CHAPTER 7

SOIL CONSERVATION MEASURES APPROPRIATE FOR INTEGRATING INTO FARMING SYSTEMS IN THE CARIBBEAN

Most of the farmers on hillsides in the Caribbean cultivate small areas of land, are resource-poor and are not technically educated. Generally, they do not have or cannot afford to hire machinery for soil conservation, and other farm activities compete for the scarce available labour. Sometimes the land is too steep for the safe operation of machinery. The soil conservation measures must therefore fit into this background. The measures that are suitable for integrating into the farming systems fall into two categories:

- Biological or Agronomic
- Simple engineering

They can be used separately or in combination depending on the conditions and these are discussed later.

For effective soil conservation in the Caribbean context of many small farmers on the hillsides, it is important to ensure that a micro-watershed operates as a unit under the control of an association of all the farmers and with appropriate leadership. The importance of a strong institutional basis cannot be over-estimated. This is further discussed with reference to Jamaica. An incentive (cash and/or community facility) should be considered in return for farmers agreeing to allow their land to be planned for conservation (e.g. continuous contour hedges or ditches) and for carrying it out. In this arrangement if some fail to agree or to perform, all are excluded from benefiting. In this way there is community pressure to conform.

7.1 Biological or Agronomic Measures

Many of these measures are not normally associated with soil conservation but because they provide early, rapid and more complete ground cover or better root growth and soil binding, they reduce soil erosion.

7.1.1 *Soil Management*

Improvement of the physical and chemical properties of the soil increases plant growth and soil protection against erosion by water. Improving soil structure increases the water holding capacity, infiltration rate and erodibility of the soil. This can be achieved through tillage, drainage and the incorporation of organic matter, growing trees with fibrous root systems or certain trees which can return leaf litter to the soil or stabilize the soil against erosion. Fires which destroy soil organic matter and hence soil structure must be avoided.

Several minerals are known to be essential for plant growth and must be provided in adequate amounts and in the correct ratio or balance to avoid antagonism in the uptake of minerals. Fertilizer application and liming to increase pH of acid soils are essential for rapid growth the crop establishment which are particularly important in monocropping systems.

The role of minerals in plant growth and the fertilizer requirements of crops can be obtained from books on basic soil science such as Brady (1974), or Russell (1973) .

7.1.2 *Tillage*

Tillage is an important soil management activity which impacts on the sustainability of agricultural systems in the tropics. Excessive tillage of sloping soils increases soil erosion and therefore tillage systems which minimize the use of implements and soil disturbance are preferred. Conventional tillage which may include a combination of primary and secondary operations is normally performed in seedbed preparation and mostly on flat or gentle to moderate slopes. On steeper slopes several tillage practices are preferred. These are:

- Zero (no) tillage: where the crop is planted directly into the soil without preparatory tillage.
- Conservation tillage: a tillage system which facilitates the conservation of soil and water.
- Zonal tillage: tillage of only the strip or zone of the soil in which the crop is to be planted.

Several researchers (Lal, 1975; Lindsay and Gumbs, 1982) have shown that there is much greater soil loss and reduced runoff from tillage compared with no-tillage plots. No tillage can reduce soil loss to almost zero.

Reduced and minimum tillage, in which the total number of tillage operations preparatory to planting is reduced from the conventional tillage for that soil type, is sometimes recommended for the gentler slopes. They increase infiltration and reduce runoff and soil erosion.

7.1.3 *Timing of planting*

The establishment of crops, possibly with irrigation, late in the dry season or early in the wet season before the onset of the heavy rains, provides better ground cover before the heavy rains come.

7.1.4 *Pest and Disease Control*

Crops must be adequately protected to avoid leaf destruction and poor growth. In view of the high cost of biocides, frequent unavailability in many rural communities in developing countries, and environmental hazards, methods of control besides the use of chemicals e.g. biological control and integrated pest management involving the use of multiple cropping, rotation, resistant varieties must be pursued.

7.1.5 *Crop Rotation*

This can promote healthier and rapid crop growth and ground cover by preventing the build-up of pests and diseases and by improving soil properties.

7.1.6 *Plant spacing*

Many crops have traditionally been planted in rows far enough apart to permit interrow tillage to kill weeds, spraying of pesticides, application of supplemental fertilizer and the harvesting of the crops. This is applicable to mechanized crop production on flat land or gentle slopes but not on steep slopes were mechanization is not feasible. In addition, interrow cultivation keeps the soil loose and therefore erodible. There is usually more erosion in row crops than closer growing crops.

The number of plants grown per hectare can be very important to both yield and erosion control. Many crops can be grown on hillsides at row spacings that are less than those recommended for flat land without reducing yield (Mohammed and Gumbs, 1982). In some cases yield can be increased. The closer spacing has been shown by Mohammed and Gumbs (*ibid.*) to reduce soil loss. The closer spacing is therefore preferred on hillsides in the Caribbean where crop husbandry is not mechanized. It also provides earlier ground cover, higher leaf area ratio and better ground protection against raindrop impact.

7.1.7 *Contour Cultivation*

An important practice on hillsides is contour cultivation. On gentle slopes it can largely eliminate soil erosion and on steeper slopes it can contribute to the reduction of soil loss. Tillage, planting and other crop cultivation activities must be carried out on the contour. For this reason it is important for all farmers on hillsides to be taught how to layout contour lines using the 'A; frame. The details of the construction and use of the 'A' frame is given by Gumbs (1987).

7.1.8 *Vegetative barriers*

Live or dead vegetation can form effective barriers for controlling or reducing erosion even on steep slopes. Examples are described below

Grass barriers

Grass barriers are strips of grass planted at intervals on the contour (**Figure 7.1**) and are used frequently in the Caribbean. They can also be established by leaving 0.5 - 1.0m strips of land untilled at intervals on the contour. Local grasses and other weeds soon become established as barriers. Several grass species can be used for the planted grass barrier. Vetiver or Khus Khus (**Vetiveria zizanioides**) is the most popular or commonly used grass. Other grasses used include Napier grass (**Pennisetum pupureum**), Guatemala grass (**Tripsacum laxum**) and Guinea grass (**Panicum maximum**).

Some farmers prefer not to use grass barriers because they claim it occupies too much space on their small holdings or it encourages the nesting of rodents. To overcome the unattractiveness of growing non-commercial species as barriers, commercially viable species, e.g. pineapple, aloe vera, can be substituted, or commercial products can be developed from vetiver. This latter approach cannot

Figure 7.1 Grass barrier of Vetiver

be undertaken by individual small farmers but would need technical and business enterprise support and cooperative farming.

Grass barriers are adapted to hillsides where orchards or row crops are to be established, but are not suitable for slopes which are stony, non-uniform and where many gullies exist. The soil trapped behind the barrier gradually converts it into terraces.

The normal width of grass barrier is 0.3 - 0.5 m, but it should be wider on steep erodible soils. On the gentler slopes (10 - 20 per cent) grass barriers can be 20 - 40m apart; on steeper slopes (20 -40 per cent) they should be 10 -20m apart. If grass barriers are used with mini-terraces or hillside ditches, the distances between barriers can be increased.

Construction Procedure:

- Clear the contour line of obstacles (e.g. stones, shrubs) and smooth out land irregularities;
- Stake out the barrier lines with stakes every 5-10m;
- Use fresh root cuttings for planting material; plant two rows closely in a staggered or triangular pattern to form one grass barrier; the spacing between plants can be 10 - 30cm depending on grass species;
- Cut grass 15cm above ground level to promote regrowth.

Dead vegetation barriers

Various types of dead vegetation, e.g. tree trunks and branches, banana pseudostems and leaves or trash (**Figures 7.2** and **7.3**), grass and other vegetative cuttings, and bamboo (**Figure 7.4** and **7.5**) can be used as trash lines or barriers which are staked along the contour, or simply laid out without staking if the vegetation cannot readily be washed downslope. Further details of the techniques are presented by Gumbs (1987). Mulching over the soil surface as a whole (not in trash lines or bands) is very effective in reducing soil erosion but the mulch must provide adequate coverage and must not be readily washed downslope. This is sometimes a problem where the slope is steep and the mulch is thin. This

Figure 7.2 Banana pseudostem and trash barrier

Figure 7.3 Trash barrier in banana field

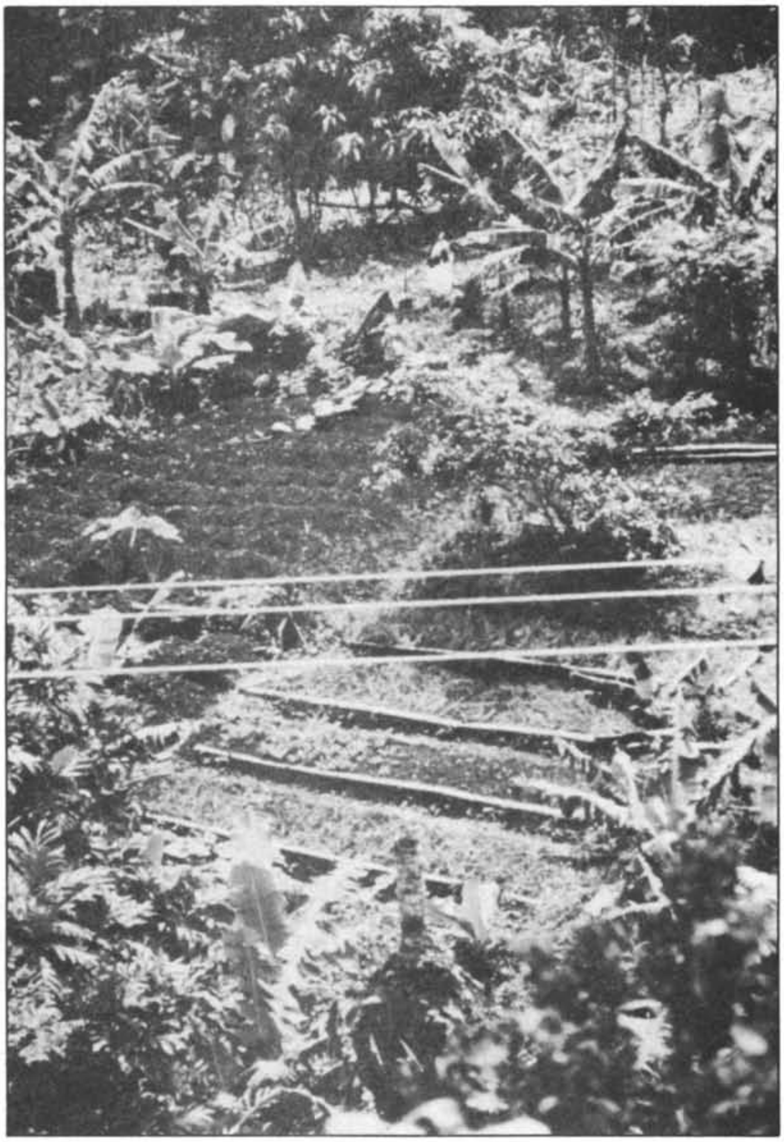

Figure 7.4 Bamboo barrier

Figure 7.5 Bamboo and trash barrier

method of using vegetation to reduce erosion can be exploited in programmes of tree crop rehabilitation.

7.1.9 *Cropping Systems*

There are two basic types of cropping systems, namely, monocropping and multiple cropping. The latter is very much the more desirable system on hillsides but sometimes farmer preference and other considerations may make monocropping the desired system. Monocrops, however, have to be grown in a way that limits soil erosion since this system is the most difficult to manage to achieve acceptable levels of erosion control on sloping lands.

Monocropping

Monocropping is the growing of a single crop species on a given area of land in a given time. In a monocropping system, especially with non-perennial crops, the land may remain bare for a period of time. This is the time when the soil is most prone to erosion. In this case monocrops have to be combined with some form of soil conservation measure (barriers, drains, mulching) to prevent erosion.

If the monocrop is a tree then the threat of soil erosion is not severe, especially if the tree crop is planted on the contour. **Figure 7.6** shows citrus planted on the contour but the plants in successive rows are not staggered. Therefore, the rows appear to be up-and-down the hill. The young citrus plants in the foreground of **Figure 7.7** cannot protect the soil and therefore a grass ground cover is essential. If the tree crop has to be replanted on steep slopes, the young trees can be interplanted among the older trees which are progressively removed as the young tree become large enough to provide soil protection.

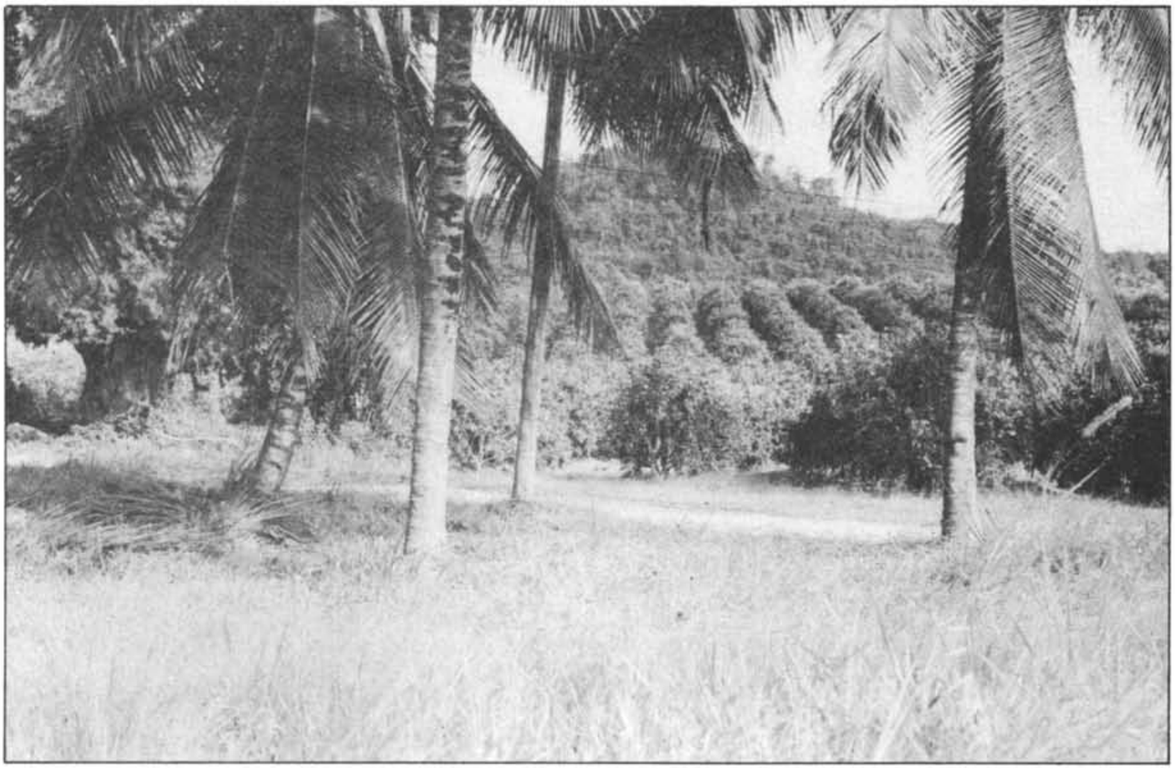

Figure 7.6 Citrus on the contour with rows unstaggered

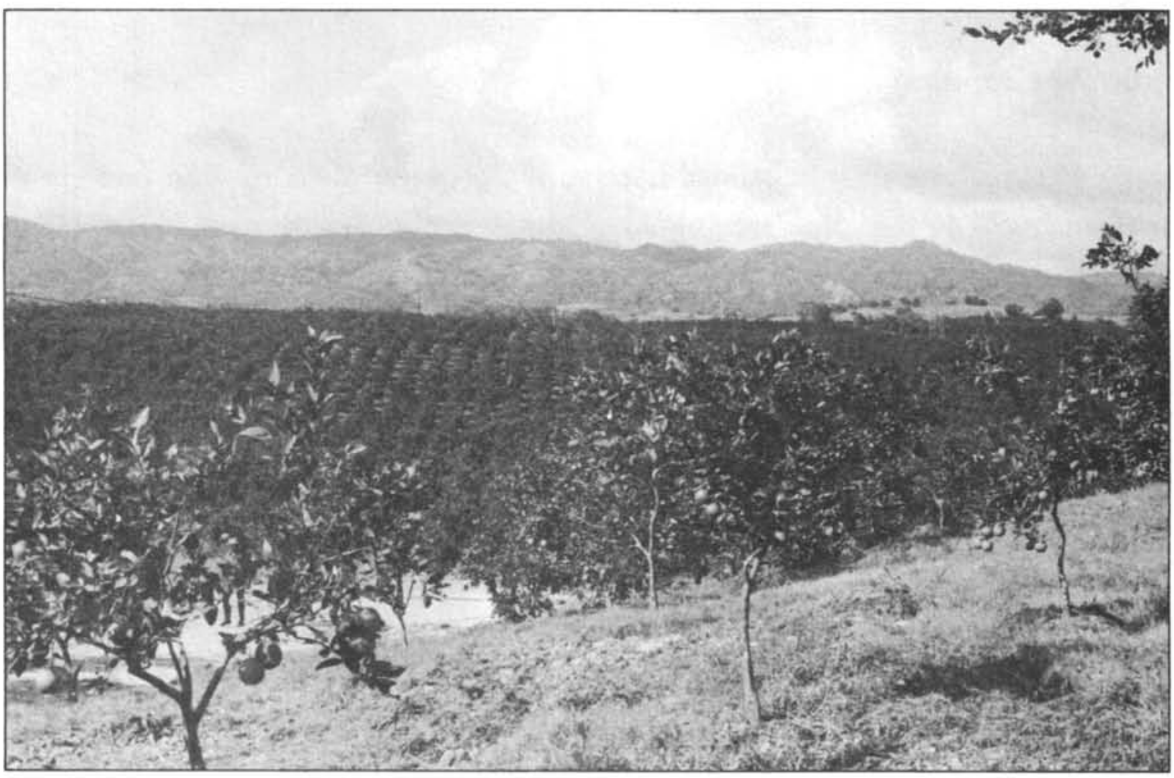

Figure 7.7 Citrus on the contour and grass cover in young citrus

The type of monocrop must be suitable for the slope on which it is to planted or must be combined with soil conservation measures. The following guidelines can be followed:

Degrees	
0 - 5	Any monocrop
5 - 10	Any monocrop and barriers
10 - 20	Avoid growing small annual crops; large crops like banana, plantain and barriers and/or drains; Fruit trees or tree crops
20 - 30	Fruit trees, tree crops (e.g. cocoa, coffee)
30 - 40	As for 20-30° but with drains, or Forest
>40	Forest

When monocropping systems are used, especially with small annual crops, careful attention must be paid to the agronomic factors mentioned above. Good soil fertility management, most suitable crop varieties, closer row spacing, good pest and disease control, and crop rotation can be reduce soil erosion and, in effect, be good soil conservation measures.

Multiple Cropping

Multiple cropping is defined here as the growing of more than one crop simultaneously on the same area of land. It does not include sequential cropping where two or more crops are grown in sequence on the same field per year.

Multiple cropping is therefore synonymous with *intercropping* and may be:-

Mixed intercropping : Two or more crops are grown simultaneously with no distinct row arrangement (**Figure 7.8**);

Row intercropping: Two or more crops are grown simultaneously where one or more crops are interplanted in rows (**Figure 7.9**);

Figure 7.8 Mixed intercropping with no distinct row

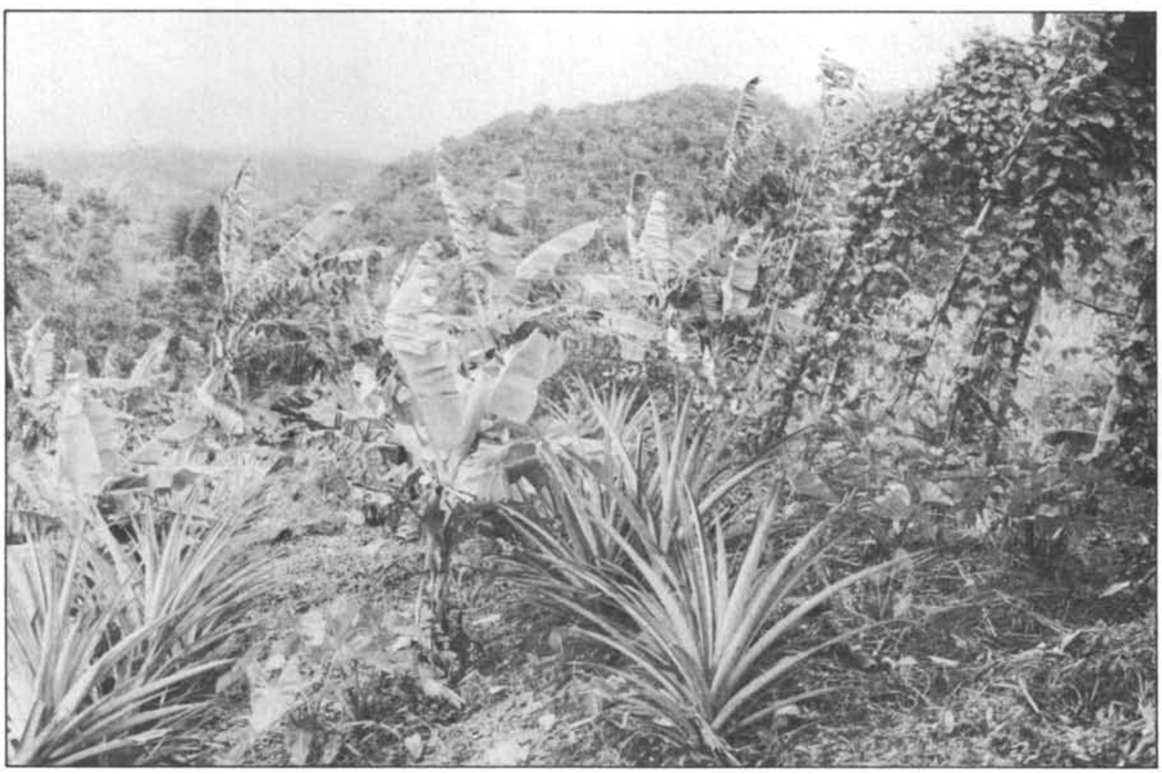

Figure 7.9 Row intercropping with several crops

Strip intercropping : Two or more crops are grown simultaneously in different strips wide enough to permit independent cultivation but narrow enough to interact agronomically;

Relay intercropping: Two or more crops are grown simultaneously during part of the life cycle of each. A second crop is planted after the first crop has reached its reproductive stage of growth but before it is ready for harvest.

Intercropping is a good method of soil conservation because the ground is always covered or can be arranged to be always covered with vegetation. There may be only short periods when the ground is not fully covered. Under these conditions, raindrops are intercepted, rate and amount of runoff are decreased and erosion is markedly reduced.

The intercrops may be similar in height or it may be at different elevations providing a tiered canopy. Intercrops in which the leaves and roots occupy or dominate different elevations above and below the ground, respectively, have certain distinct advantages in the efficient utilization of growth factors for rapid crop growth. Agroforestry systems are good examples and these are discussed from the soil conservation view point.

7.2 Agroforestry systems

Agroforestry refers to land use systems in which woody perennials are grown in association with crops and/or animals on the same land unit. The different forms of agroforestry are:

Agrisilviculture (trees and crops)
Silvopastoral (trees, pasture and livestock)
Agrisilvopastoral (trees, crops, pasture and livestock)
Other combinations (e.g. trees and bees, trees and fish pond)

There are both economic and ecological benefits to be derived from agroforestry systems. In order for the agroforestry system to be sustainable it must be environmentally sound, economically and technically feasible, and sociologically acceptable to the farmers.

Trees can be used specifically for soil stabilization and erosion control by, for example, mechanical reinforcement from the root system, root wedging, butressing, interception of raindrops, physical barrier to soil and water movement downslope, accumulation of soil organic matter from leaf litter and consequently improvement of soil physical properties. Land use problems can be ameliorated by agroforestry systems, e.g., soil erosion, declining soil fertility, deforestation, forest degradation, pasture degradation, river degradation, and crop and animal protection. Trees can provide food, animal feed, energy (fuelwood, charcoal), shelter (materials for housing), raw materials and cash income for social commitments. Trees can therefore play very important roles environmentally, economically and sociologically in hillside farming if suitable tree species are selected and used appropriately. This has been emphasised in the Land Use and Watershed Management Reports of the TFAP (1991-1992).

7.2.1 *Agrisilviculture*

Spatial arrangement of trees

Figure 7.10 shows the different spatial arrangements of trees in agrisilviculture agroforestry systems.

The random mixture is commonly used in the Caribbean where forest species, coconut or citrus may be the tree crops which are interplanted with banana or other food crops (**Figure 7.11** and **7.12**). Sometimes the trees on the land are not removed or some trees are planted to provide shade, fruits, additional income and soil conservation. An example of this is shown in **Figure 7.13** where pineapple has been planted on land with mango and other tree species.

In the alley cropping system annual food crops are grown in the spaces (alleys) formed by hedgerows of woody perennials. The woody perennials include legumes, bamboo and various shrubs. ***Leucaena leucocephala, Gliricidia sepium, Acacia mangium, Calliandra calothyrsus*** are the more common species used in the Caribbean. ***Cajanus cajan*** and ***Sesbania grandiflora*** are good candidates but they have not been used in this way. The hedgerows are cut at intervals during cropping to minimize shading and to reduce competition with

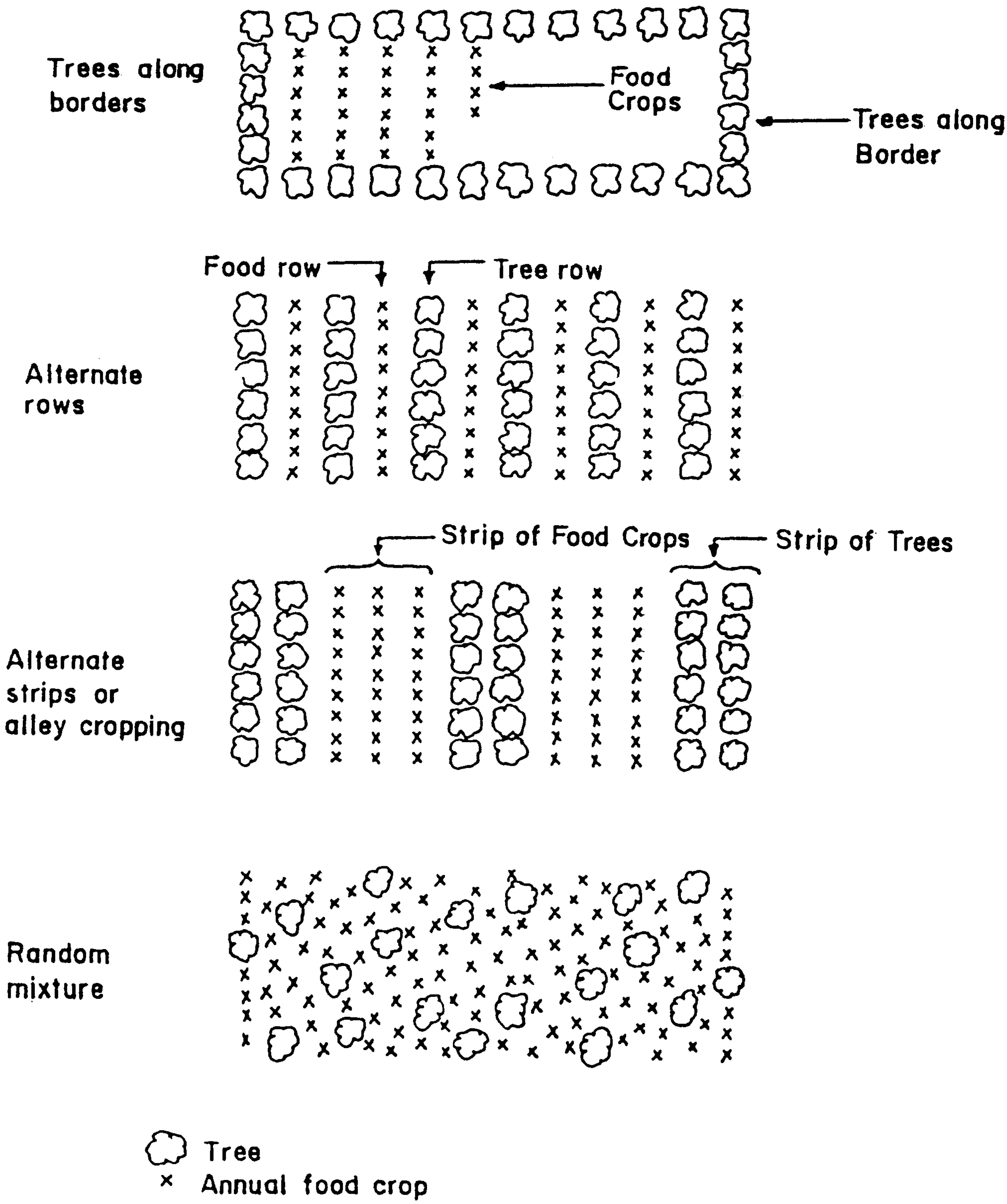

Figure 7.10 Spatial arrangements of agroforestry systems

Figure 7.11 Agrisilviculture system with several tiers of crops

Figure 7.12 Agrisilviculture system of citrus and banana

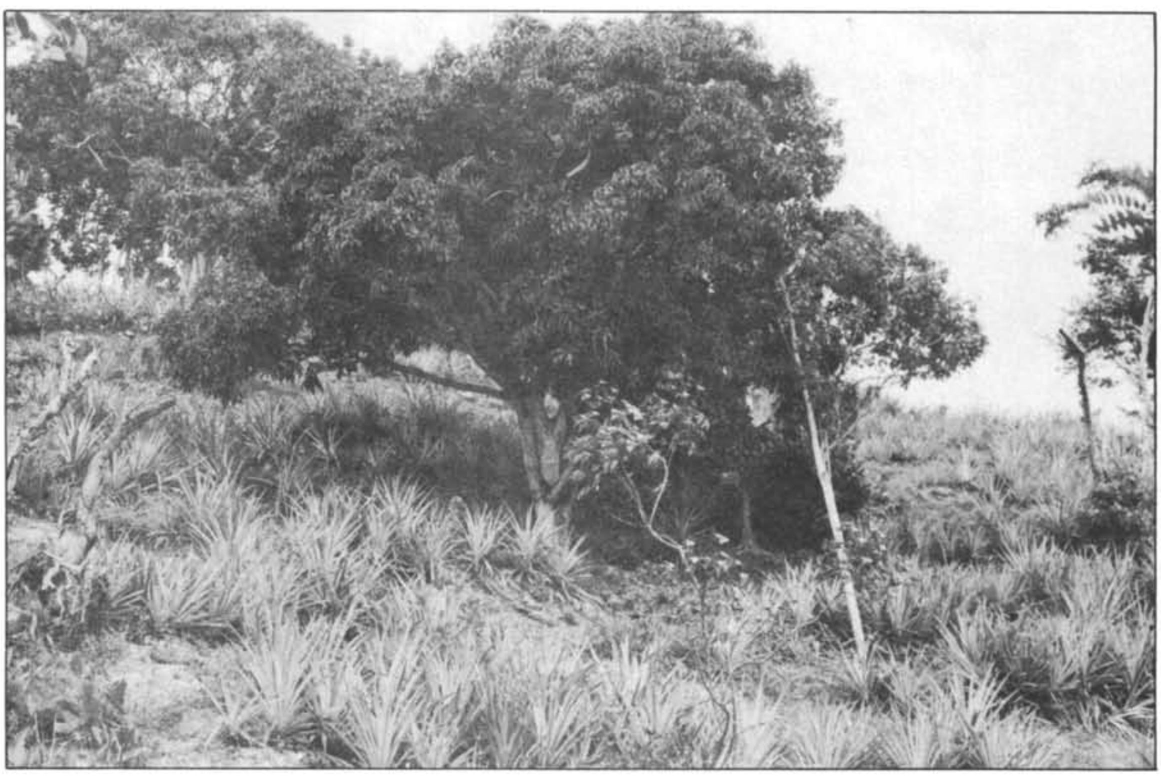

Figure 7.13 Pineapple planted on land without removing all trees

the crop. The cuttings may be used for animal feed or as mulch. If the hedgerows are allowed to grow during non-cropping periods, they can be cut for firewood, charcoal, stakes or fence posts.

Where alley cropping is carried out on sloping land the perennial hedgerows are planted on the contour across the slope. This system has been shown to increase yields and reduce erosion.

Tree crop rehabilitation for erosion control

Soil erosion on farms with poorly maintained tree crops can be reduced by a programme of crop rehabilitation. Trees are trimmed, pruned and fertilized and the trimmings applied to the soil as barriers or as mulch where possible to reduce erosion. This method of soil conservation is appealing to farmers because it is inexpensive and results in improved crop growth, yield and income. Pruning can be repeated as appropriate and the method of soil conservation can be combined with other methods like intercropping to further reduce erosion.

7.2.2 *Silvopastoral and Agrisilvopastoral Systems*

Caribbean farmers have found combining trees with livestock, or trees with livestock and annual crops economically and sociologically beneficial. Systems utilizing coconut (or citrus), pasture and cattle and/or sheep are common. While farmers are reluctant to grow grass as barriers or as pastures for soil conservation, they are more receptive to growing grass if livestock is included in the system. With such a system the farmer practices soil conservation without making a conscious effort. Alternatively, he can be encouraged to adopt soil conservation measures if it brings economic benefits.

Because livestock can damage young trees the system must prevent this from taking place. Livestock can be introduced when the trees are mature or hardy. Cattle can be provided with a nose-shield to prevent eating the developing trees. Goats are not used in these systems because of their ablity to graze excessively even on the barks of trees. If annual crops are grown in combnation with trees and livestock, the annual crops must not be accessible to livestock during crop growth and harvest.

7.3 Simple engineering methods

Sometimes agronomic or biological methods are not fully effective in controlling erosion and these methods have to be combined with physical structures. The latter has to be simple and low-cost if they are to be acceptable to small farmers. There are four types of engineering structures which are relevant to small farmers of the Caribbean.

- Contour or cut-off drains
- Downslope waterways
- Mini - terraces and eye - brow terraces
- Gully control structures

Storm drains are large drains at the top boundary of the farm. It is seldom relevant in the Caribbean context of several non-contiguous small farmers located at different elevations on the hillside. It would be meaningless for a small farmer to dig a storm drain at the top boundary of his small holding without provision for the safe discharge of the intercepted water. Frequently a cut-off or contour drain is adequate.

Stone barriers are not recommended for the Caribbean. They are very labour demanding and are really only feasible where stone is commonplace on the site and especially if it restricts farming. There are few places where all the conditions are right.

7.3.1 *Contour or cutoff drains*

Cutoff drains may be needed at intervals in the cultivation to limit the overland flow of water. These drains may be at 10 to 30 m intervals along the slope depending on the degree of slope and intensity of rainfall. In some cases the interval is 50 m or more. Cutoff drains are to be constructed when there is evidence of soil wash and erosion rills on the farm or on other farms on the same soil type employing similar agricultural practices. They should be combined with other conservation measures to prevent erosion of soil between the drains. Where the highest point on the farm adjoins the public or farm road, a cutoff drain should be placed a few metres below roadway level.

Cutoff drains usually measure 50 or 60 cm wide and 40 cm deep. In stable clayey soils almost vertical side walls can be used, but in the more unstable sandy soils, the walls must recline. Excavated soil from construction can be placed on the downslope side of the drain to form an embankment. A relatively shallow cutoff drain is shown in **Figure 7.14** The cutoff drain in the foreground of the banana field in **Figure 7.15** has either been constructed too large or there has been erosion and enlargement of the drain. The side slopes are largely unprotected and prone to further erosion.

7.3.2 *Downslope waterways*

Water from the cutoff drains and terraces should be discharged into a natural waterway, non - erodible stony ground, grassland with good cover, or an artificial waterway.

An artificial waterway is a wide and shallow drainage channel for bringing water safely downslope. The downslope grade of the waterway should not exceed 25 per cent. On steeper slopes, check dams should be used. If water from the cutoff drain has to flow down the bank of a river, especially if it has a steep grade, the flow path should be protected with stone or grass sod. The inlet, in particular, must be stabilized with stone or grass sod. If the water is discharged onto grassland, the cutoff drain should be widened at the discharge end to distribute the water over a larger grassed area.

7.3.3 *Mini-terraces*

Several types of terraces have been described and construction specifications given by Gumbs (1987). The bench terrace and modified bench

Figure 7.14 Cutoff drain

Figure 7.15 Eroded cutoff drain

terrace have several disadvantages. They are costly to construct, require much labour if constructed manually, and can result in reduced crop yields due to exposure of poorer subsoil. The mini-terrace, sometimes referred to as hillside ditch does not have these disadvantages and is more manageable by small farmers.

The procedure followed in forming mini-terraces is as follows:

- Contour lines are established where the centre of the terrace will be located. The spacing between contour lines will depend mainly on the steepness of the slope, rainfall intensity and crops to be grown.

- Starting from the top of the hill or where the uppermost terrace will be located, the soil is pulled downward to form the mini-terrace on which crops will be grown. The mini - terrace slopes backwards so that it functions as a drainage channel which is established on a 5 per cent grade across the slope. Some terraces may be left uncropped and are used for trafficking across the hill.

- If the terraces and drainage channels abutt each other the field layout is referred to as ridging or ridge and furrow (**Figure 7.16**) .

A mini-terrace with citrus grown on the terrace is shown in **Figure7.17(a)**. In this case it is referred to as an orchard terrace. Sometimes the land between the terraces alone is cropped and the terraces are used for drainage and traffic. In other cases both areas are cropped with food crops as shown in the diagram in **Figure 7.17(b).**

Eye-brow terraces are short or discontinuous mini-terraces across the slope. They, therefore, give the appearance of eye-brows across the slope of the hill.

7.3.4 *Gully control*

Gullies are developed by water erosion and will continue unless the gully is stabilized by structural control measures and revegetation. Gullies can be classified by size and by shape.

Figure 7.16 Ridge and furrow mini-terraces

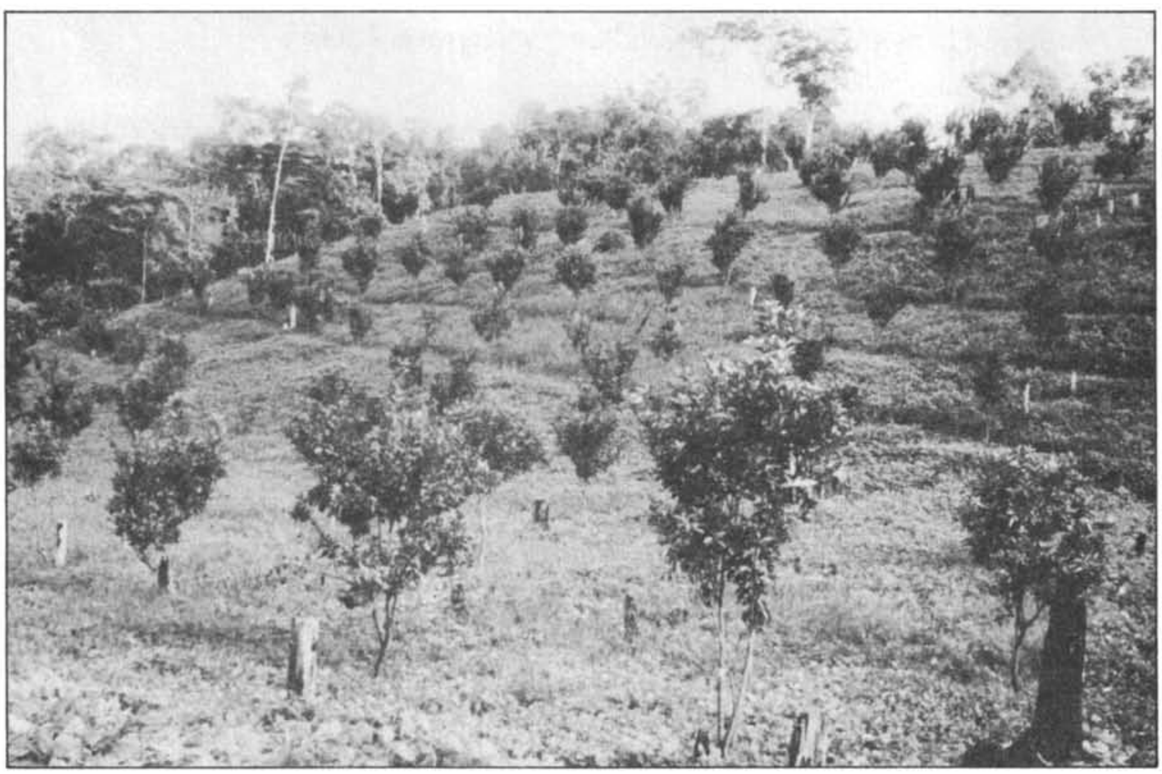

Figure 7.17(a) Mini-terrace or Hillside ditch with citrus (Orchard terrace)

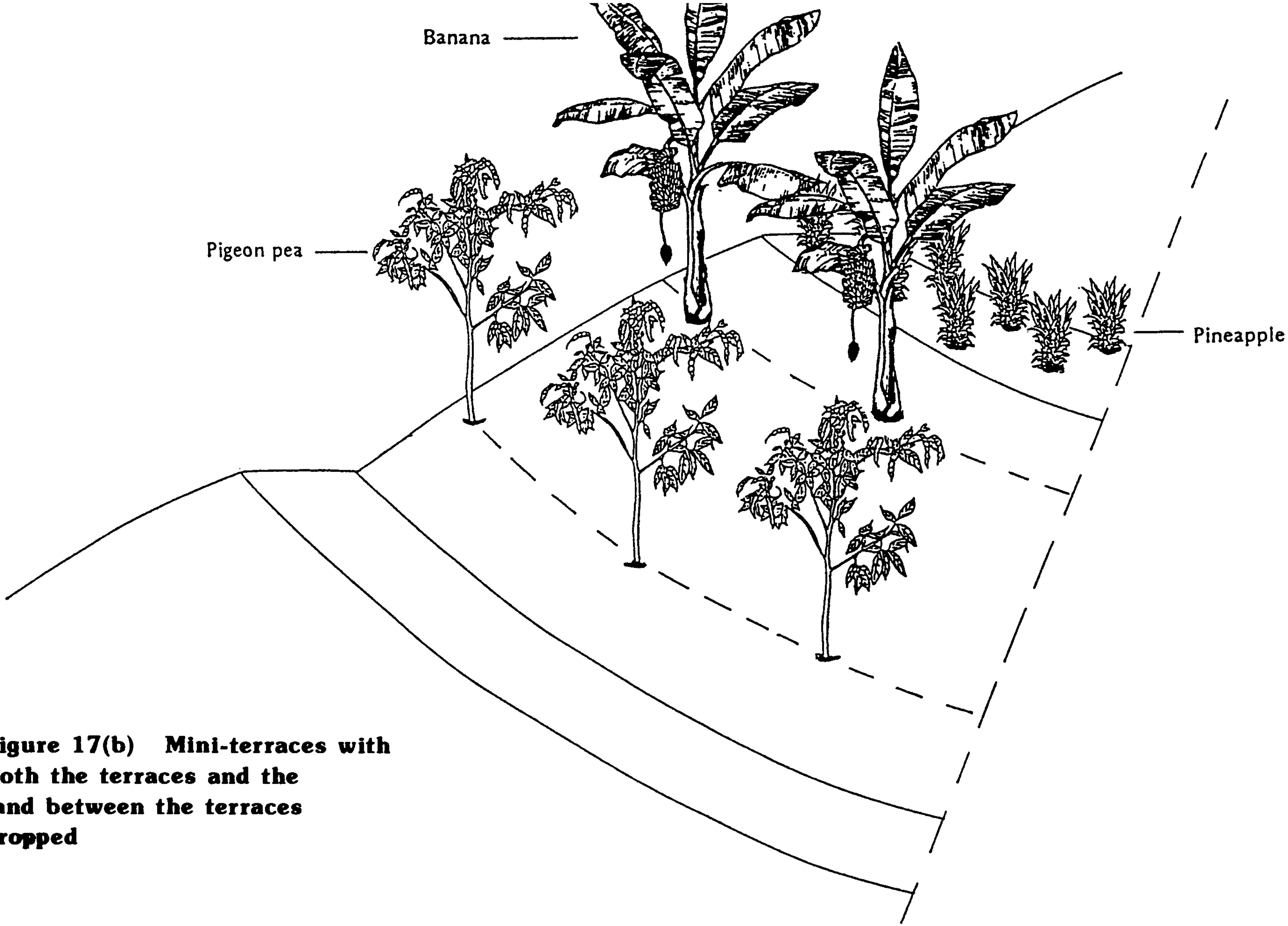

Figure 17(b) Mini-terraces with both the terraces and the land between the terraces cropped

Gully size	Gully depth (m)
Small	< 1.0
Medium	1.0 - 5.0
Large	> 5.0

These can have shapes that are U shaped, V shaped or trapezoidal in cross-section.

Large gullies and most of the medium sized gullies require substantial cement - masonry structures which are beyond the capability of most small farmers. A large gully often affects several farmers and sometimes the community as well. The plugging or control of these gullies usually require the intervention of government or other agency.

Gully treatment measures

(a) *Filling and Shaping*

Small gullies with low water flow can be stabilized by filling and shaping after the surface water is diverted. Steep gully heads and gully banks should be shaped to a gentler slope (about 1:1) . The gullies can be filled in by spade, shovels and plough. However, filling, shaping and diversion alone will not be enough to control gullies where the rainfall is very heavy. Additional gully control and slope stabilization measures such as check dams,. stone barriers, wattles and revegetation should be undertaken.

(b) *Grade stabilization structures*

If a gully is too large to be eliminated by filling, shaping and revegetation, it must be stabilized against further erosion. Two approaches can be followed

- Temporary structural measures such as woven wire with or without stone or rock fill, brush wood, logs, loose stone and boulder check dams can be used to facilitate the establishment and growth of permanent vegetation. The structure must be designed in relation to the size of the gully, the rainfall intensity and rate of water flow in the gully to prevent it becoming readily washed away.

- Permanent check dams constructed across the gully bed to stop channel and lateral erosion, reduce the original gradient of the gully bed, and the velocity of flow and erosive power of run-off. Check dams can be made of gabion baskets, wire and rock fill, masonry - concrete. The check dam must be designed and constructed to withstand the maximum flow of water in the gully. Check dams for large gullies require engineering skills. The gully catchment must be well vegetated to prevent erosion to the gully edges and walls.

Number and spacing of check dams

The number of check dams required is determined from the gully reach (total length of the gully) and the longitudinal profile or slopes of the gully bed between the proposed first and last check dam. **Figure 7.18** shows graphically an example of the longitudinal profile along the gully bed. It shows the angle and vertical height of rise of the gully bed at different horizontal distances. The angles can be measured with a clinometer or dumpy level and the horizontal ground distance with a tape starting from the bottom to the top of the gully.

The gradient between each check dam is called "compensation gradient". It is formed when material carried by flowing water fills the check dams to spillway level. The compensation gradient, the effective height of the check dam and the longitudinal profile determine the spacing between check dams. The check dams

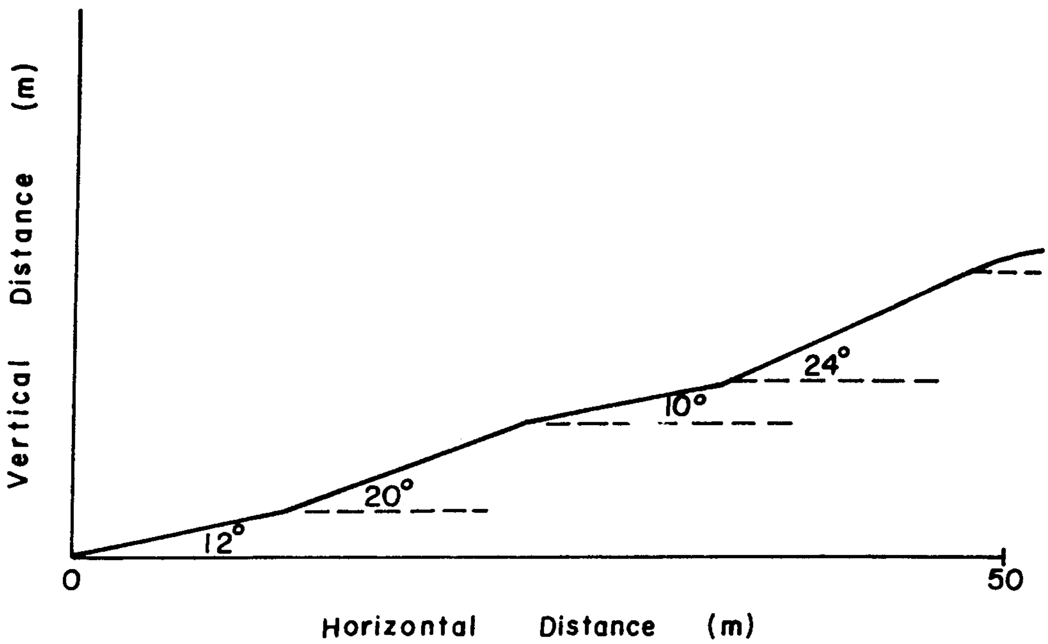

Figure 7.18 Longitudinal profile of gully bed

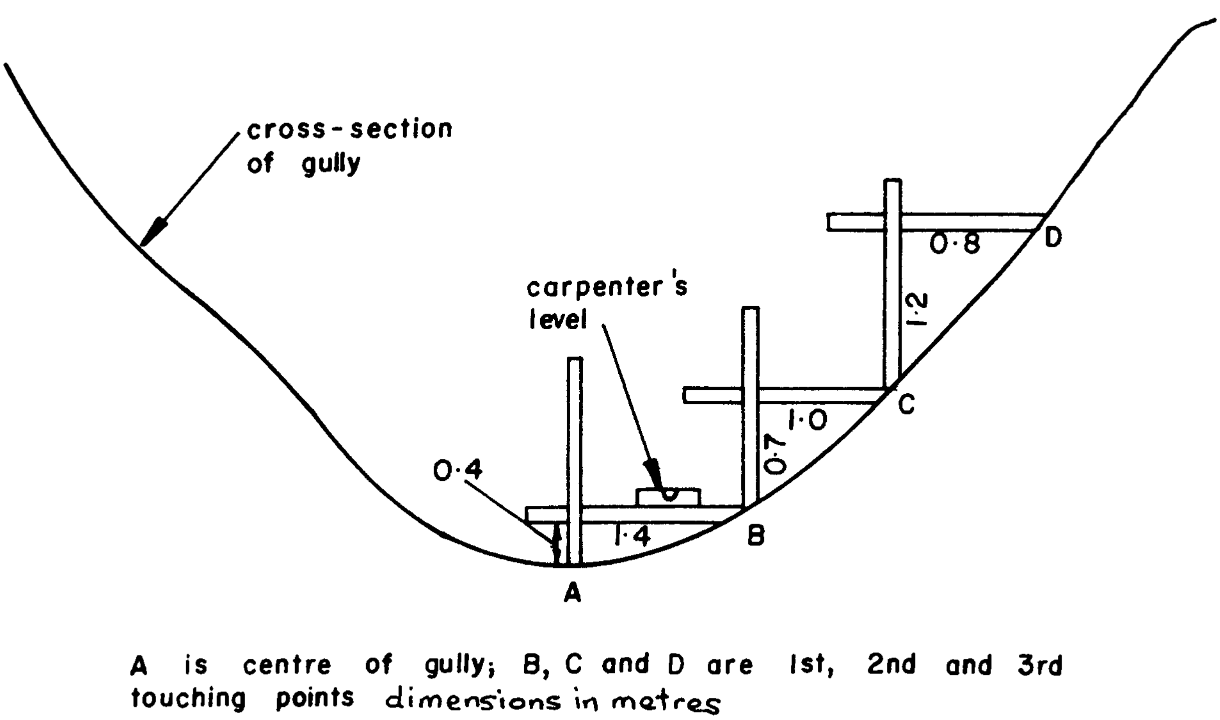

Figure 7.19 Measuring the profile of the cross-section of the gully

are located on the graph of the longitudinal profile by:

- Selecting the location of the first check dam at the lowest point in the gully reach;

- Identifying the effective height of the first check dam;

- Starting at the effective height a 3% slope line is drawn to intersect the profile. The point of intersection is the location of the second check dam site. The process is repeated to determine points where the ensuing check dams are to be built.

The number of check dams required is obtained by counting the intersections on the profile curve.

Surveying the cross section of the gully

The profile of the cross-section is the major factor in the determination of the dimension of the check dam and hence the cost of construction. The cross - section is measured as indicated in **Figure 7.19** at the point where the check dam is to be located. Two rods, a measuring tape and a carpenter's level are sufficient to measure the cross - section profile.

One worker holds the rod vertically at location A in the centre of the gully bed (the lowest point of the cross-section). Another holds the other rod horizontally by using a carpenter's level so that one end of the rod intersects the vertical rod at O and the other end touches the ground at location B. The vertical rod at A is then moved to the point where the first horizontal rod touches the ground, B, and the horizontal rod is made to touch the ground at a new point and the measurements recorded. This process is repeated at other points of the gully sides as shown in Figure 7.19. The cross-sectional profile eg. ABCD, is obtained from the vertical and horizontal distances of the touching rods.

Construction Procedures

The construction of check dams or earth plugs or gully plugs generally start from the bottom to the top of the gully. However, if rocks for the dam have to be transported from the bottom to the top of the gully through the gully channel, then construction must start at the top. Construction must be done in the dry season.

(a) Brushwood check dams

Two rows of posts are driven into the soil at intervals across the gully floor and brushwood is placed between the two posts as shown in **Figure 20 (a)** and **(b)** to form the dam. A third row of shorter posts is driven into the soil about 2 - 3 m downslope to form the lowermost of the three rows of posts or counter-dam. Brushwood is intertwined in this row of posts (**Figure 7.20 b**). The main objectives of the check dam are to slow the rate of flow of water and to hold fine material carried by the flowing water. Sediments collect at the upstream sides of the dam and counter-dam to form a gully bed and apron, respectively, as shown. These reduce or absorb the energy of flow of water and prevent the gully floor around the check dam or drop structure from being eroded. Vegetation should be established on the brushwood side of the taller row of posts to further reduce the velocity of flow of water and thereby stabilize the structure. Brushwood dams are temporary structures and are used as interim solutions.

(b) Log check dams

Hardwood logs and posts are placed across the gully. They can also be built from poles, planks, heavy board and slabs. The main objectives of log check dams are to reduce the velocity of flow of water in the gully and to stabilize gully heads.

Log check dams are designed in accordance with the geometry of the cross section. The front and cross section of a log check dam are presented in **Figures 21 (a)** and **(b)**. The following are the design considerations:

* The maximum height of a dam is 1.5 m from the ground level.

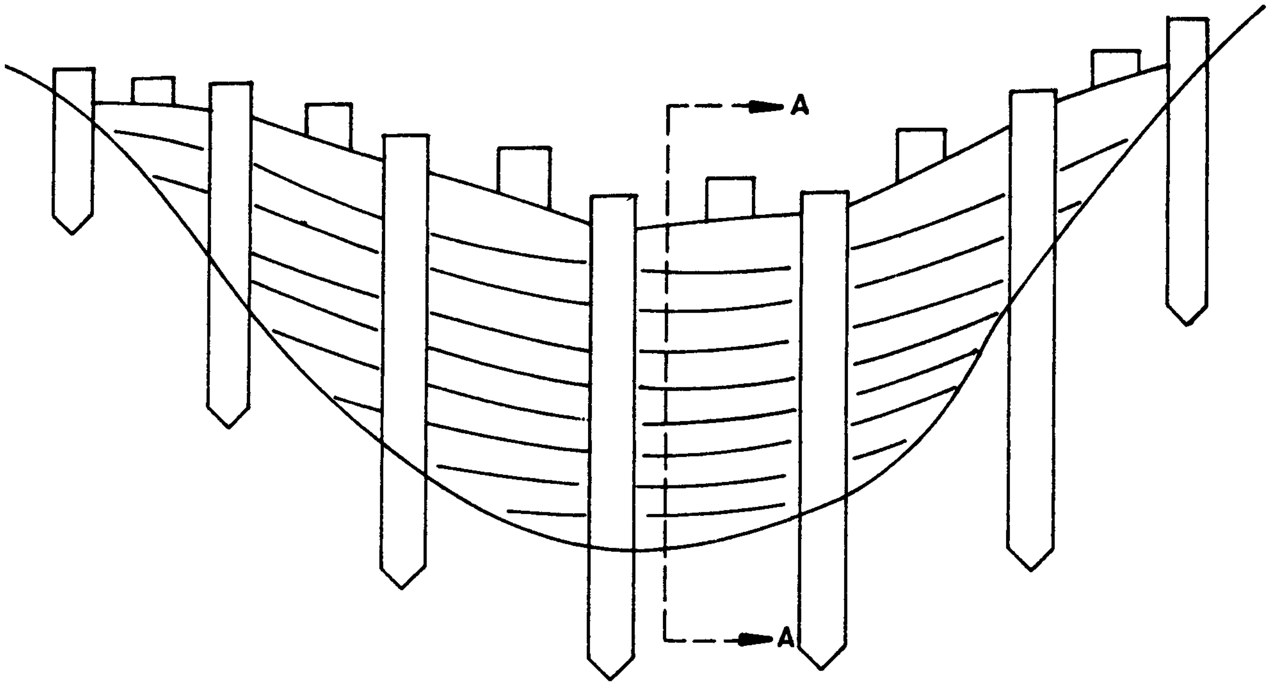

Figure 7.20(a) Brushwood Check Dam

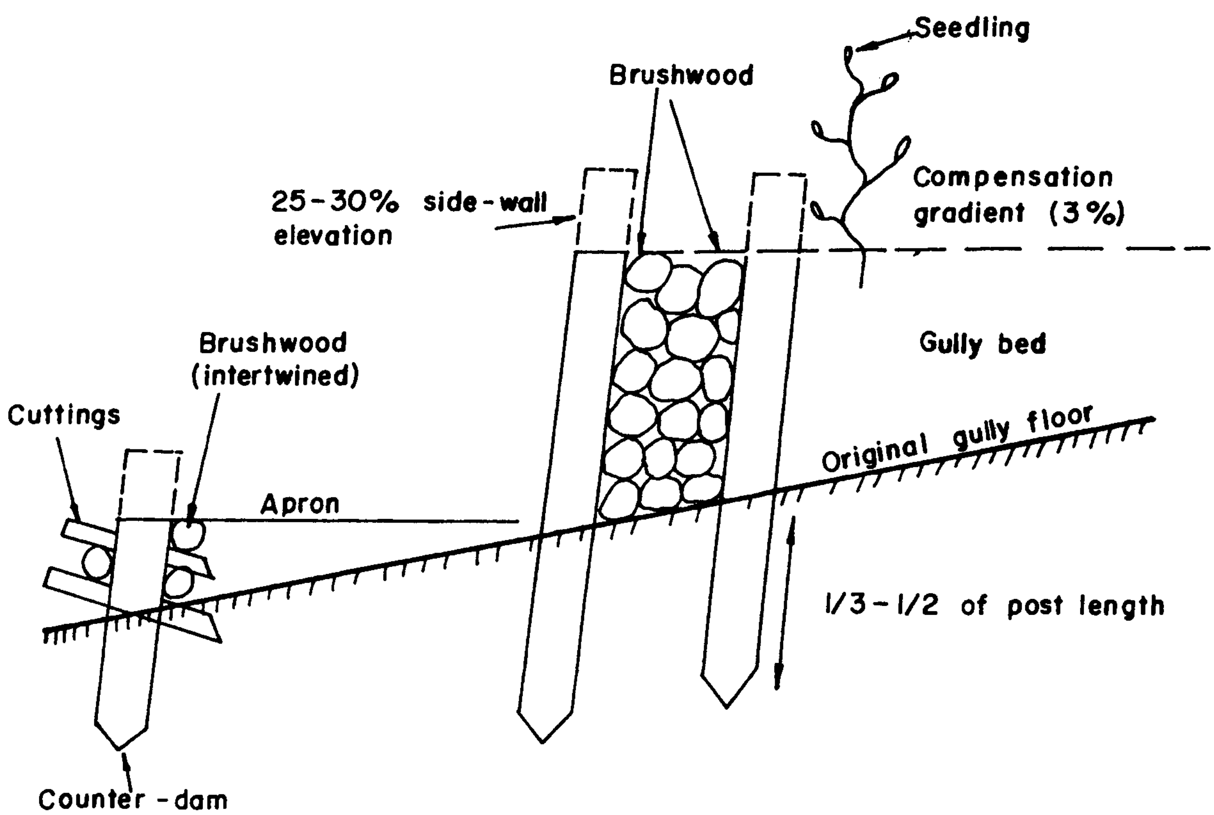

Figure 7.20(b) Cross-section of Brushwood Check Dam

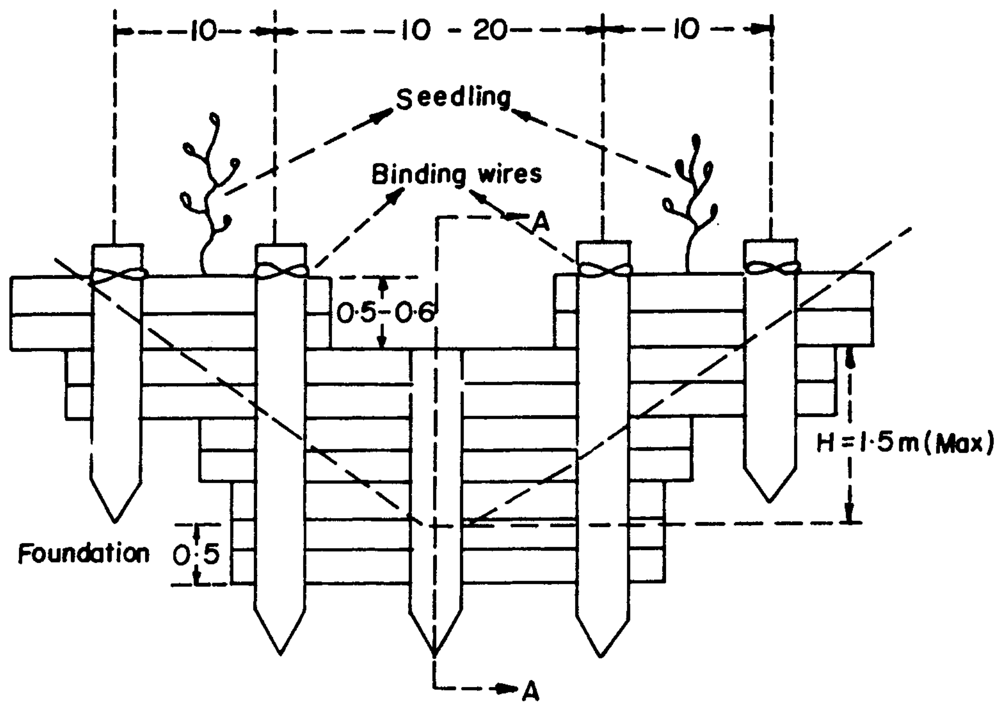

Figure 7.21(a) Log Check Dam

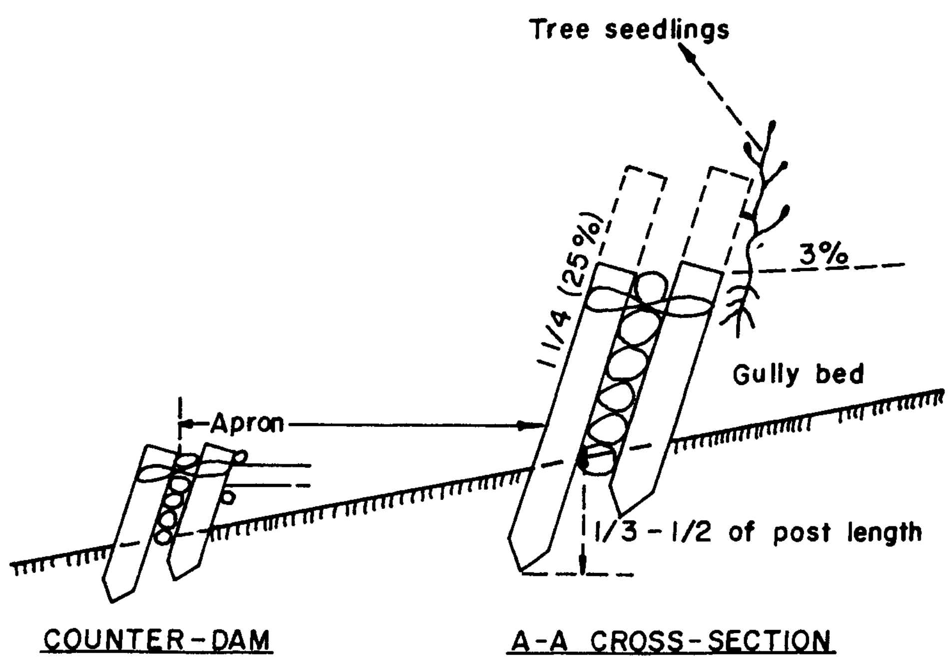

Figure 7.21(b) Cross-section of Log Check Dam

- The length and depth of the spillway vary between 1.0 to 1.5 m and 0.5 to 0.6 m.
- The length of posts used is 1.5 to 2.0 m and their top end diameter more than 8 cm.
- The ends of the logs should enter at least 50 cm into each side of the gully.
- The tops of the posts should be tied with building wire.

(c) Loose stone check dam

Relatively small rocks are placed across the gully so that they sit properly and interlock. The main objectives are to control water flow and channel erosion along the gully bed and to stop waterfall erosion by stabilizing gully heads. A loose stone check dam is sometimes reinforced with wire across the gully. The front view of a loose stone check dam is shown in **Figure 7.22**.

The design specifications are as follows:

- Maximum effective height of the dam is 1.0 m, and its foundation depth is at least 0.5 m.

- The foundation of the dam is dug so that the length of the foundation will be more than the length of the spillway and the foundation of the wings should be dug in such a manner that the wings will enter at least 50 cm into each side of the gully wall.

- The crest and middle must be constructed with bigger stones than the rest of the dam.

(d) Gabion check dams and Masonry check dams

These dams are generally too expensive and technically too difficult for small farmers to construct. Gabion check dams constructed to stabilize a gully in the Scotland District of Barbados are shown in **Figures 7.23 (a)** and **(b)** and a diagram of a masonry check dam is shown in **Figure 7.24**. The technical specifications are:

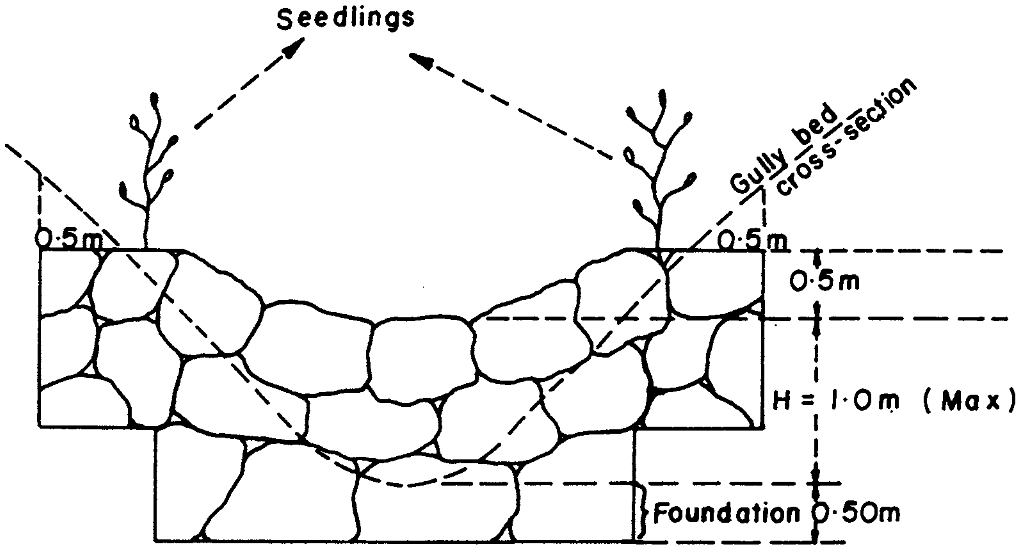

Figure 7.22 Loose Stone Check Dam

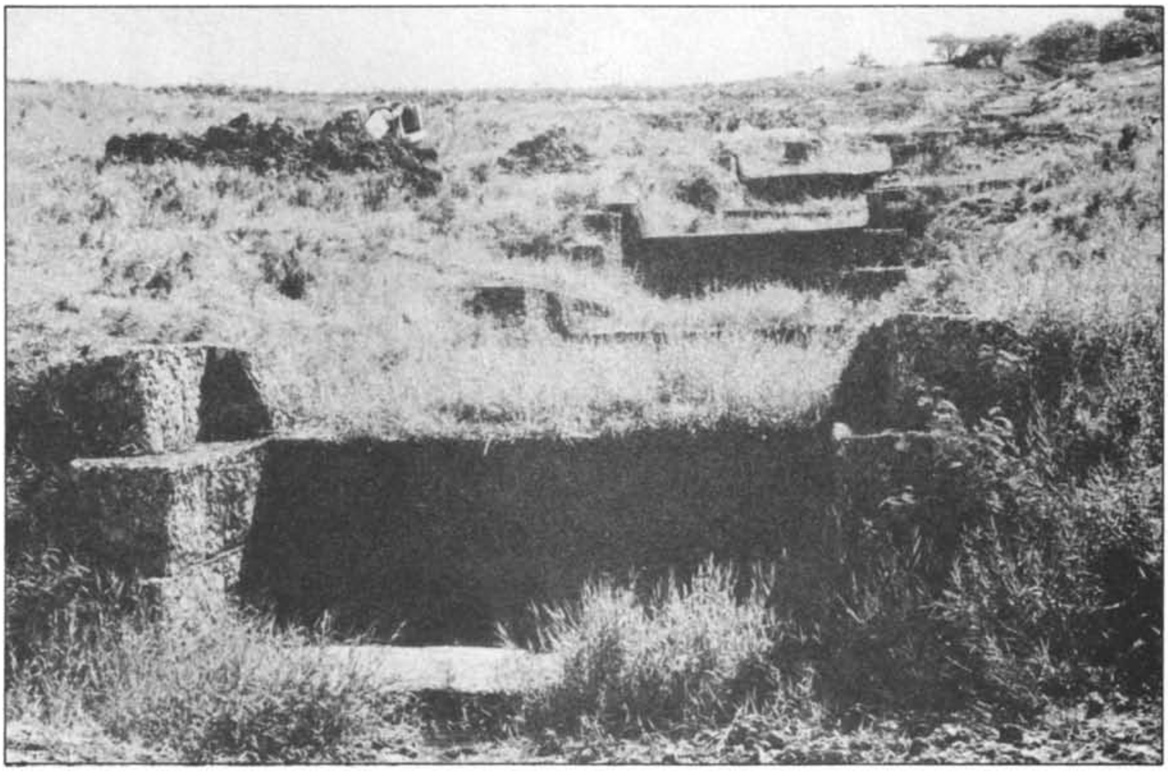

Figure 7.23(a) Gabion Check Dam

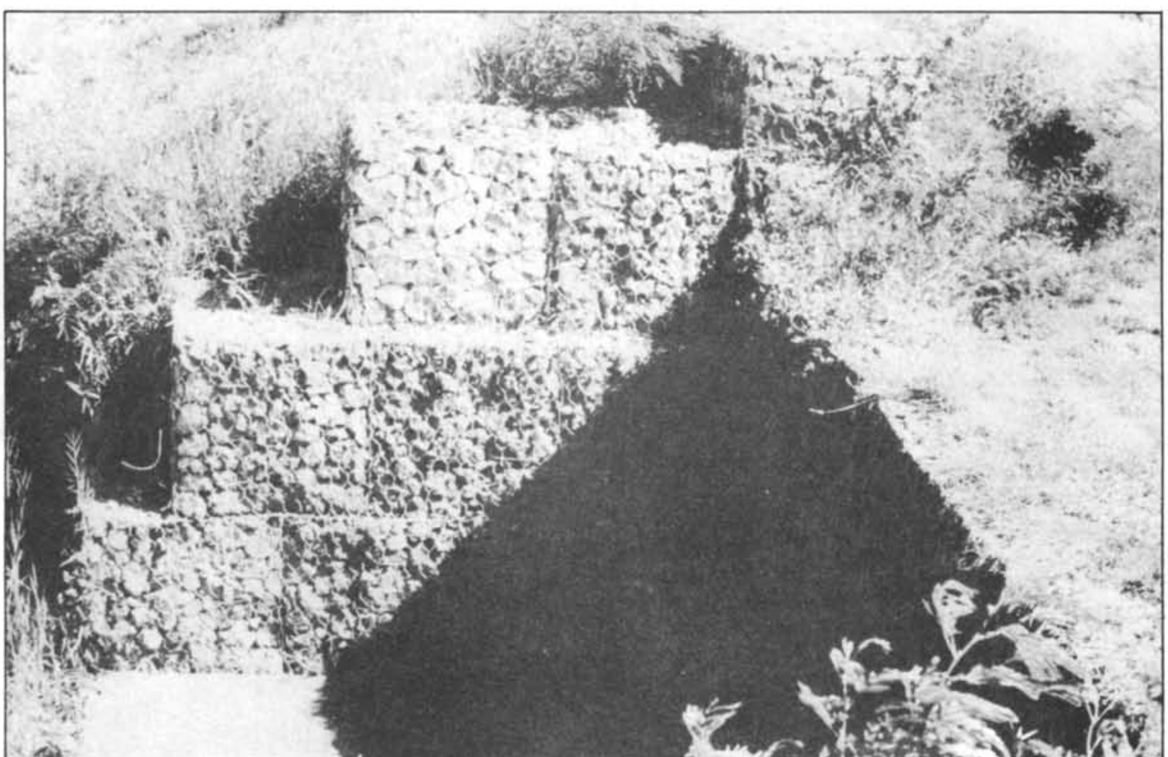

Figure 7.23(b) Close-up of Gabion Check Dam

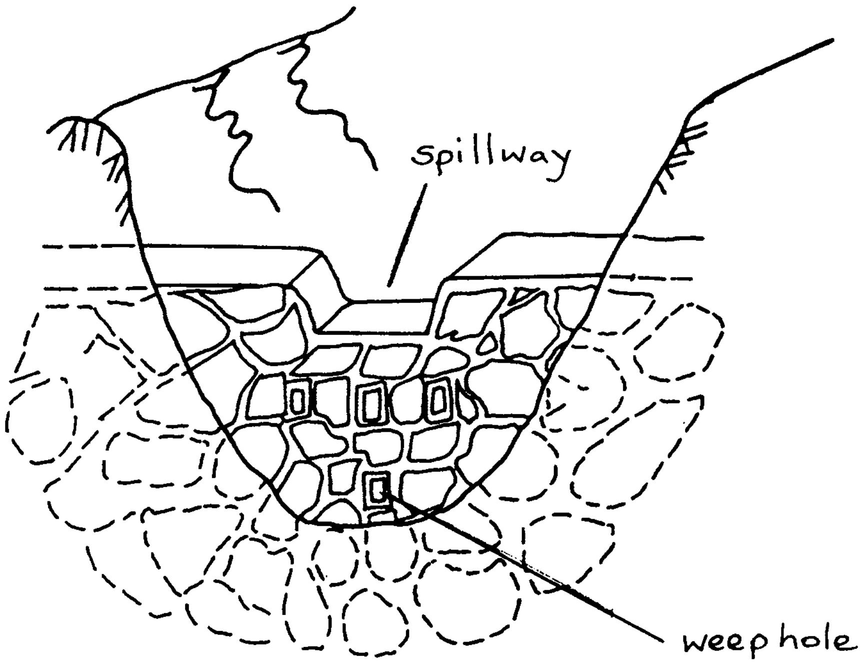

Figure 7.24 Masonry Check Dam

Specifications for Gabion check dams

- The foundation of the dam should be excavated to a depth equal to one-half the effective height of the dam and the banks should be excavated to allow the wings of the dam to enter at least 45 cm into each bank.

- A layer of gabion baskets is placed in the area excavated for the foundation baskets. The vertical sides of the baskets are tied with binding wire of the same diameter as the wire of the baskets.

- Random rubble stones hard enough to withstand abrasion, non-disintegrating, and resistant to weathering, are packed inside the baskets. The bigger stones should be put along the sides of the baskets while the smaller ones occupy the middle.

- After filling of the gabion baskets with stones to one-third, place five parallel ties between their inner and outer sides. Five more are placed when the boxes are two-thirds full.

- After overfilling a gabion basket slightly to allow for subsequent settlement, a lid is laced with binding wire to the top of the four sides. The lid must be stretched to fit exactly to the sides.

- If there is more than one layer of baskets in a gabion check dam, the ones in the upper layer must be laced to those below.

- The soil excavated for the foundation and from the gully bed should be used as back fill behind the dam and wing walls.

Specifications for Masonry check dams

- The dams should be built at a stable point of the gully bed just below the sliding area to hold debris and material as well as to stop the movement of soil.

- The foundation of the dam must be dug to a durable layer below, such as solid rock. If there is no solid layer, the foundation should be dug at least 1 m deep, and a reinforced concrete layer at least 30 cm thick be constructed. On this concrete layer, the body of the masonry check dam must be built with random rubble stones, and cement mortar (ratio 3:1).

- The wings should enter at least 1m into the sides of the gully and where this is not possible due to rocks, the wing walls should be tied to the rocks using mortar.

- The foundation should be longer than the spillway.

- A weephole must be built at ground level and other weepholes built in that section of the dam under the spillway.

- The upstream face of the dam is vertical, whereas the inclination of the downstream face is 20 per cent (0.2:1).

- Stones must be piled behind the mouth of the weephole.

- The space behind the wings of the dam must be filled with soil to a height equal to the depth of the spillway.

- The stones used in constructing masonry check dams must be hard enough to withstand abrasion, non-disintegrating, and resistant to weathering.

7.4 Land Clearing

Many problems of severe erosion have their genesis at the time of land clearing. Land is usually cleared by land developers for agricultural and non-agricultural uses and by farmers themselves. Land clearing for agricultural land development may be large scale by private farmers or by the government for land settlement programmes, or small scale by small private farmers. In all cases the appropriate land clearing methods must be employed to avoid damage to the land and to minimize soil erosion.

Several factors have to be considered before choosing land clearing methods. Lal and Russell (1981) have listed several of these which include land area, history of land use, climatic conditions (in particular amount and distribution of rainfall), vegetation (type, species, size and density), socio-economic conditions (cost and availability of labour), environmental issues (pollution potential, sediments), soil conditions/properties (soil type, stoniness), topography, soil management (tillage methods and harvesting techniques), and intended land use.

7.4.1 *Methods of land clearing*

The methods of land clearing can be classified as follows:

- Manual
- Chemical (tree poisoning)
- Ring barking
- Burning
- Mechanical

Manual land clearing

This involves the use of hand held mechanical tools e.g.. hoes, cutlass, spades, axes, winches and saws and is the method commonly used in subsistence agriculture. It is suitable for use under the following conditions:

- small land area
- time is available
- labour is cheap and available
- topography is too steep, rugged, wet or rocky for mechanized land clearing
- sites are fragile and could be readily damaged by mechanized land clearing
- soil characteristics and environmental conditions do not justify large scale mechanical operations.

With the manual method land can be cleared selectively and over time so that large areas of soil do not remain unprotected during the rainy season. The cleared areas should then be planted and crops established before other areas are cleared. On steep sloping soils, trunks, branches, stems and other vegetative material can be laid on the contour across the slope as a soil conservation measure as discussed in **Section 7.1.3**.

Manual land clearing is more expensive and time consuming per unit area of land then mechanized methods but it is recommended for Caribbean conditions where small farms and steep slopes are dominant.

Chemical methods

Trees and bushes can be killed with the use of chemical weedkillers such as 2, 4-D without damage to the soil. The amount of chemical has to be sufficient to kill the vegetation and prevent regeneration. The high cost and unavailability of chemicals often make this method unsuitable for small farmers.

Ring barking

The removal of the bark of trees in a complete circle can result in the death of certain species. Sometimes chemicals are used in conjunction with ring barking to speed up the rate of kill.

Burning

Vegetation is frequently burnt in the dry season before cutting the remaining standing material to clear the land. This method can have some beneficial effects if the land is left fallow for a prolonged period to allow for soil regeneration. Burning also increases the supply of exchangeable bases and available phosphorous. It is less damaging to the soil than bulldozing but if steep slopes are to be left fallow the cut material after burning should be used as barriers across the slope as a soil conservation measure.

Mechanized land clearing

Where large areas of land are to be cleared and labour is not cheap enough and available in large quantities to complete the job quickly, mechanized land clearing becomes necessary. The slope of the land must not be too steep to prevent the safe operation of mechanized equipment. Where the slope is steep, the chain saw, as a mechanical aid, is used to increase the rate of land clearing. The chain saw is such an effective tool for cutting trees that it is easy to use it wantonly and consequently damage the environment.

Where the girth of woody perennials is not too large and the slope of the land gentle/moderate, the brush cutter or jungle buster is effective and can quickly clear the land. The bulldozer can be very destructive to the soil when used to push down large trees and uproot tree stumps. Many soils which support tall vegetation are often low in fertility. They may be low in exchangeable bases, acid, shallow and have undesirable physical properties. When they are cleared by bulldozers and the topsoil disturbed or removed, the remaining soil cannot support adequate crop growth. This has frequently led to accelerated erosion. Care has to be taken when the bulldozer is used. Selected felling combined with soil conservation measures are required.

The use of chains for hauling cut timber with tractors from the field can damage the soil. When the land is steep and cultivation will not be mechanized most of the cut timber can be left in the field to protect the soil. Selected paths can be used to haul the remainder of the timber to minimize soil damage.