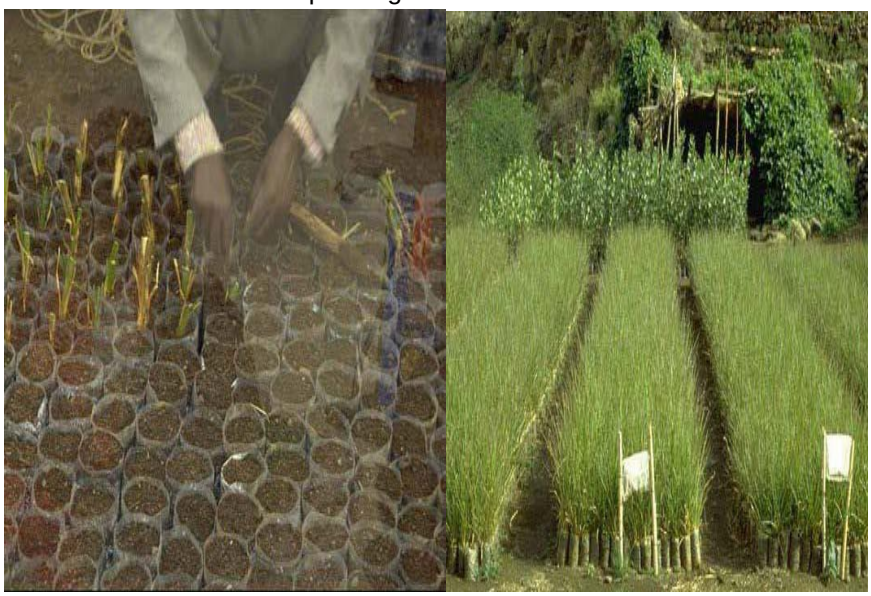


**Figure 12 & 13: Planting Vetiver grass slips into plastic bags & ready for transplanting into the field (manual of soil conservation & slope cultivation (**Source: Caribbean Agricultural Research & Development Institute, CARDI, July 2010)

**Useful tips**

- For checking rills and small gullies, plant small but dense Vetiver hedges across where the water flows
- Try planting fruit trees in front of a Vetiver hedge, the moisture and soil trapped there will provide an excellent environment for fruit trees.

**Figure 14 & 15: Vetiver grass recently transplanted into the field & growing along the contour**

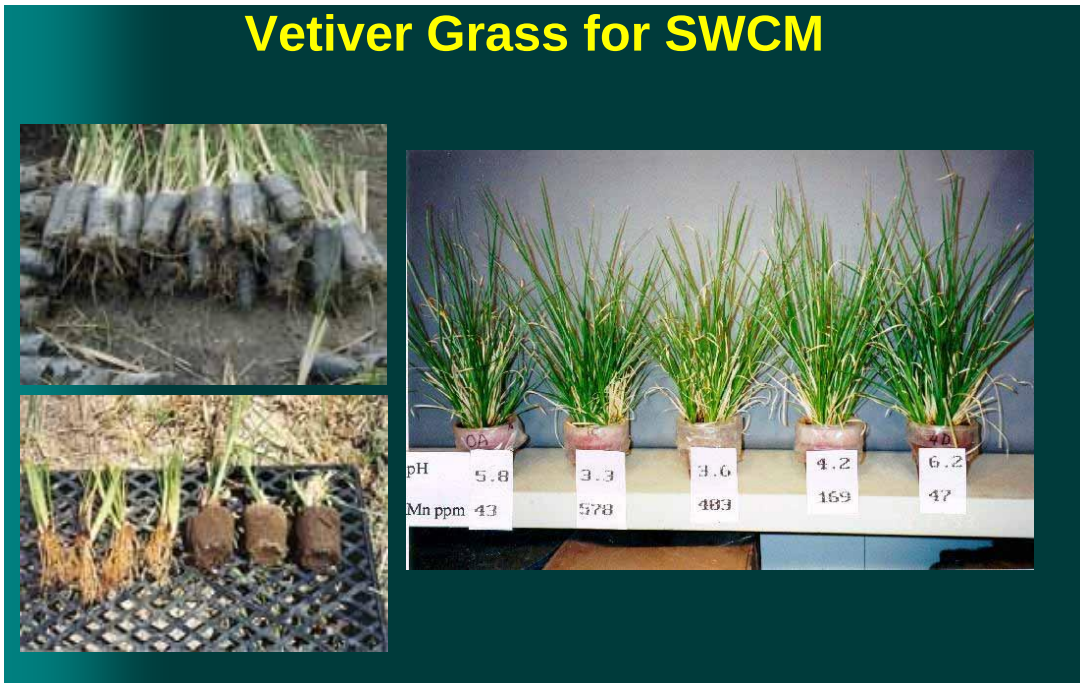



**Figure 16: Vetever grass production with polyethylene tubes**


**Figure 17: Production of Vetiver grass in the Nursery**


**Figure 18: Vetiver Grass in treated micro watershed**


**Figure 19: Vetiver grass for road embankment stabilization**

## *2.3 Preparation of planting site*

Bund stabilization can be carried out on different parts of the bund which including top width of the bund, lower/upper part of the bunds, and the berm. Slight land preparation is required to be carried out for direct seeding or vegetative plantation. In most cases, the top width of the bunds (40cm) is expected to be planted with mix of planting materials to ensure effective bund stabilization. Thus, the top width of the bunds (40cm) should be cultivated by hand to smooth the soil for direct seeding or vegetative (seedlings and cuttings) planting. As far as, the top width of the bund is concerned, the land preparation should be carried out across the bund to produce a line/row with space of 20cm between rows and 10cm between plants. If it is direct seeding, the planting depth for small sized seed should not exceed more than 2cm.

**Planting pit preparation**

Carry out pit preparation 6 months or a year before planting,

- ♣ Do not forget that, the longer the period for pit preparation, the more favorable conditions to be created for the survival of the seedlings,
- ♣ During pit preparation, put the top soil to the right side of the pit and the sub soil to the left side,
- ♣ Mix the top soil with various organic materials, crop residues and compost,
  The top soil should be returned to the pit followed by the sub-soil, which allows for the decomposition of organic matter to create conducive environment for the seedlings at the planting time.
- ♣ Do not forget to put a peg or mark with locally available materials to remember the exact location of the pit during planting time,

# 3. Stabilization of Other Physical Structures

Stabilization of physical structures needs **to be seen as a "multiple cropping" activity within the physical structure area** and integrated with additional soil management techniques within the terraces or treated areas. In several countries physical structures and their immediate surrounding area constitute cash crop belts where fruits and cash crops grow.

**Vegetative fencing (VF**) is conservation practices which consist of a combination of vegetative planting materials resistant to cattle grazing planted in rows and with grass/ legume plant species sowed behind these rows. VF is used to protect and enrich reclaimed areas like closures and gullies, farm boundaries and specific community assets like ponds. By doing so it also helps controlling runoff

and erosion. It is the “first level of defence” against animal interference that allows other valuable trees to be planted after the fence is established. VF can be exercised as a “grid system” in closures, around reclaimed gullies, and farms, providing increased sense of ownership to users.

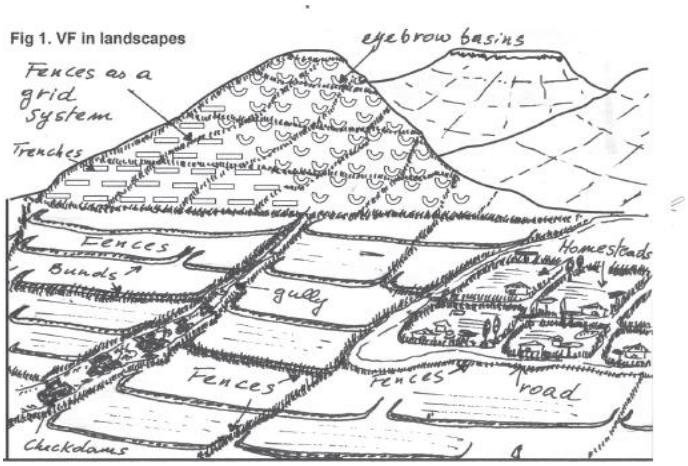



**Figure 20: vegetative fencing in landscape**

**Main Fence:** made preferably of 2 rows of species planted staggered such as Euphorbia candelabra (tall Euphorbia or “Koal-koal”) and finger Euphorbia (“Kincheb”), Erithrina (“Korch”), Aloe, Sisal and other plants. Spacing of plants in main fence: 50 cm between rows and 20 cm within row, possibly using a combination of the above species. Single row also possible - plants 10 cm or very close apart based upon local knowledge (necessary to obtain a tight and continuous vegetative fence).

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

In areas already treated with hillside terraces place single row VF following lower part of stone raiser (see Figure 16 above). For measures like trenches, eyebrows and similar structures place single row VF in between series of those structures based on the size of plots.

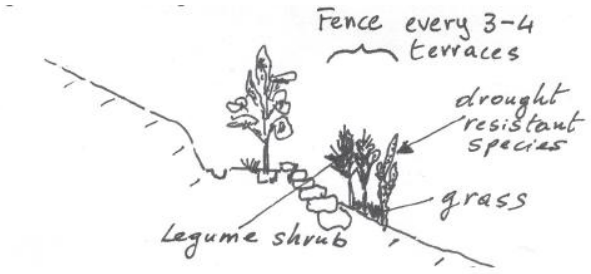



**Figure 21: Vegetative fence along hillside terraces**

**Stabilization of Half Moon structures:**

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). 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.

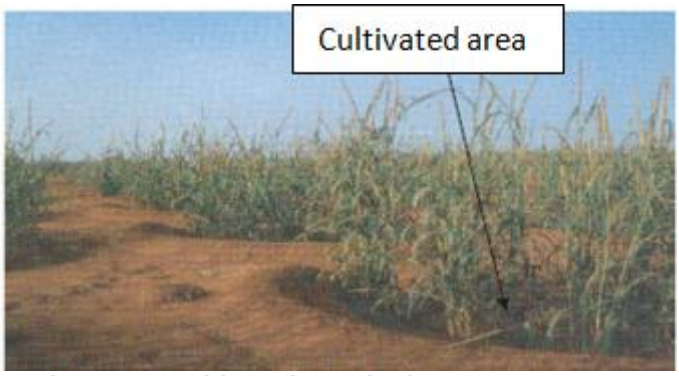



**Figure 22: Cultivated area in the moon structure**

**Plantation of grass/legumes behind main fence:** this is to further support and make the fence thicker and more productive. Direct sowing of Sesbania, Pigeon peas, Acacia Saligna, Tree Lucerne and local grass strips is recommended. Plant one line of grass as close as possible to the fence or between the two rows. Plant one or two rows of legume shrubs by opening a furrow of 20cm behind the fence. In areas already treated with hillside terraces place single row VF following lower part of stone raiser (see Figure 17 above). For measures like trenches, eyebrows and similar structures place single row VF in between series of those structures based on the size of plots.

**Stabilization of Micro-basins and Eyebrow basins**

Micro and eyebrow basins have a good potential to stabilize and improve degraded and steep hillsides - mostly for area closure and multipurpose trees and fodder trees plantations. When combined with sound moisture conservation trenches and proper management, they will contribute to watershed rehabilitation, biomass production and recharging of water tables. They also have multiple effects in moist areas, which they provide a small platform for tree planting in dry areas and they are used to harvest water from a larger area with 3-10 m diameter on gentle slopes, sometimes with additional water collection ditches.

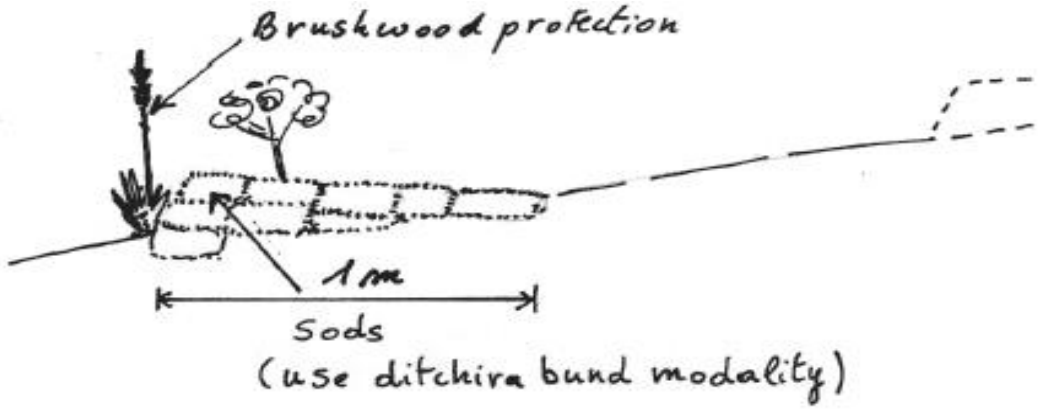



**Figure 23: Micro basin constructed with sods in areas without stones (max 20% slope)**

**Stabilization of Waterways:**

Waterways are stabilized with local grass - sods - dry straws lines buried into the ground during first year. Grass cover shall be encouraged to grow in the waterway. To support the establishment of grass, install scour checks in channels of <4% slope (at level scour checks); on 5-30% slope (raised scour checks); and on slopes greater than 30% (low check dams). For surface stabilization, use plant varieties of low growing creeping grasses in the channel and productive fodder grass on embankments.

**Stabilization of Cut off Drains:**
Plantation of grass, alloevera and sisal on the embankment, the berm and the upper side of the channel is needed to prevent the soil entering the channel.

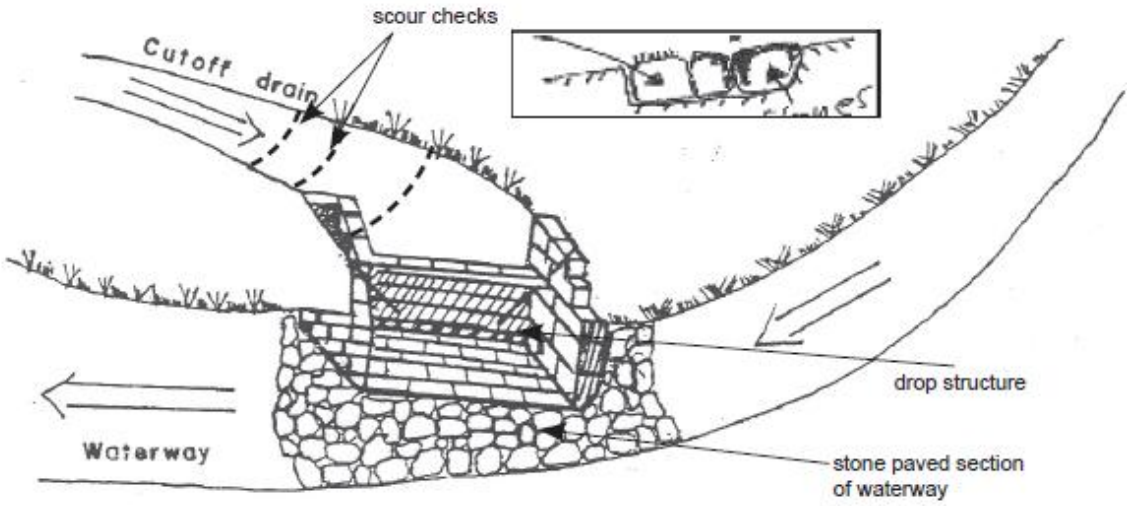



**Figure 24: Cut off Drain stabilized with stones and grasses**

# 4. Area Closure

Area closure is one of the components of the biological conservation measures and it is practised on all land types where soil erosion has becomes serious and the land has lost its productive potential. However, generally the eroded hillsides are the prominent sites of area closure.

Area closure is a simple conservation activity carried out on highly degraded lands. When land has been severely degraded due to soil erosion and it is unable to produce sufficient biomass. Especially when the chances of recovering this land by conservation measures are not encouraging, it is advisable that the area should be provided complete rest and this is called Area closure. However, necessary supporting activities such as water harvesting and enrichment planting etc are carried out in order to enhance the rate of recovery.

Area closure is suitable for degraded areas in most agro-climatic parts of the country. It is commonly practiced in Ethiopia with different levels of performance. Best closed areas found when directly managed by the community and groups of interested farmers, mostly degraded hillsides and large gully networks.

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

Guarding and no livestock are allowed to graze for 3-5 years, and no or limited human interference is tolerated until 80% grass cover is obtained in the area closure.

The following activities are included under area closure:

- Closing off the entire area from the interference from human and livestock until it is completely conserved and ready to be reused...
- Necessary soil and water conservation work is carried out on these lands.
- Unwanted and uneconomical plant species are removed from the land

- Planting material of suitable species kept ready in advance of planting
- Suitable plant species are planted in between existing plant species
- Strip planting of forage species and spot planting of fodder, forest and other trees should be carried out during the early years
- Plants generating income should be planted on suitable sites
- To improve soil fertility some application of organic manure to planted species should be carried out.
- Management includes, weeding, removal of unwanted plants, pruning of trees, and safety from livestock.
- Allow forage crops to produce seeds in the first year.
- Biomass should be utilized by manually harvesting and feeding livestock under stall feeding system.
- Once the area has been well stabilized and conserved, it can be used for more intensive planting of suitable crops but without encouraging soil erosion.

The following benefits can be obtained if the conservation activity is carried out in the area closure:

- It is the simplest and most economical method of conserving degraded lands
- The hillsides which were previously closed have now become productive
- The community is producing a large amount of biomass
- The biomass generates substantial income for the community
- It has resulted in conservation of water in situ and runoff is reduced
- It has reduced flooding of lower areas,
- It has improved water table and revived springs
- Wild life has returned and environment is improved

The rate and extent of success for area closure benefits depends on many factors such as severity of land degradation, Rainfall, Natural vegetation, Effectiveness of soil conservation measures, Effectiveness of enrichment planting, Efficient management of area closure and Interest of the community in this activity.

Area closure activity has now been extended to farmlands and it is called **farm closure**. It has been observed that sustainable land management and improved production cannot be achieved unless the free livestock movement is controlled. Intensive crop production is possible only when the land is safe from livestock throughout the year. Only then natural resources can be intensively exploited for maximizing farm production.

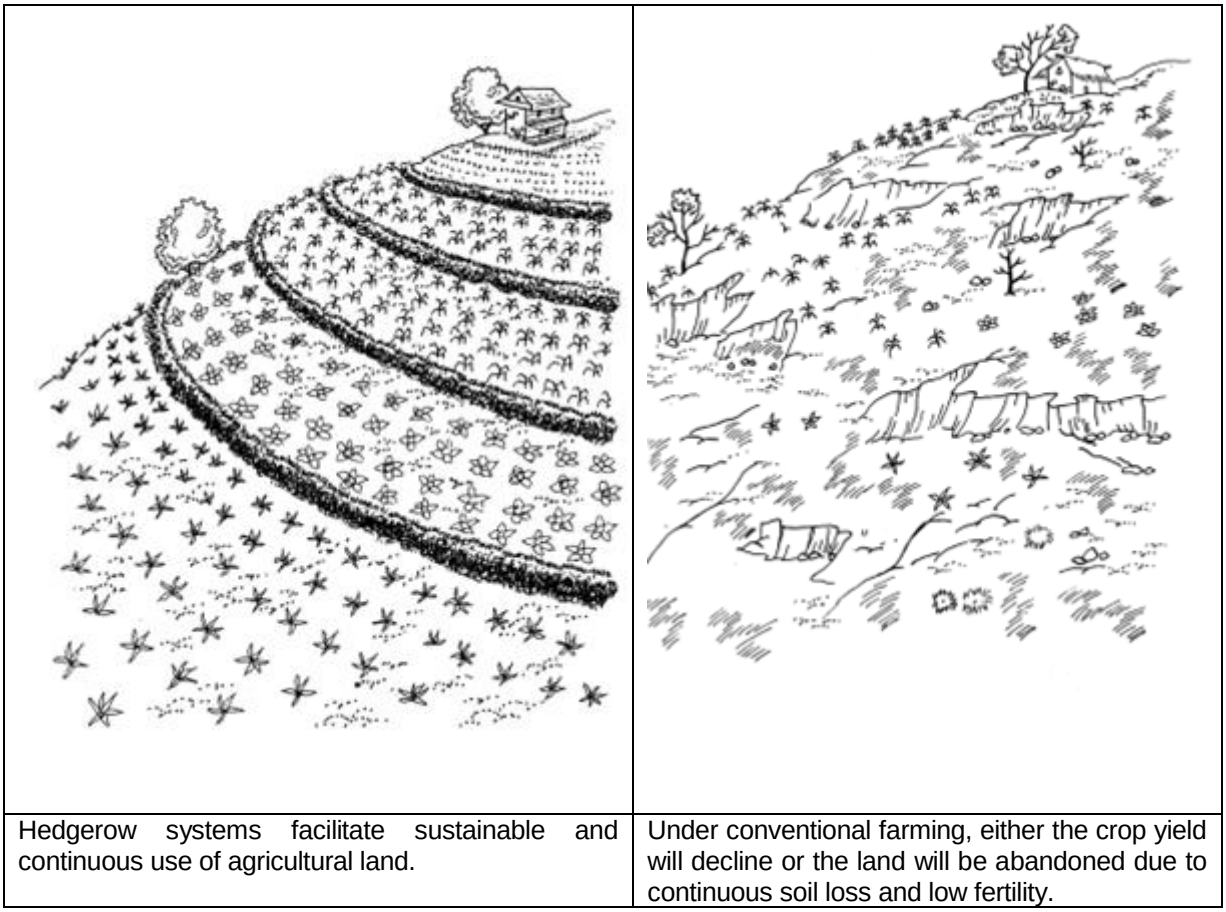
## 5. Hedgerows

Hedgerow plantation is primarily a soil-conserving technique, which involves the planting of different types plants such as grasses, leguminous and fodder trees along the contour lines on the slope at a distance of four to six meters. Plantation can be done in mixed form and/or pure stands with recommended space between plants and rows, as well as, manageable height above the ground either on farmland or on hillside/degraded lands. If dense hedges are allowed to grow along the contour at appropriate vertical interval to filter out the soil particles, then degraded land on steep slopes can be safely used for cultivation. When it is to be applied on a field without bund, besides its conservation objective, it can contribute to saving of labour required for bund construction. The hedgerow plants are periodically pruned and managed during the cropping phase to prevent shading of the companion crops. In this case, the pruned foliage and young stems are incorporated into the soil as green manure or used as mulch. Some portion of the tree foliage can be also harvested and used for livestock feed, particularly for small ruminants.

In addition, the space between the hedgerows can be used for agricultural and cash crops production. Farmers can also grow cash plants, such as mulberry, within the double hedgerows on each contour line. In general, this technology helps to increase farm income, facilitate multiple use of the land, and provides opportunities to marginal farmers to improve their living standards. In general, once the hedgerow is established it can have both the direct and indirect benefits for the individual farming family.

**Some of its direct benefits are:** Conserves soil and water, Improves soil fertility/soil properties, Creates more farming options, Increases farm productivity, Increases fodder/fuel-wood supply, Low external input utilization. In addition, it reduces runoff and erosion, formation of bio-terracing, increases water infiltration, maintains nutrient balance of the soil, increased soil fertility, increased productivity,

**Some of its indirect benefits**: Extracts and recycles nutrients from deep soil layers.



| | |
|---|---|
| Hedgerow systems facilitate sustainable and continuous use of agricultural land. | Under conventional farming, either the crop yield will decline or the land will be abandoned due to continuous soil loss and low fertility. |

**Figure 24: the creation of farming options**

## *5.1 Species selection and agro-ecology for Hedgerows*

Hedgerows plantation can take place by using different types of planting materials such as grass species, leguminous and fodder plants. The materials can be planted within different agro-ecologies including Dega, Woyna dega and Kolla areas. Thus, appropriate selection of different types of planting materials for hedgerow plantation is extremely important and to a large extent it determines the success or failure of the technology. The following major factors can be considered when selecting appropriate species of planting materials for hedgerows. Apart from its nitrogen-fixing ability, the hedgerow plants should be selected according to the local needs and availability of fuel-wood or fodder.

**The selection criteria for hedgerows**: the species should be nitrogen-fixing, fast-growing and deep-rooted, the species should have the ability to withstand frequent cutting, good coppicing ability (re-growth after cutting), the mixture of species should cater to the local needs and be agro ecologically adapted, the species should be deep-rooted with a different root distribution to the crop, it should be

multi-purpose –fodder, fuel wood, in addition to mulch or green manure, ease of establishment from seeds or cuttings, it should have the ability to withstand environmental stresses such as drought, water logging, and extremes of pH, dry season leaf retention and freedom from pests and diseases.

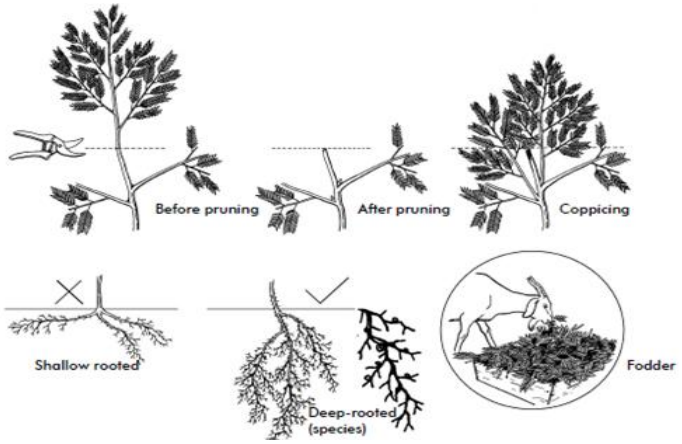



**Figure 25: Some practical criteria for selection**

**Grass species suitable for the establishment of hedgerows**

From grass planting materials Elephant grass and Vetiver grass are more suitable for the establishment of grass hedgerows where the amount of rainfall is sufficient for their establishment and successful growth. However, the establishment and normal growth of these species is possible only in pocket areas of the Mid and Low altitudes receiving adequate amount of rain fall (more than 800mm) in the region. The pocket areas where these species could grow are found in the central and northern plateau of the mid altitudes and South western mid and lowlands of the Region. Trimming the hedges to a height of 30-50cm prevents them from seeding, makes them thicken up, and thereby increases their effectiveness in filtering out soil particles. Considering their importance for hedgerow these two planting materials are shortly described as follow

**Elephant grass** known as also Napier grass is a vigorous and tall perennial grass which grows in a dense cluster (mass) up to 6m height. It consists of Bana grass and Green-gold commercially varieties that can be used for SWC measures. It can grow well below 2100 meters above sea level with temperature range of 25-40$^0$C. Above 2100m, its growth will be slowed down by lower temperature. Most of the time, it stops growing when the temperature falls below 10$^0$C.

**Vetiver** has been almost about four and half decades since vetiver was introduced to Ethiopia (Land Use Forum (SLUF) and the International Vetiver Network (TVNI) in March 2009). For the first time, Vetiver grass (Chrysopogon zizanioides) was identified to be introduced to Jimma Agricultural Research Center (JARC) in 1971. After two decades, Menschen fur Menschen (MfM), has initiated the promotion of vetiver grass for the purpose of soil and water conservation in the Metu area of Illubabor Province (south west Ethiopia) in 1990.

**Figure 26: One year old Vetiver grass at Ano Farm**

Vetiver is a perennial grass growing up to 2 meters high, and averagely 3-5m root to be grown deep in the ground. It has a strong massive root system, which is vertical in nature descending 3-4 meters in the first year, ultimately reaching five meters under suitable growing conditions. The depth of root structure provides the plant with great tolerance to drought, permits excellent infiltration of soil moisture, recharge underground water.

**Figure 27: A year old Vetiver root at Ano ,SLUF & TVNI vetiver workshop, 2009**

Naturally, most grass species are characterized to have shallow and fibrous feeder roots, which spread out in a horizontal pattern. Their roots don't penetrate vertically deep in the soil like that of vetiver grass. Unlike the other grass species, the root system of vetiver grass does not expand horizontally; rather the main and secondary roots of vetiver penetrate vertically deep in to the soil. The horizontal expansion of the vetiver root system is limited up to only 50cm. It has the capacity to grow deep in the soil up to 5 meters. This peculiar character enabled the vetiver grass to withstand drought and avoid becoming dislodged when exposed to a strong water flow. In addition, it doesn't have the capacity also to make lateral invasion towards to the farmland and this behavior makes it to be the best planting material for biological SWC measures.

It is obvious that, vetiver can significantly increase agricultural production and productivity through its contribution for soil and water conservation. Moreover, vetiver can reduce the impact of pests on adjacent crops (maize stem borer), and significantly protects problems related to nematodes in vegetable crops. In addition, vetiver plants can also give several benefits such as mulch (improved soil organic matter and nutrient recycling), thatch (long lasting over - 10 years), mattress stuffing (lice repellent) and forage (when cut or grazed regularly).

**Figure 28: Ato Hassan Ali's farm produces up to 80 ton/ha equivalent of dry biomass used for various purposes such as mulch, thatch and mattresses.**

Vetiver grass has a wide range of environmental conditions. It can grow within altitudinal range 0-3000masl, rainfall ranges from 600- 2200mmper annum, and wide ranges of soil type. In general, it can survive total drought, but normally requires a wet season of at least three months. It has also the capacity to tolerate prolonged drought, flood, and complete submergence in water for up to three months. It has also wide range of soil preferences.

In general vetiver can be planted as hedgerow on existing physical structures such as stone terraces, soil bunds, trench bunds, and also on untreated farmland, along the contour. Vetiver hedgerows are a living porous barrier. It slows and spreads runoff water and traps sediment. As the flow is slowed down, its erosive power is reduced and at the same time allows more time for water to infiltrate to the soil, and the hedge traps any eroded materials. Therefore an effective hedge will reduce soil erosion, conserve soil moisture and trap sediment on site. The main intention of this topic is to give necessary information on vetiver plantation as hedgerow on hillsides/degraded areas.

**Leguminous /fodder plants**

A wide range of tree species and some limited grass species can be used for hedgerow plantation. Out of these, Leucaena has been found to be the most favored species more suitable on high base soils. However Flemingia macrophylla trees are more performing on acidic low base soils. In general, the hedgerow practice and species described in this background training material will need adaptation according to local conditions. Thus, it is possible to conduct farmer-led demonstration in order to find out the best suit local species and practices for future implementation of hedgerow technologies.

Table 2: Different hedgerow species and suitable agro-ecologies

| ***No*** | ***Species*** | ***Agro-ecology*** | | | ***Remark*** |
|---|---|---|---|---|---|
| | | ***Dega*** | ***Woyna-dega*** | ***Kolla*** | |
| 2 | *Stylosanthes guianensis* | | | | |
| 3 | Tree lucerne, and | ✓ | | | |
| 4 | Erythrina brucei | ✓ | | | |
| 5 | Acacia decurrens | ✓ | | | |
| 6 | Flemingia macrophylla | ✓ | | | |
| 7 | Acacia albida | | | | |
| 7 | Sesbania sesban | | ✓ | | |
| 8 | Croton macrostachyus | | ✓ | | |
| 9 | Calliandra callothyrus | | ✓ | ✓ | |
| 10 | Leucaena leucocephala | | ✓ | ✓ | |
| 11 | Cajanus Cajan | | ✓ | ✓ | |
| 12 | Cassia siamea | | | ✓ | |
| 13 | Gliricidia sepium | | | ✓ | |
| 14 | Salt bush | ✓ | ✓ | ✓ | For moisture scarce areas |
| 15 | Cactus pear (*Opuntia ficus-indica L. MILL*) | | ✓ | ✓ | For moisture scarce areas |

**Growth requirements**

All hedgerow planting materials have their own soils preference, altitudinal and rainfall for their effective growth and better performance. In general, the summary of growth requirements of hedgerow planting materials is mentioned as follow.

Table 3: The growth requirements of some hedgerows plant species

| ***No*** | ***Species*** | ***Growth requirement of the selected species of hedgerows*** | | | ***Remark*** |
|---|---|---|---|---|---|
| | | ***Soil*** | ***Altitude (m asl)*** | ***Rainfall (mm)*** | |
| 1 | *Grass species* | | | | |
| 1.1 | Vetiver | Well-drained soil | Up to 3000m | 600-6000m | |
| 1.2 | Elephant grass | Deep, friable fertile soil | - 2000 | 2000masl 1480-1620 | |
| 1.3 | Dasho grass | na | na | na | |
| 1.4 | Chemo grass | na | na | na | |
| 2 | Fodder plants & forage leguminous tress | | | | |
| 2.1 | *Stylosanthes guianensis* | Grow well on coarse texture, well drained soil, | Up to 1800m | 900-4,000mm | |
| 2.2 | Tree lucerne | Well-drained | Up to 3200m | 550mm | |
| 2.3 | Flemingia macrophylla | Wide range | 2000m | 1100-3500mm | |
| 2.4 | Erythrina brucei | na | na | na | |
| 2.5 | Acacia decurrens | Light –medium | 1800-2500m | | |
| 2.6 | Acacia albida ✓ | Prefers deep sandy soil | 0-1800m | 450-800mm | |
| 2.7 | Acacia nilotica | Wide range | 0-600m | 200-1000mm | |
| 2.8 | Acacia mullifera | Prefers loamy soil with hard surface, sandy soils & rocky hillsides | 0-1500m | 250-700mm | |
| 2.9 | Sesbania sesban | Wide range | 200-2500m | 600mm | |
| 2.10 | Croton macrostachyus | na | na | na | |
| 2.11 | Calliandra callothyrus | na | na | na | |
| 2.12 | Leucaena leucocephala | Wide range | 600-1400 | 600-2000mm | |
| 2.13 | Cajanus cajan | Light-medium | Up to 2600 | 300mm | |
| 2.14 | Cassia siamea | Light medium deep soil | 600-1000m | | |
| 2.15 | Gliricidia sepium | Wide ranges | Up to 1800 | 900mm | |
| 2.16 | Parkinsonia aculeata | Sandy/Light-medium | 600-1400m | 200-800mm | |
| 2.17 | Caesalpinia pulcherrinma | na | na | na | |
| 2.18 | Ziziphus abyssinica | Wide range | 0-800m | 200-500mm | |
| 2.18 | Saltbush *(Atriplex nummularia*) | Wide range (can grows on marginal lands and salt affected areas). | Wide range (Kola, W/dega and dega) | 150-500 mm | |
| 2.19 | Cassia sturtii *(Senna artemisioides* ) | Wide range | Wide range (Kola, W/dega and dega) | 200-500 mm | |
| 2.20 | Cactus pear (*Opuntia ficus-indica L. MILL*) | Wide range | 1800-2200 | 200-250 | |

# 6. Plant Management and Utilizations

Management of established vegetation is important to become effective in soil and water conservation and to produce required biomass over a long period.

**Gap filling**: After planting if uniform population is not achieved, gap filling should be carried out before the rainy season is over.

**Weeding:** Frequent weeding may be necessary to reduce weed competition and reduce loss of water and nutrients. This is especially important in drier areas. In addition after 1 or 2 months from planting, weeding of other spontaneous aggressive vegetation may be necessary.

**Thinning**: Thinning of plants may be necessary to obtain desired plant population and density and this must be done at the earliest.

**Pruning of trees:** Frequent pruning of fodder and fruit trees may be required to reduce shading effect on the companion crops. Trees are pruned to obtain maximum biomass or proper shape to produce maximum fruits.

Safety from livestock: - All the crops must be safe from the livestock and human activities all the times.

**Watering:** Watering fruit trees during the dry season and occasional watering of valuable trees such as fruit plants will avoid death of the plants. Watering is a more or less continuous activity in the nursery from the preparation of beds and seedlings to lifting of the seedlings when it is time for planting. So many factors influence the water requirement. As a rule of thumb, the water needed on the bare-root beds or on the pots each day should correspond to a sheet or layer of water of 0.02 meters depth. Though water is always needed, there are some periods when special attention should be paid to the activity. These periods are:

- After seeding, to get good germination
- After transplanting to enable the seedlings to recover as soon as possible
- After root pruning to stimulate the development of fibrous root system
- After thinning and replanting in the bare-root be to help plants become better established
- During hardening-off to prepare the plants for conditions at the planting site
- Just before lifting

**Shading:** Seedlings need protection against heavy rain, burning sunshine and strong winds. Therefore, they need shade constructed from locally available materials i.e. branches, grasses, etc. The shades are constructed following the direction of the seedbeds and the sloping roof against the changing apparent movement of the sun seasonally.

**Manuring:** Seasonal application of organic manure should be carried out at the beginning of the rainy season. A large amount of organic manures is often left unused and this should be avoided by encouraging farmers to apply manures to the crops. Also encourage farmers to prepare compost on the farm.

**Use of compost as a moisture harvesting measure in areas treated with bunds**

Compost can be used in all soils with low fertility. It is especially good in areas that have low rainfall, where artificial fertilizers cannot be used effectively because of lack of moisture. It is also useful in sandy soils which have poor water-holding capacity. Compost improves the structure and drainage of all soils. Compost is used to apply for high value crops within homesteads (horticulture) to fertilize conserved fields and/or supplement artificial fertilizers in cultivated lands treated by bunds/terraces. It is also to apply around valuable trees plantations and inside.

Cultivated sloping lands treated with bunds have deepest soil and higher moisture content near the terrace embankment. To take advantage of this situation:

1. Use “selective” applications: apply significant amount of compost along the first 2-3 meters of cultivated land above bunds during the first year. This will have maximum impact in creating a re-cycling zone where the soil is deeper and moisture is the highest. Plant cash or high value crops along those strips.
2. Apply additional compost to the same area plus apply compost 2-3 meters upwards every year. In this regard, compost making or supply of compost from compost makers need to be planned (see figure 7 & 8).

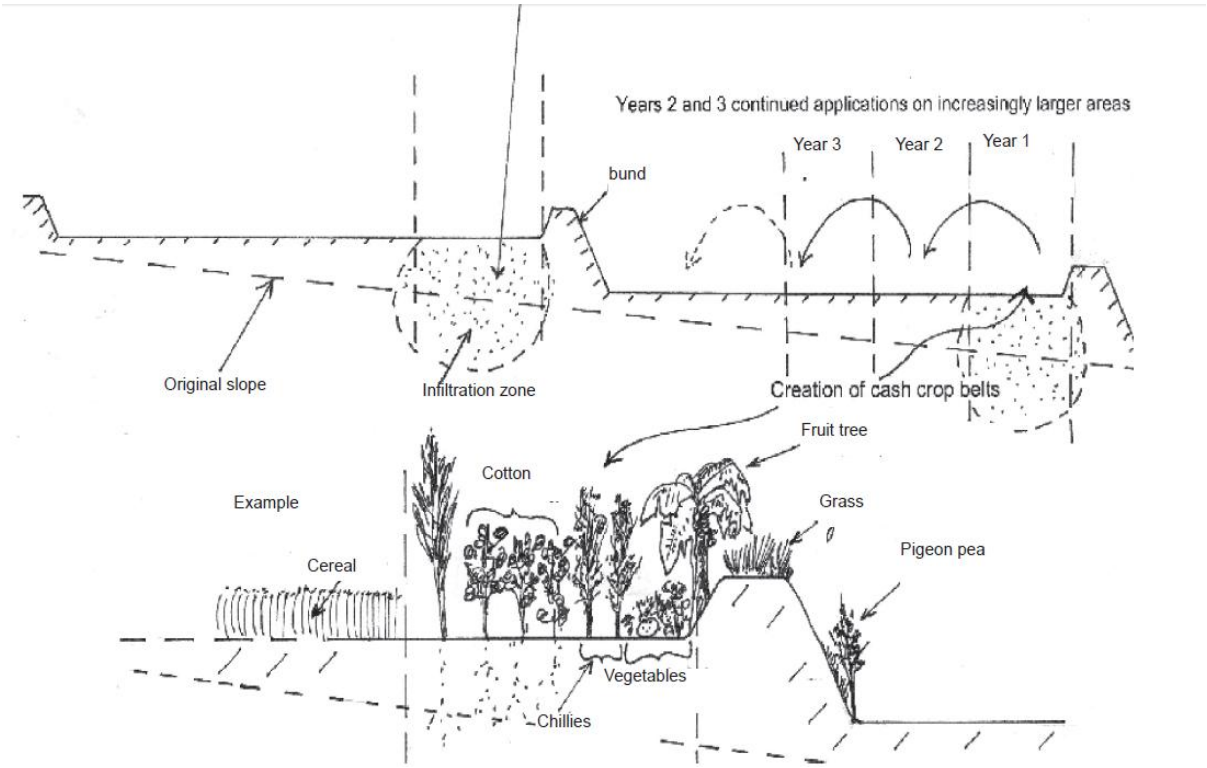



**Figure 25: application of compost above bunds and terraces to create cash crop belts**

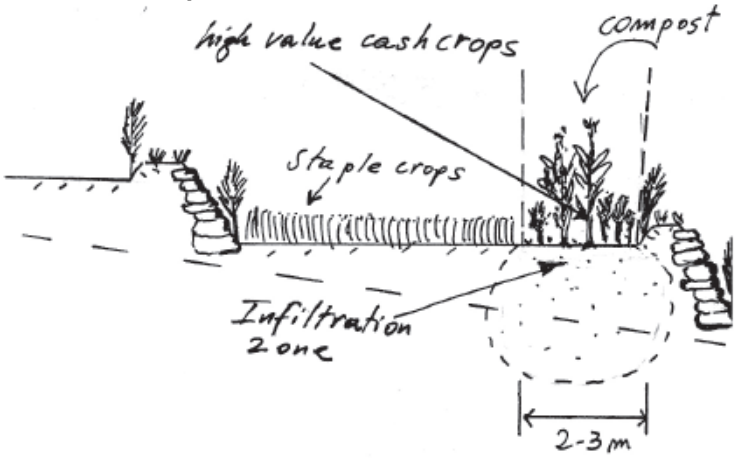



**Figure 26: Stabilization and application of compost above bunds**

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

**Harvesting of grasses, legumes:** Forage crops should be allowed to produce seed during the first year of planting. If there is excessive growth then it should be harvested in advance of flowering so

that flowing and seed production is not affected. Forage should be harvested before or at flowering stage to harvest nutritious feed. Harvesting should be done about 10 cm above ground level so that re-growth is encouraged and plants do not die. This biomass can be used for feeding livestock as green or dry feed in the form of hay. Good quality hay should be made on time. Under the dry conditions, depending on the rains, one or two harvesting per year may be possible. Grasses should be harvested before flowering, when their nutritional value is high. Harvested grass can be used as green fodder immediately or kept for a longer period through hay making. At harvesting time any crop growing on the embankment should be harvested by cutting the stem and not by pulling them out so that the stability of the bund would not be affected.

**Harvesting of fodder trees:** Fodder trees should be allowed to grow strong in the first year except that they should be pruned at the top to allow side branching to produce more biomass. While harvesting, only young leafy branches should be cut with sharp knife and the old branches should not be damaged. Frequency of harvesting will depend on the weather conditions. Fodder trees provide high protein green feed and therefore, should be harvested during dry season. The green leaves should be mixed with dry grass while feeding livestock.

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

**Harvesting of fruits:** Fruit plants take time to grow and produce fruits. Timely pruning enables the farmer to produce more fruits from the same plants. Some plants may start flowering in the first year but this should be discouraged to allow the plant to grow strong to bear more fruits.

**Management of crop residues:** Efficient management of crop residues on the farm is very important especially in dry areas. It should be either used as livestock feed, mulching material or making organic manures such as compost.

**REFERENCES**


Amhara-GIZ/SLM (2011). Training Manual on Biological Soil and Water Conservation Techniques, Bahir Dar, Amhara.

Azene Bekele-Tesemma 1993. Useful Trees and Shrubs for Ethiopia. English press p.o.box 30127, Nairobi, Kenya.

Badege Bishaw. Agroforestry and Community Forestry for Rehabilitation of Degraded Watersheds in the Ethiopian Highlands.

Betru Nedessa. 1996. Biological conservation measures on grazing lands. (MoA/WFP-ETH/2488/III) Ministry of Agriculture / World Food Program, Addis Ababa, Ethiopia.

Daniel. D., Betru N. et al, 2001, Soil and Water Conservation Team Natural resource management and Regulatory Department Ministry of Agriculture The Federal Democratic Republic of Ethiopia.

D.Rocheleau, F.Weber and A.Field-Juma 1998. Agroforestry in dry Africa. International council for Research in agroforestry, Nairobi, Kenya.

Hugues Dupriez and Philippe De Leener 1998. Trees and Multistory Agriculture in Africa. Text book for agroforestry. Imprimeries Guyot, Brussels, Belgium.

International Symposium on Contemporary Development Issues in Ethiopia, July 11-12, Addis Ababa, Ethiopia 2003.

Kindeya Gebrehiot. Dryland Agroforestry Strategy for Ethiopia. Mekele University, Ethiopia, 2004.

Manual of soil conservation & slope cultivation (Caribbean Agril. Research & dev't Institute (CARDI, July 2010

MoAD, CBPWD, 2005, Community Based Barticipatory Watershed Development Guideline part 1.

MoARD-MERET (Ministry of Agriculture and Rural Development-Managing Environmental Resources to Enable Transition to More sustainable Livelihoods. 2004. Report on study tour to China and Kenya. MOARD-MERET, Addis Ababa., Ethiopia.

Oromia-GIZ/SLM (2012). Biological Soil and Water Conservation Measures (Agronomic, Vegetative and soil fertility management measures), Training Manual. Ambo. Oromia

P. A. Chadhokar: 2010, Biological Soil and Water Conservation Measures (Vegetative measures and soil fertility management) Training Manual. Natural Resource and Management Directorate through Federal Public Work Coordination Unit (FPWCU, MoARD), Addis Ababa., Ethiopia.

P.K.Rama Chandra Nair 1993. Kluwer Academic publisher Dordrecht (Boston), London.

Smallholder Dairy Development Project Ministry of Agriculture**.** POSSIBILITIES TO INCREASE TREE COVERAGE IN THE ETHIOPIAN HIGHLANDS SDDP Extension Manual No. 8. August 1999 Addis Ababa, Ethiopia

SLUF & TVNI (2009): Vetiver workshop, Jimma Agricultural Research Center, Ethiopia,