FARMERS AND SOIL CONSERVATION IN THE CARIBBEAN

Commonwealth Secretariat

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F A Gumbs

University of West Indies
St Augustine, Trinidad

COMMONWEALTH SECRETARIAT
Marlborough House, Pall Mall
London SW1Y 5HX

June 1994

PREFACE

In July 1992 the Commonwealth Secretariat published a report by Dr. Frank Gumbs, Reader in Soil Physics, Faculty of Agriculture, University of the West Indies entitled Integrating Soil Conservation into Farming Systems in the Commonwealth Caribbean. This was described as a Status Report and it provided a useful overview of the successes and failures in soil conservation work in the Region.

This work was initiated at the request of CARDI by the Commonwealth Secretariat and funded by the Commonwealth Fund for Technical Cooperation (CFTC). This work was well received and it was decided to explore the subject in greater depth and Dr. Gumbs began a second document, which we are now pleased to publish under the title ***Farmers and Soil Conservation in the Caribbean***.

This document is presented in two volumes. Volume I examines the status of soil erosion and conservation in the Region, the sociological factors in soil conservation programmes, and the legal and institutional context in which all soil conservation must be implemented and managed. It is now realised that these factors are as important as the technology of soil conservation and have not been given sufficient attention in the past. Volume II focuses on the technology. It examines the farming systems approach to soil conservation and the methods now being employed to ensure that conservation projects are integrated into the farming system. The Hillside Agricultural Project in Jamaica is a major initiative in the Caribbean and has attempted to adopt this integrated approach. This project is therefore discussed in some depth.

A short final Chapter draws conclusions and suggests some guidelines for future projects and programmes which will be of interest to planners, agriculturalists and everyone concerned with land use in the Region.

Core funding for the project was supplied by the Commonwealth Fund for Technical Cooperation (CFTC), and the Overseas Development Administration (ODA), UK assisted with a grant which is gratefully acknowledged.

Copies of the first report and additional copes of this volume are available from the Commonwealth Secretariat.

Brian Kerr
Chief Project Officer

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CHAPTER 1

INTRODUCTION

Soil erosion by water is the main form of soil loss in the Caribbean and conservation measures designed to reduce this type of soil loss is considered in this book. Here Caribbean refers to the English speaking Caribbean Community (CARICOM) Member States of Antigua and Barbuda, Bahamas, Barbados, Belize, Dominica, Grenada and Cariacou, Guyana, Jamaica, Montserrat, St. Kitts-Nevis, St. Lucia, St. Vincent and the Grenadines, and Trinidad and Tobago. These are sometimes referred to as the Commonwealth Caribbean and are all members of the Commonwealth. The location of these States in the Caribbean Basin is shown in **Figure 1**.

Belize and Guyana are also Commonwealth countries on the mainland of Central America and South America, respectively. Neither country is very mountainous and almost all of the agriculture is practised on flat land. Soil erosion is therefore not a major problem in these two countries, although some erosion does occur on the relatively flat, poorly structured, sandy soils of the intermediate savannas. Water runoff from heavy rainfall, especially during the early part of the wet season when the ground is not adequately covered with vegetation, erodes soil from the surface of these relatively infertile, fragile soils. The maintenance of adequate vegetation is usually enough to conserve the soil against erosion. Methods of conserving these soils from erosion are not considered any further in this text.

The other countries are islands and can divided into **three groups** based on size and topography. The first group of small islands consists of land of relatively low elevation and a small percentage of steep slopes e.g. Antigua and Barbados. The second group is also small islands but is characterized by a high percentage of steep slopes e.g. Dominica, Grenada and Carriacou,

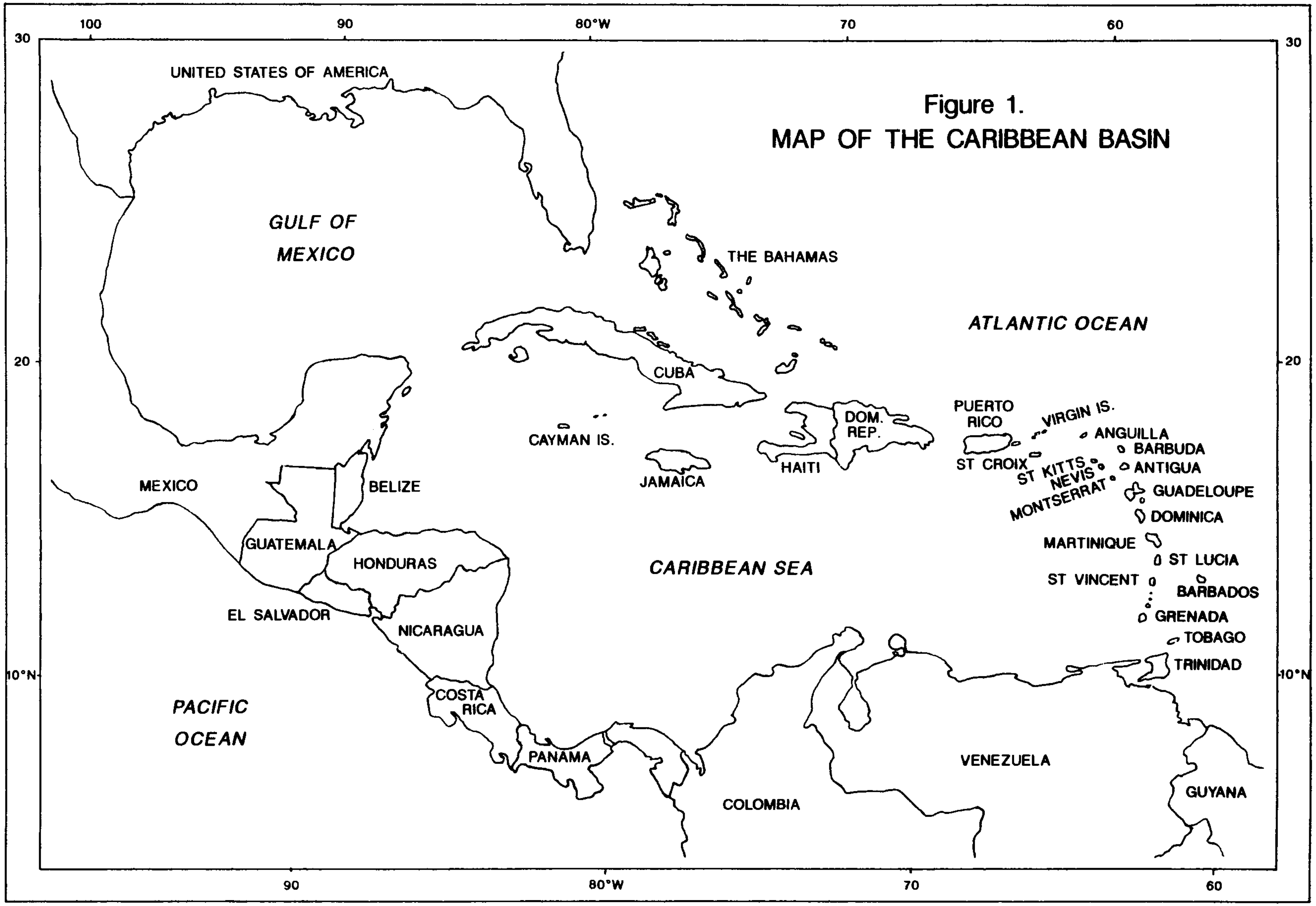

Figure 1.
MAP OF THE CARIBBEAN BASIN

Montserrat, St. Kitts and Nevis, St. Lucia, St. Vincent, Tobago. The third group is the larger islands of Trinidad and Jamaica which have high percentages of both flat or gently sloping land and steep land. Most of the islands belong to group two.

The mountainous nature of the topography in most of the islands, high rainfall, and poor soil management practices cause excessive soil erosion by run-off. Many attempts have been made over the years to demonstrate soil conservation techniques, provide training and encourage adoption by farmers. However, the adoption and sustainability have not been commensurate with the investment in time and money. Soil conservation has not generally become a part of the culture of the farmers.

Many of the introduced methods are frequently those that have been tried and successfully adopted in other countries such as North America and the Far East where the economic, social and cultural context is different. The methods must take the local situation into consideration and must also consider the needs, desires and resources of the farmer. New approaches therefore have to be considered to ensure adoption and sustainability. In the Caribbean, soil conservation methods must be cheap or cost effective and must fit into the sociological and socio-economic conditions of the farmer. Conservation ideally must be integrated into the farming system.

This book is presented in two volumes. **Volume I** examines the status of soil erosion and conservation in the Caribbean, sociological factors in soil conservation and the institutional and legislative framework in which soil conservation is implemented and managed. These factors are as important as the technology of soil conservation for successful adoption and sustainability. **Volume II** focuses on technology. It examines the farming systems approach to soil conservation and the methods appropriate for integrating into farming systems in the Caribbean. The Hillside Agricultural Project of Jamaica, the major project in the Caribbean which attempted to use the integrative approach is also discussed in this volume. Finally, existing and proposed systems for integrating soil conservation into farming system are also presented.

CHAPTER 2

SOIL EROSION STATUS AND SOIL CONSERVATION PROGRAMMES IN THE CARIBBEAN

2.1 Soil Erosion Status

The amount of soil erosion occurring in the Caribbean has not been quantitatively determined. Visual observations on soil sediments in streams, rivers and the sea, particularly immediately after a rainstorm, siltation of water courses and the depth of topsoil have been used to assess erosion status. The severity of soil erosion depends largely on topography, rainfall, natural vegetation, erodibility of the soils, land use and soil management.

Several Caribbean islands are characterized by steep slopes with a high percentage of the land area having slopes greater than 30° (58%). Many slopes are greater than 45° (100%) and farming is practised on these steep slopes. The distribution of slope classes in selected Caribbean islands is shown in **Table 2.1**.

Rainfall is largely influenced by the moisture laden northeastern Trade Winds and topography, so that rainfall decreases from the windward to the leeward coasts and increases with elevation. It is higher on the more mountainous islands than on the flatter islands. Annual rainfall can vary from a low of 625 mm on the leeward coast of relatively flat Antigua to a high of about 7500-8000 mm in the wettest area of Dominica. The amount of rainfall in the other islands is between these two extremes and a common range is from about 1300 to 3000 mm. Total annual rainfall is not only high but precipitation can be intense. Intensities of 25-127 mm per hour (and occasionally higher), have been recorded. Strong winds frequently accompany the storms thereby increasing the erosivity of the rainfall. Hurricanes which can and do occur, cause tremendous soil losses. Studies in Trinidad (Lindsay and Gumbs, 1982) have shown that two major storms (non-hurricane) of 49.8

TABLE 2.1: Distribution of slope classes in selected Caribbean islands

Slope Class %	Antigua ha	Antigua %	Dominica ha	Dominica %	Grenada ha	Grenada %	Trinidad ha	Trinidad %	St. Vincent ha	St. Vincent %
A	1120	4.3	4450	8.1	480	1.6	110400	22.7	1225	5.1]A]+
B	12290	47.0	1590	3.0	1020	3.4	39835	8.2		]B
C	5525	21.1	6120	11.3	1470	4.9	84070	17.3	4900	20.7]C]+
D	5170	19.7	15340	28.2	5755	19.2	101755	21.0		]D
E	1940	7.4	18780	34.5	14285	47.6	62765	12.9	5715	24.1
F	145	0.5	8080	14.9	6980	23.3	86730	17.9	11840	50.1

Slope Class	Degree	%	Description
A	0 - 2	0 - 3	Level
B	2 - 5	3 - 9	Gently Sloping
C	5 - 10	9 - 17	Moderately Sloping
D	10 - 20	17 - 36	Strongly Sloping
E	20 - 30	36 - 58	Steeply Sloping
F	> 30	> 58	Very Steeply Sloping

and 75.7 mm during the year accounted for between 70 and 90% of the total annual soil loss depending on soil slope. The annual soil loss varied from 28 to 55 t/ha.

All the primary vegetation has been removed or lost from the islands as a result of hurricanes, shifting cultivation, fires and deforestation for human settlements and other uses. The secondary vegetation is not as protective of the soil against erosion as the primary vegetation.

Some of the sloping soils are prone to landslippage and are therefore erodible. In Trinidad, Jamaica and Barbados substantial areas of steeply sloping soils are developed on shales and in these soils landslips are common. Landslips are also common where soil is developed on impervious calcareous clays or impervious indurated and cemented clay or ash layer as in the case of the shoal soils of Grenada and some locations in the volcanic islands, for example, Dominica and St. Lucia. Many soils are, however, not inherently very erodible. Their good soil structure and high infiltration rates reduce their erodibility. However, the intense rainfall, steep topography and poor soil management result in high soil losses overall.

Although the rainfall, vegetative cover, soil type and topography are factors which contribute to the high soil losses by water erosion, it is inappropriate land use and poor crop and soil management which are the most important factors. Most of the farmers cultivate small farms on hillsides, usually steep slopes, without adequate or the most appropriate soil conservation methods. Shifting cultivation by squatters, clear felling and slash-and-burn cultivation increase erosion since the land is bare at the start of the wet season. It takes some time for the crop to grow sufficiently to protect the soil.

The occurrence of surface erosion, gullying, landslips, the amounts of eroded soil carried by streams and rivers during and after a heavy rainstorm and the depth of topsoil or shallowness of the soils have been used to qualitatively assess the severity or status of soil erosion in the Caribbean. A brief summary is presented below, using the grouping of the islands set out in Section 1.

2.1.1 Group One (Antigua and Barbados)

Antigua

Erosion is not as severe in Antigua and Barbuda as in many other parts of the Caribbean because of the relatively level topography and low rainfall (Hill, 1964). However, much accelerated erosion has occurred in the hilly areas of Antigua. Cotton which was grown extensively and requires a long fallow period, was generally grown under poor management. Consequently, erosion has been reported even on the more gentle slopes. Monoculture of sugar-cane in the past has also added to the loss of much soil in hilly areas. The dry season is often long and harsh and torrential rains often occur after long periods of drought when vegetation is sparse. This has contributed to the erosion problem. Overgrazing under the climatic conditions of Antigua and during times of poor vegetative cover and growth is another cause of accelerated erosion. The result of these factors is that the soil in many places has been eroded to such an extent that the topsoil is shallow or completely lost and rock outcrops are prominent.

Barbados

About eighty-five percent of Barbados occupies relatively flat coral soils on which erosion is not considered to be severe although Vernon and Carroll (1967) did suggest that erosion control measures may be necessary on the soils of the upland plateau of St. John's Valley.

In the hilly Scotland District, erosion is very severe. Cumberbatch (1969) reported that it was estimated that seventy percent of the area was threatened by erosion and that eleven percent of it had reached a very severe state of degradation. Land slides and gullying are common.

2.1.2 Group Two (Dominica, Grenada and Carriacou, Monsterrat, St. Kitts and Nevis, St. Lucia, St. Vincent, Tobago)

Dominica

Dominica is characterised by steep slopes where 86% of the land area has slopes greater than 20° and only 2% of the land has slopes between 0-5°. Over 66% of the land is covered by forests and rainfall is heavy i.e. average of 4450 mm per year and 7500 mm in the wet interior (Caribbean Conservation Association, 1991).

Most of the soils are generally highly permeable and therefore erosion is not as severe as might be expected given the steep mountainous topography of the island. Slopes greater than 50° (120 %) are cultivated without much erosion, indicating the unusual stability of the soils (Lang, 1967). In addition, erosion is limited because much of the land is still under forest.

Most of the shoal soils and other soils of low permeability occur on the leeward side of the island. Erosion of these soils is widespread and significant. Poor crop and soil management have been the major reasons for the erosion. The slow regeneration of soil suitable for cropping in the dry areas, like in St. Lucia, increases the seriousness of the problem.

According to the Environment Profile of Dominica prepared under the aegis of the Caribbean Conservation Association, 1991, Dominica has great potential for agricultural development without substantial incursions into forest lands which are more suited for other purposes. In the pre-independence period before 1978, large estate ownership was dominant (1.4% of farmers occupied 56.4% of the land and 61% of the acreage had farm sizes 50 acres and over). Since independence, large estates have declined in importance and have been either divided and sold or in some cases, left to lie idle due to absentee landlords. Demand for land has resulted in Government distribution of crown land to farmers, usually in lots of less than 4 hectares. Through Government's, Integrated Rural Development Programme (IRDP), and other land reform projects, several estates have been divided into small plots and distributed among local tenant farmers e.g. Carholm in the centre of the island;

Melville Hall, Castle Bruce and Newfoundland in the east; Geneva, Bagatelle and Petite Saavane in the southeast; and Soufriere in the south.

These programmes have not always prevented further encroachment into neighbouring forested areas. Also since 1978, a sizeable portion of forest has been turned into agricultural land. In Dominica's National Structure Plan (GOCD, 1985) a substantial amount of "unutilized" land is to be transferred to more intensive use (including agriculture) by the year 2001. This changing pattern of land use has implications for soil erosion and conservation.

Forestry and forestry development are important to Dominica. Timber extraction is undertaken but according to Russel (1974) it damages only a relatively small area and the erosion caused is not significant. In discussions with current officers in forestry and agriculture in Dominica, this view still seems to be valid. The view is that soil loss from logging is not severe because of selective felling. The exception is where lands are being brought into agricultural production and there is clear felling for extraction of forest species before land preparation.

The introduction of the chain saw and the clearing of land for agriculture throughout the year (with little attention to seasonality) has accelerated erosion. The removal of plantation tree crops and substitution of mixed cropping is also a contributor. The cutting of roads to make agricultural lands more accessible without proper consideration of soil type, road cutting techniques and road engineering has aggravated the problem. The expansion of agriculture has led to the increased utilization of marginal lands (e.g. steeper slopes, shallower soils) and this has led to greater erosion hazards.

Grenada and Carriacou

Grenada has suffered less from erosion and fertility exhaustion than many of the other islands. The two main reasons for this are:

(a) the island's agriculture is based largely on tree crops, cocoa (***Theobroma cacao***) and nutmeg (***Myristica fragrans***). Banana and food crops are frequently interplanted with, for example, cocoa, and major forest fires are not prevalent;

(b) the soil parent material is very base-rich and the soil has been further enriched by additions of volcanic ash from eruptions in nearby islands in recent times. Thus, even if some surface soil is lost, the underlying exposed material is almost as fertile and promotes rapid vegetative growth.

Although cocoa and nutmeg are not a guarantee against erosion, they cause less erosion than under less permanent crops. Some severe erosion is nevertheless evident on hills where factors conducive to erosion exist, for example, land clearing, shifting cultivation, charcoal burning, fragmentation of land, poor land distribution, squatting, land tenure problems, and poor cultivation practices. Gullies frequently develop in nutmeg fields as a result of the nature of the soil and clearing of the ground cover for nutmeg collection. The neglect of these small gullies can lead to the rapid development of large gullies. In Grenada, significant landslips occur in some soil types. Examples of a significant landslip in Grenada are shown in **Figure 2(a)** and **(b)**.

In contrast, Carriacou has suffered very severe erosion over nearly the whole island and in many cases only the parent rock remains. This situation has been created by the erodible nature of the soils, cutting down of the original vegetation, using unsuitable cultivation methods and over grazing. Over grazing has been aggravated by the **"let go"** season when animals are allowed to roam freely. This has encouraged denudation of vegetation, soil compaction, reduced infiltration and erosion. The low annual rainfall which does not promote rapid vegetative growth aggravates the problem of overgrazing and denudation. Extensive cotton growing in the earlier years with poor soil management practices played an important role in aggravating soil erosion.

The soils of Cariacou are skeletal soils over ash and agglomerate, soils formed from other igneous rocks, and those formed from limestone. They are all susceptible to erosion and deep gullies are also evident on some of the flatter coastal areas.

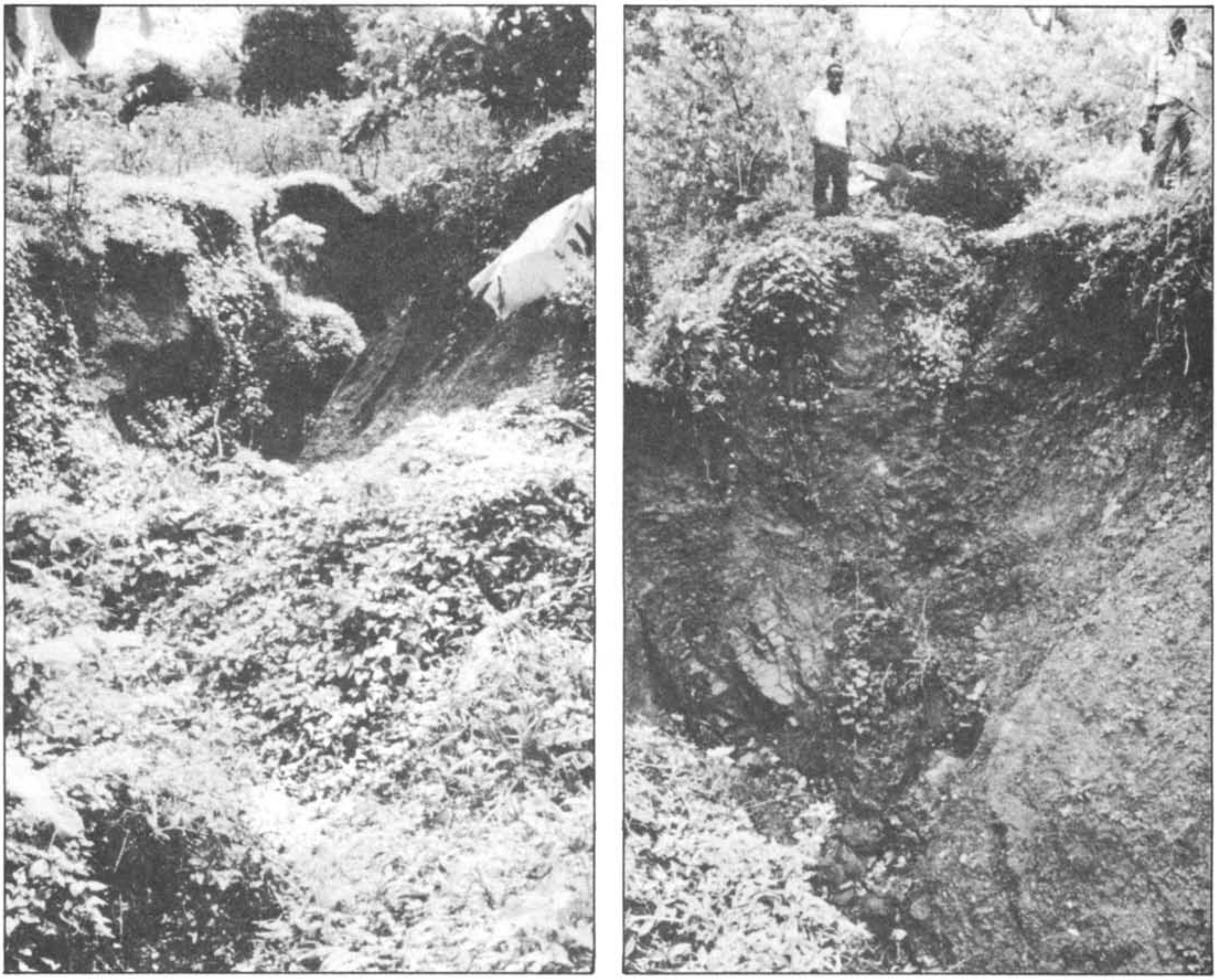

Figure 2   Landslips in Grenada

Montserrat

Lang (1967) describes the whole island of Montserrat as suffering from severe soil erosion and the greater portion of the island as having lost all its topsoil. The extensive monocrop cultivation of cotton in the 1940's and 1950's under poor soil management has contributed significantly to the widespread erosion. Unlike the soils of Dominica, the soils of Montserrat are generally unstable and many soils are highly erodible if cultivated on slopes greater than 10° (18%). The assessment of Lang may be harsh but the level of erosion is severe without a doubt.

Montserrat is an island of mini-farms which offers a challenge to effective soil conservation and to conservation on a watershed basis. This is not unique to Montserrat. Effective conservation in this situation requires the cooperation of many farmers. This is aggravated by the fact that farmers mostly practise clean cultivation of vegetable and food crops (e.g. root crops and tuber crops) on steep slopes which leave the fragile soil exposed to erosion. Relay-cropping is seldom practised and the standard of soil conservation is not high.

St. Kitts and Nevis

The retention of forest cover in the mountainous areas of St. Kitts has served to reduce erosion (Lang and Carroll, 1967). Where the forest has been cleared and planted to crops, some accelerated erosion is seen. However, since the soils are very permeable and free draining, erosion is not severe. The extensive growing of sugar cane helps to reduce erosion except during the period when the fields are cleared for replanting before the wet season arrives.

On the island of Nevis in contrast, much erosion can be seen. In many areas and particularly on the smectoid soils, the surface soil has been lost completely. This situation was caused primarily by poor farming practices and the widespread cultivation of cotton under poor soil management.

St. Lucia

Soil erosion is a major problem in St. Lucia. Many of the soils of the interior are very susceptible to erosion and during heavy rains soil can be seen being washed away by even the smallest rivulets (Stark *et al.*, 1966). In areas of allophanic clay soils, slumping is a problem and gullying is also common throughout the island. The common practices of clean cultivation of very steep land and of clearing steeply sloping forested land which would better be left under its original vegetation have accentuated the situation. Probably the most severe effects of erosion are on the so-called "shoal soils" (Vertisols) which contain a layer of indurated material in the subsoil. Once the surface soil has been lost it is impossible to grow crops on them and regeneration is very slow since these soils occur in the drier parts of the island. Large areas of land formerly under cultivation have been misused to such an extent that they have been abandoned and left idle for many years. Rehabilitation may be very difficult or impossible.

St. Vincent

The soils of St. Vincent are entirely of volcanic origin. Four major soil groups are recognized (a) High- level and Low-level Yellow Earths developed over massive rock; (b) Recent Volcanic Ash soils; (c) Shoal soils and (d) Alluvials. Because of the high permeability of the soils, they are not easily eroded under natural vegetation. The Yellow Earths are well structured soils and not naturally erosion prone. However, several of the soils in this group have relatively shallow topsoil and the parent material or "rotting" rock can be found within 0.50-0.75 m of the soil surface. The saturation of the topsoil in the wet season and the shallow rooting systems encourage land slippage. The soils are erosion prone when denuded of vegetation or poorly managed. Land slippage also occurs in the shallow shoal soils. The Recent Volcanic Ash soils (developed over cindery materials) are more prone to gullying than surface wash (sheet erosion). Nevertheless, sheet erosion is common under poor soil management.

Soil erosion is, however, considered to be a serious problem in St. Vincent, because of the types of crops grown and the deficient or inadequate crop and soil management (Watson *et al.*, 1958). Clean cultivation of root crops, groundnuts, banana, (and previously cotton) without adequate soil conservation has encouraged erosion. Cultivation of root crops and groundnuts entails a great deal of disturbance of the soil and relatively long periods in which much of the soil is left bare.

Many farmers of St. Vincent have traditionally practised soil conservation which, for many years, represented the best examples of soil conservation in the Commonwealth Caribbean. This was a consequence of the policy of the Government to financially support or subsidize soil conservation. With the decline in Government subsidy the standard of soil conservation has declined and there is evidence of increased erosion and siltation of water courses. The expansion of annual cropping and banana cultivation to very steep slopes which should remain in tree crops or forest has also increased erosion in recent times.

Tobago

The soils of the mountainous area of Tobago are formed from parent materials such as volcanic tuffs, breccias, diorite and schists and are highly prone to erosion. The northern and wettest end of the island is still under original forest or permanent tree crops so that erosion is restricted. Further south, erosion is a more serious problem. Hardy has described heavy erosion in the Castara-Palatuvier area on the leeward side of the island where intensive peasant and estate cultivation was carried out. At present, the topsoil is very thin in many places and much of the land has been abandoned and has reverted to secondary growth. A few farmers still persist with limited subsistence crop production on the less eroded and less steep slopes.

On the windward side of the island, land on the volcanic soils are cleared, mainly by burning, and planted to arable crops. Evidence of sheet erosion, gullying and soil slump can be seen throughout the area wherever the land has been cleared.

The most eroded area of the island is the Mason Hall-Les Coteaux district. The sandy clay loam soils of this area formed from diorite is very irregular, steeply sloping and highly erodible. The degradation started more than one hundred years ago when they were cleared and used continuously for sugar cane cultivation. After the collapse of the sugar cane industry in Tobago the lands were settled by shifting cultivators. Today, the drier parts of the area resemble a desert while the wetter parts are covered with scrub vegetation. In spite of this degradation some areas are still cleared regularly and planted to row crops. Frequently, a fire started in the drier parts to clear a small patch for planting will spread widely, leaving the soil bare for the heavy rains of the wet season. Fortunately the parent rock weathers quickly to a friable easily worked material which will support limited cropping. If the land is not cropped too often, there will always be some soil left on which some cropping can be carried out. Similar erosion damage on the more slowly regenerating volcanic rock or schist would have been more disastrous to crop production.

Limited soil conservation is practised mainly in the form of intercropping and occasionally trash mulching. On eroded soils the topsoil is shallow and parent material may protrude on the soil surface. Some soil series have a distinct eroded phase of low fertility and restricted cropping potential.

2.1.3 Group Three (Jamaica and Trinidad)

Jamaica

Soil erosion is rampant and severe in many parishes and on many soils of the island. One of the major factors is population pressure which results in increasing frequency and intensity of land use or the use of land beyond its capability. The parishes of Westmoreland, Portland, Hannover, Clarendon and St. Elizabeth are especially noted as suffering severely from accelerated soil loss, but serious erosion is noted in all parishes. Soils on which erosion is a serious problem are the limestone soils, shale-derived soils and the soils formed on grano-diorite.

The shale soils are noted for their shallowness, poor infiltration and permeability, factors which contribute to serious erosion problems. They are among the most important soils in areas of extreme soil erosion such as Christiana and Yallahs Land Authority.

One serious consequence of extensive erosion is the common flash flooding in the plains of many areas after heavy rains. The flash floods themselves cause much damage to crops, livestock and property.

Trinidad

The earliest comprehensive report on soil erosion in Trinidad was by Hardy (1942). He reported considerable gullying and sheet erosion in the foothills of the Northern Range, particularly in the west where intensive cultivation was being carried out. Burning to clear the land for planting at the start of the wet season is common and landslips are frequent. In some places the soil surface is within 15 cm of the parent rock. In the Las Lomas district, the sandy soils are described as being very erodible, but since much of the land is in forest reserve, erosion is not such a severe problem. In the Central Range, land creep is a major problem and the southern slopes show many landslip scars. Chenery (1952) mentioned that Brasso clay, the most widespread soil of the Central Range, is very eroded due to prolonged cultivation up and down slope. He also mentioned that Montserrat clay, a very productive cocoa soil, is highly prone to gullying.

Both Hardy and Chenery commented on the severe erosion of the marl soils and the associated red soils of the Naparima District in southern Trinidad, with caps of exposed white marl being a common feature of the hills of the region. In the Southern Range where soils are derived mainly from sandstone, erosion occurs wherever the original forest cover has been removed.

There has been no comprehensive nor sustained programme of soil conservation. Poor agronomic practices have persisted so that topsoil continues to be lost especially from soils in the Northern Range and the topsoil is now shallow in many locations.

2.2 Soil Conservation Programmes

Many soil conservation projects or programmes have been undertaken in the Caribbean, sometimes at considerable cost, to protect the soil against erosion, to train farmers and agriculturalist in methods of soil conservation, to facilitate production on hillsides and to increase the productivity of hillsides. This effort has been greater in Jamaica than any other Caribbean island. The problems, however, are still many and serious and much remains to be done. The Government of Jamaica through the relevant Ministries and Statutory Agencies has undertaken various watershed protection activities e.g. reafforestation on public lands, establishment of permanent tree crops and engineering works for gully control, river training and drains.

Gumbs (1992) reviewed the soil conservation projects undertaken in the Caribbean over the previous 20-25 years and assessed the successes and failures of these projects. A brief summary of the major projects undertaken is presented below.

2.2.1 *Barbados*

The Scotland District was the target of most of the soil conservation effort. The main approach has been the use of engineering methods requiring earth moving equipment for land reshaping and stabilization, construction of terraces, dams and silting ponds, surface and subsurface drainage, the construction of gabion weirs and gabion boxes, and reafforestation. This was costly and when Government and International funding ended, farmers were unable to maintain the effort. Farmers' plots are also small and non-contiguous and limit implementation. In some cases reshaping of the land aggravated and increased erosion because the reshaped land was often more prone to land slippage and surface erosion than the original. In addition, toxic oil and salt from the subsoil were sometimes exposed at the surface during reshaping.

2.2.2 *Grenada*

The largest and most significant project was the UNDP/FAO project which was implemented over the period 1975-1985. However, most of the soil and water conservation methods required costly earth moving machinery and were labour intensive. The terraces were costly to construct and had to be used continuously to justify the cost. Farmers did not adopt the methods and the demonstration effect failed.

2.2.3 *Dominica*

There has not been any major projects specifically dedicated to soil conservation which have received international funding. The country has, however, been soil conservation conscious and the farming practices reflect this. The use of tree crops has been a major component of the approach to soil conservation.

2. 2.4 *St. Lucia*

The main projects undertaken were:

(i) Soil and Water Conservation Project funded by the European Development Fund. The major thrust was drainage and land reclamation.

(ii) Development of Soil Conservation Practices for Small Farms funded by CIDA through Mc Gill University. The main aims were to establish a soil conservation demonstration, training and research field site, and to upgrade the technical capability of staff of the Ministry of Agriculture, St. Lucia. The demonstration effect was not successful, the site was not maintained after the project ended, and farmers did not adopt the methods.

(iii) Mabouya Valley Development Project. This project is ongoing and has shown promise of continued adoption and potential for sustainability. The approach adopted by the project of providing incentives and promoting community involvement and participation seems to be an important reason for the achievements so far.

(iv) Forest Management and Conservation Project is funded by CIDA and was projected to terminate by the end of 1992. In the project three sub-watersheds were selected for rehabilitation in a pilot phase and to provide a model for extension to other areas. The project has not been finally evaluated but the approach of involving the entire family, the community, national farmers association, social considerations, avoidance of the gratis mentality, and provision of institutional supports to the farmers, seems to be contributing, to the success of the project.

(v) Locally Funded Soil Conservation Projects of the Land and Water Use Unit and the Forestry Division of the Ministry of Agriculture.

2.2.5 *St. Vincent*

(i) Cumberland Watershed Management Project which was undertaken 1984-1989 was the major soil conservation project. It was a complementary project to the Cumberland Hydro-Elective Project funded by USAID, and the main objectives were to maintain good watershed conditions, intensify agricultural and forestry productivity without soil degradation, and extend the experience to other critical watersheds. The project was not very successful for many reasons which have been discussed by Gumbs (1992).

(ii) Small Holder Crop Improvement Project is in progress (1990-1997) and is funded by the International Fund for Agricultural Development (IFAD). It has a soil conservation component which is outlined by Gumbs (1992).

(iii) Watershed Management Plan for the Colonarie River Basin is currently being formulated (1990-1995) with funding from CIDA. The project is essentially an inventory, capability assessment and planning exercise for the Basin. It proposes to develop management plans, proposals for farming systems and soil conservation. However, it is not clear how comprehensive and implementable they will be.

2.2.6 *Jamaica*

The following major projects have been undertaken or are being undertaken:

(i) Forestry Development and Watershed Management in the Upland Regions (1968-1975) funded by FAO;

(ii) First Rural or Kenilworth Project (1971-1977) funded by UNDP;

(iii) Second Rural or Second Integrated Rural Development Project (1978-1983) funded by USAID;

(iv) Projects of the Soil Conservation Unit and Land Authorities;

(v) Strengthening the National Soil Conservation Programme for Integrated Watershed Development (1979-1982) funded by UNDP, Norway and Government of Jamaica;

(vi) Hope River Watershed Project was initiated in 1987 and consisted of three Phases. It is still ongoing;

(vii) Small Farm Credit Project (1989/90-1996) is funded by IFAD. Funds are provided to the Agricultural Credit Bank (ACB) and People's Cooperative Banks for lending to small farmers. A specific Hillside Farmers Support Project in which soil conservation was to be an explicit requirement of the project was undertaken.

(viii) Hillside Agricultural Project (HAP) and Hillside Agricultural Sub-Projects (HASP) implemented under HAP. This project was initiated in 1987 and is due to terminate in 1994. It has shown some degree of success and is specifically reviewed in Chapter 8.

(ix) The Sustainability of Contemporary Agricultural Land Use in the Blue Mountains of Jamaica was initiated in 1991 and is proposed as a three year project.

The majority of projects have failed to achieve their objectives of adoption and sustainability of soil conservation by farmers. Many of the reasons are sociological and, to a lesser extent, administrative and technical. These are discussed in the succeeding chapters.

CHAPTER 3

SOCIOLOGICAL FACTORS IN SOIL CONSERVATION

Although farmers on hillsides in the Caribbean are aware of the need for soil conservation, the level of adoption and implementation is low. It was generally accepted that the development of technologies, the demonstration of those technologies and the provision of technical assistance were all that was needed to achieve implementation and sustainability of soil conservation. The belief was that if farmers can see the reduction in soil erosion and improved crop yield through the use of soil conservation measures they will implement the methods. The lack of success of soil conservation projects over many decades using this approach has led to the realization that soil conservation policy, the method of implementation, and human behaviour are more important than technology.

Soil conservation is not only a technical problem, it is also a behavioural or social problem. Socio-cultural and socio-economic factors and decision making methods must be considered in the design and implementation of soil conservation projects. It is a mistake to believe that because bench terraces are widely adopted by farmers in the Far East and the United States of America, they will be readily adopted by farmers in the Caribbean because a scientist says they are good and should be implemented.

The review and assessment of the successes and failures of soil conservation projects in the Caribbean (Gumbs, 1992) have revealed the social problems which have constrained the successful and sustained adoption of soil conservation. This chapter examines the important socio-cultural and socio-economic factors which must be considered and are relevant to the implementation of soil conservation projects, and assesses the actual experiences with the implementation of soil conservation in the Caribbean.

3.1 Socio-Cultural Considerations

The four cultural criteria in project implementation are:

- Identification of critical behavioural factors.
- Familiarity and closeness of project designers and technical staff with project events.
- Ability to measure and evaluate success in quantifiable terms.
- Evaluation of the role and performance of the project designers and implementing agency.

Identification of Critical Behavioural Factors

It is important to recognize that the critical behavioural factors must be identified and considered in the project design. With every successful project, social change which is necessary for successful project implementation, will occur. The acceptance of this change is necessary if the change is to be sustained and recipients are not to revert to their former ways.

Relevant information has to be gathered which will inform all aspects of project design and implementation. There are two ways in which this information can be obtained **(a)** by a review of existing literature; **(b)** data collection in the field. A very popular method employed today in collecting information very quickly and cheaply is the **Sondeo** which is a rapid rural reconnaissance or appraisal. The information gathered by this method is later verified and strengthened by conducting a Baseline Survey which is a more formalized method of data collection.

The questionnaire, discussions with the rural community and subsequent appraisal of the information should identify, *inter alia*, current systems, problems and constraints, reasons for certain actions, results of previous attempts to effect change, and attitudes which have been conditioned by the physical, social and cultural environment or by tradition. The views of prospective project participants must be sought and considered, and the participants given on opportunity to contribute to project design.

Familiarity and Closeness of Implementors with Project Events

Project staff must be familiar with all aspects of the project and must be equipped to implement the project. Because all technical and social factors and their interactions may not be known at the project design stage, there may be a need to adjust the design of the project to meet the objectives. This must be allowed after suitable consultations.

Some of the more important factors which are necessary to ensure this relationship are:

(i) knowledgeable and socially aware managers and agents;

(ii) agents and extension officers must clearly understand the project objectives and the role the extension officer has to play;

(iii) early appointment and continuity of staff;

(iv) effective line of communication which must not be too long;

(v) authority of managers to adjust or even redesign in light of experience;

(vi) suitable extension officer/participants ratio for effective servicing and monitoring;

(vii) ability to provide timely inputs in accordance with agreement;

(viii) proper monitoring to ensure that project design is being adequately implemented;

(ix) evaluation at important stages to show that the project has met policy, audit, and economic targets and legislative criteria, and to apply the lessons learnt to other projects;

(x) project must be located close to participants i.e. in their locality;

(xi) involvement of local people in service delivery and in bringing about changes in attitudes.

The organizations which can be involved are voluntary associations, cooperatives, traditional associations, women's groups, churches and other similar organizations. It is important to consider membership composition, leadership, meeting procedures, and the influence of such organizations when deciding on the role that they should play in project implementation. The leadership must be carefully chosen and therefore it is necessary to consider their social and economic background, the process by which they are selected, the terms of their office, the ways in which they are rewarded, and the process by which they can be replaced or removed. The important interest groups must be represented and attention must be paid to continuity or turnover in membership and the obligations of members. The frequency of meetings, procedures for calling meetings, methods of publicizing, regularity of attendance, the independence under which meetings are held and the influence and authority of those who attend are relevant considerations.

The aim of a successful soil conservation project is to have the behavioural changes which have been introduced by the project, institutionalized. When this occurs the specific project supports can be withdrawn or reduced to a minimum. Projects are frequently designed for three to five years. While this time period may be adequate for infrastructural development projects (e.g. construction of facilities or structures, training), longer periods (10-15 years) may be a more realistic period when behavioural change is a factor. It is often not feasible to sustain or fund a project for such long periods and therefore realistic and specific targets must be set for a project which falls within the 3-5 year period. It is critical that the required behavioural changes are clearly understood and institutionalized by both public sector and community organizations in order to ensure continuity after the project. Soil conservation projects are frequently substantially subsidized, thus reducing the potential for long-term behaviour change. The view that farmers who practise soil conservation must be assisted by grants becomes entrenched.

Measurement and Evaluation of Success

For the success of a project to be assessed it is necessary to have measurable criteria. Input and output parameters which measure behavioural change must be quantified. Success must not be measured in terms of the number of farmers who have adopted the proposed practice but the impact of the cost of adopting the techniques on the farmers' income and the improvement of his standard of living or quality of life. The number of people who have been targeted and who have benefited have to be assessed. Socio-economic assessment is considered in **Section 3.2**. However, it must be noted here that for a farmer, money is the bottom line, and for soil conservation practices to be sustained they must result in economic benefits.

Evaluation of Project Designers and Implementing Agencies

The role and performance of project designers, implementors and participants are all important to the success of a project. A poorly designed project or failure of participants to cooperate will cause a project to fail regardless of how good the other components are. The project designers, the funding agency, in addition to the implementing agency and participants must be evaluated. These evaluations will allow the identification of the basis for success and failure. It will avoid similar errors being repeated in other similar projects and prevent alienation of the community from participation in other projects. Conversely, successful projects, methods, or systems can redound to the benefit of other projects.

If a project is not to collapse after project funding and other supports are terminated, the organization's or recipient's implementation capacity must be improved or must be adequate. This must be assessed before the project is embarked on. It may be better to extend the project for a while longer if this would increase the chances of survival than terminate at the official termination date.

3.2 Socio-Economic Considerations

Analysis of economic efficiency or cost/benefit analysis must be carried out. Sometimes it is necessary to assess the economic efficiency of project alternatives. Lack of trained manpower and time often prevent the exploring of alternatives.

It is not always easy to obtain prices to assess cost/benefit. Some benefits may not be easily and accurately quantifiable. In addition, many distortions in the pricing system which are common in developing countries occur e.g. protective tariffs and quantitative restrictions of imports and exports; unrealistic exchange rates which undervalue or overvalue national currency; government controls over interest rates. These distorting factors can make appraisal of the social or economic benefits of a project based on actual prices both incomplete and inaccurate. If market forces operated freely in the presence of domestic and international competition, actual prices of all factors of production would give an accurate assessment.

Projects such as soil conservation which are socially profitable but which incur a loss on the basis of market prices may have to subsidized as a matter of public policy. The kinds of subsidies and methods of implementation can have adverse social impacts which must be avoided.

Farmers in developing countries seldom keep good records of their activities which are essential for any accurate economic analysis. More attention must be paid to proper record-keeping both by farmers and implementing agencies if the true economic impact of soil conservation is to be obtained.

3.3 Influence of Sociological Factors on Soil Conservation Projects in the Caribbean

The economic impact of the soil conservation projects implemented in several countries of the Caribbean have not been evaluated and the information to permit this evaluation has not been collected. The projects can therefore only be evaluated on the basis of the number of farmers who have adopted and implemented the technical recommendations. The implementation of the methods promoted by the projects has not been widespread and usually does not reflect the effort and expenditure. Most of the conservation projects did not achieve the objectives of adoption and sustainability by farmers. Several factors are responsible for this and many of them are common to projects which have been implemented in the Caribbean islands. The main factors are:

(i) Squatting and land tenure

Farmers who do not have title to their land or are squatting do not readily adopt soil conservation if it costs them time, money and labour. Preventing soil loss is not a priority since they do not own the land.

(ii) Small farm size

Many conservation practices are considered unacceptable because they reduce the already small land area for cropping e.g. drains, terraces, some types of contour barriers, trees.

(iii) Engineering structures

Conservation based on engineering structure are often too costly and technically difficult for resource poor small farmers who comprise the majority of farmers on hillsides.

(iv) Educational level and trainability

The farmers on hillsides often lack formal education and therefore the training programmes must take this into consideration. The farmers cannot be expected to quickly absorb technically complicated measures, unless they are correctly presented.

(v) Top-down rather than botton-up approach

The system of instructing farmers to adopt methods which are assessed by the technicians to be good for them, has not led to successful adoption. This approach does not always consider the needs, limitations and social context of the farmer. The bottom-up approach which involves the participants and relevant members of the community at the planning and implementation stage overcomes many of the difficulties.

(vi) On-farm demonstration rather than demonstration on Government stations

Demonstrations on Government stations in particular have not proved to be a successful method of transferring soil conservation technology. Farmers generally feel that they do not have the resources of the Government stations to implement the measures.

(vii) Labour availability and cost

The various farm activities compete with soil conservation for labour. Soil conservation does not take precedence when labour is scarce and/or expensive.

(viii) Economic benefits

Farmers are more motivated to adopt soil conservation for economic reasons than altruistic reasons like saving the soil for posterity. Some soil conservation methods e.g. bench terraces, often result in yield declines in the early years especially when the subsoil is exposed during construction.

(ix) Subsidies and dependency

Financial support provided for soil conservation leads to the farmers ceasing to practice soil conservation when the subsidy is terminated. They come to accept soil conservation as a measure which must be financed in total or in part by the Government. Some assistance seems to be necessary but the type of subsidy and method of administration are critical if it is not to be abused or to be ineffective.

(x) Poor project management

Early appointment of staff, fully trained staff with full awareness of objectives, staff continuity, timely inputs, available markets for the crops recommended have influenced the successful implementation of the projects.

(xi) Role of extension officers and agents

They must know and understand their roles and use the most effective methods for disseminating information and transferring technology. The perception that the messengers are not competent, reliable or sincere impacts negatively on the participants and reduces the chances of successful implementation. These factors have played important roles in limiting the success of the implementation of soil conservation and must be considered in future projects or programmes.

CHAPTER 4

LAND TENURE AND SOIL CONSERVATION

4.1 Legal Tenure

A distinctive feature of agricultural land tenure in the Caribbean is the large number of small holdings which occupy a disproportionately small area or percentage of agricultural land. A high percentage of the land is not owner occupied. The data for Grenada, St. Vincent and St. Kitts presented in **Table 4.1** are typical.

Lack of secure tenure by the large majority of farmers restricts the effective functioning of both the land market and the incentive for long term investments in land and agriculture. In St. Lucia a major limitations is **"family land"** which is jointly claimed by members of an extended family, sometimes more than 50, who have undivided rights to cultivate or otherwise occupy a portion of the family's land. The actual cultivator of the land is therefore without incentive to invest in the land or to use it as collateral. Many of the very small farmers have short term rented land and would like to lease or own to be able to access credit and increase investment. Farmers with short term insecure tenure do not grow tree crops and cannot readily be persuaded to do so. In St. Kitts more than 90% of the land is Government owned and only recently has it been persuaded to offer longer leases (35 years) to induce a long term view of agriculture.

In Antigua, the production from small farms is declining. Medium and some large scale entrepreneurial farmers are developing a wide variety of enterprises for the local and export niche market using improved technologies. Enterprises include meat production, melon, pineapple, pawpaw (payaya), good quality vegetables (especially onions) under appropriate irrigation. The Agricultural Development Corporation, a Government organization with a production remit, is producing pineapples, food crops, vegetables and fruits. The future of agriculture in Antigua will be determined by these groups unless Government increases security of tenure to small farmers and assist with timely

TABLE 4.1: Farm size distribution and type of tenure in Grenada, St. Kitts and St. Vincent

Grenada

(a) Farm Size Distribution

Size of farms (ha)	No. of farms	% of farms	% of land area	Area of agric. land (ha)
< 2	7218	88	31	2411
2-20	902	11	36	2800
> 20	82	1	32	2489

49% of farms were < 0.5 ha

(b) Tenure

Owner	37	2878
Owner/Renter combination	22	1711
Renter	6	467
Manager	22	1711
Family owned	11	855
Share cropped	1	78
Landless	0.7	54

St. Kitts

(a) Farm Size Distribution

Size of farms (ha)	No. of farms	% of farms
0.04 - 1.2	3000	92
1.2 - 10	220	7
>10	32	1

Cont'd

TABLE 4.1 - Cont'd

(b) Tenure

	% of farms
Owner	36.4
* Operated free	38.5
Renter/short lease	23.5
Share cropped	1.6

* as part of old estate arrangements

St. Vincent

(a) Farm Size Distribution

Size of farms (ha)	No. of farms	% of farms	% of land area	Area of agric. land (ha)
< 1.0	4888	72	15	1783
1.0- 2.0	974	14	11	1288
2.0-10.0	852	12.5	22	2612
10.0-20.0	35	0.5	4	480
> 20	50	0.7	49	5860
(b) Tenure				
Owner	4763	72	68	8124
Renter	1094	17	9	1084
Squatter	298	5	3	319
More than one form	465	7	20	2427

inputs e.g. fertilizers, water, storage, transport, marketing and technical assistance. The advantage of this trend towards larger scale production, however, is that soil conservation would be easier to implement.

The State is a major land holder (Crown Lands) in many Caribbean countries. In the extreme case of St. Kitts, the State owns as much as 90% of the land. This facilitates the protection of land as forest reserves or protected areas for water production, national parks and other activities in the public interest. In all States, the Crown has the legal right to acquire lands for public purposes. The legal right is generally prescribed in The Land Acquisition Act. Unoccupied lands may also be vested in the Crown e.g. under the Crown Lands Ordinance of St. Lucia or Crown Lands (Vesting and Disposal) Act of Barbados. However, in some islands the records of ownership and title to land are not always current and easily available. In this situation the ownership of some land is not always known or is in dispute and the exact amount of land owned by the State is not always known.

Most States have made efforts to protect small agricultural holdings by legal instruments enshrined in the Agricultural Small Holdings Act (St. Kitts/Nevis), Agricultural Small Tenancies Act (St. Lucia, St. Vincent), Security of Tenure of Small Holdings Act (Barbados), Agricultural Small Tenancies Ordinance (Grenada, Dominica).

In several islands e.g. Dominica, Grenada, St. Lucia, Governments have been purchasing estates for distribution to farmers or distributing Crown Land in land settlement or rural development schemes. Although farmers are required by legislation to practise soil conservation, this is not enforced and there is often insufficient or inadequate agricultural extension and technical support to ensure or enforce good soil management.

It seems therefore that insecure tenure is a major deterrent to farmers practising soil conservation on small holdings. Most of the farmers on these lands are not interested in soil conservation *per se* and in protecting the land which they do not own. Small farmers do not adopt soil conservation practices which they perceive to be using their limited available space and to be competing for scarce resources (e.g. labour) without bringing a cash return.

Therefore, a small farmer on steep land which he does not own is a threat to soil erosions, on his plot and downslope.

4.2 Squatting

Squatting is a growing problem in the Caribbean. It is being accelerated by the declining economies and rising unemployment. Squatting takes place largely on State-owned lands, large estates or lands with absentee owners. Squatters commonly occupy land at high elevation and on steep slopes and use the land for housing and agriculture. Because of the lack of permanence in the tenancy, there is no incentive to practise soil management which would conserve the soil against erosion. There is slash and burn activity and crops are planted in relation to market demand and not land capability. Forest fires and deforestation frequently occur from slash and burn agriculture and other activities of squatters.

The number of squatters and the area of land they occupy have not been determined but it is evident that there is substantial squatting in many of the islands. A recent media report of a speech by the Minister of Food Production of Trinidad and Tobago estimates the number of squatters in Trinidad and Tobago to be about 50,000 out of a total population of 1.2 million people. Interviews with technical staff in the Ministries of Agriculture and Departments of Forestry indicate that squatting is a serious problem. There are many squatters' settlements with poor or no infrastructure and public amenities. Many of the squatters obtain their livelihood from farming.

Squatting is such a major problem in most territories that Governments seem to have little alternative to regularising major squatting areas and providing the basic infrastructure or to providing low-cost housing in identified residential developments. There is need for an associated legislation to prevent further spread of squatting and for adequate institutional arrangements for monitoring and implementing the system.

The problem of squatting has to be addressed in any land use planning to reduce the significant erosion which occurs on squatters' holdings.

CHAPTER 5

INSTITUTIONAL AND LEGISLATIVE FACTORS IN SOIL CONSERVATION

The major activities and problems arising in the watersheds of the Caribbean relate to forestry, agriculture, tourism and settlements. Water production and the protection of water sources, deforestation, soil erosion, flooding, pollution from agricultural chemicals and sewerage disposal are the major concerns. Watersheds therefore have to be managed to protect against the kind of use which would create or exacerbate these problems.

There are five elements which are critical to the management and protection of watersheds in the Caribbean.

- Policy and management planning;
- Political will;
- Institutional arrangements;
- Supporting legal instruments;
- Technical, financial and other supports for implementation.

This section is concerned mainly with reviewing the institutional and legal arrangements for facilitating or promoting the adoption of soil conservation and minimizing soil erosion and the pollution of water sources by agricultural activities in the watershed. It is concerned with forestry management as it relates to agroforestry, soil management, and the protection of water intakes against pollution. The reports of the consultants on land use and watershed management, and on legislation, to the Food and Agricultural Organisation/Tropical Forestry Action Programme (FAO/TFAP) were important sources of information for this chapter.

5.1 Policy and Management Planning

5.1.1 Policy

Caribbean Governments have explicit or implicit policies of watershed protection. The policy translates into sectoral policies with implications to watershed management or into prescriptions against several kinds of activities in the watershed which can damage the watershed or cause environmental degradation. There is, however, a need for more clearly articulated policies on watershed management.

5.1.2 Management Planning

Planning and management of land use and watershed development are *ad hoc* and generally ineffective. There are no comprehensive land use plans nor land zoning. Countries have periodically prepared National Development Plans, and Sectoral Plans. Some have also prepared (Trinidad and Tobago), or have in preparation (St. Vincent), National Physical Development Plans which have not been approved by Parliament and implemented. Land use planning and land zoning have not been addressed in a comprehensive manner.

Urban development, water and sewerage development, and forestry development are regulated, and approval is required before activities are undertaken. Agricultural development is not regulated and activities can be undertaken without approval. In fact, statutory regulations deliberately exclude agricultural lands from Town and Country Planning control and seek to encourage agricultural expansion.

In the Caribbean, a lack of an integrated system of planning, lack of legislation to control development, and lack of capacity to monitor development and enforce compliance are important deficiencies in land use planning. In St. Lucia, proposals for development are required to be sent to the Central Planning Unit (CPU), where they are dealt with by the Physical Planning Section. However the great majority of development plans are never sent or decisions are largely decided in the political arena. Physical planners make recommendations to the Development Control Authority (DCA), but these are made on an *ad hoc* basis and there is limited contribution by Public Health, Fire Department, Ministry of Agriculture (MOA) in the case of agricultural development, and Water and Sewerage Authority (WASA). Because of the absence of a land use plan and no effective land zoning, agricultural land can be subdivided for housing without reference to MOA. Housing expansion increases water runoff, and in the absence of proper provision for drainage can increase flooding and soil erosion. There is need for a fully integrated group within the CPU to plan future land use taking into consideration, economic, sociological and environmental/ecological considerations.

In Barbados, Town and Country Planning Department approves proposals based on certain guidelines. They would seek advice where necessary from other departments with interest in land use or the environment e.g. Agriculture, Water Authority, Health, Works. The advice is based on *ad hoc* views of appropriate land use. There exists a pragmatic approach to zoning without a comprehensive plan.

In Dominica, like so many of the islands there is a lack of a coherent national land use policy and plan but planning permission is required (subject to exemptions made by the Minister) for any land development, excluding the use for agricultural purposes. This has led to unsuitable areas being farmed while more suitable lands are under utilized. Zoning restriction for various forms of agricultural land development need to be considered by Government. In St. Kitts a multiplicity of statutes relate to land use and the Town and Country Planning Act seems not to be implemented.

In St. Vincent and the Grenadines there is Physical Planning and Development Board which includes as *ex officio* members, the Chief Technical Officers concerned with the most important resource sectors. The Board has all the usual powers e.g. planning, land acquisition, development permission; may issue tree preservation orders, prohibit destruction of trees, forests and woodlands. A novel provision is the power to require environmental impact assessment. The Board was established by Act of Parliament in 1976 (The Town and Country Planning Act 1976) but this Act was repealed by The Town and Country Planning Act of 1992.

Land Use planning suffers from two types of problems:

(i) Firstly, there is an institutional need to replace the existing government agencies which have limited or overlapping jurisdiction with an appropriately constituted land use body.

(ii) Secondly, there has been a failure to integrate physical, sociological and economic factors in the planning process.

These shortcomings need to be addressed and sufficient resources provided for the execution of the mandates from the political directorate.

Policy and management planning must also address a range of constraints which affect the practice of soil conservation. These include:

Attitudinal constraints: farmers' reluctance to change, to adopt agroforestry which involves the use of trees on small farms.

Structural constraints: prevailing systems of land tenure, endemic political patronage, and institutionalised avoidance of enforcement of laws.

Squatting on Crown Lands: compromised by a political culture which ignores violation. Squatting is a serious problem in the Caribbean as indicated in **Section 4.2**. A policy and management plan to address present and future squatting are required.

Low priority to the forestry sector: inferred from the modest budgetary allocations for forestry management and development. There is need to emphasise the important intangible values of forest cultivation and the role of forest management in soil conservation.

Uncontrolled grazing: resulting in serious denudation of vegetation in the dry season and erosion in the wet season.

Lack of trained human resources: hampering management and law enforcement.

5.2 Institutional and Legislative Arrangements

5.2.1 Major Institutions

Appropriate institutional arrangements and legislative instruments are required for the successful adoption and implementation of soil conservation. Planning, management, provision of infrastructure, and technical support to farmers are all necessary functions which require appropriate, properly structured and functioning institutions. There must also be legal instruments to give authority to the institutions to carry out their functions and to enforce compliance. Soil erosion and conservation are important factors in watershed management and protection and in the Caribbean there are many institutional structures and arrangements already pertaining to watershed management and protection. This can be a problem if the institutional roles and jurisdiction to avoid overlap and conflicts are not clearly defined.

In the Caribbean, the Ministry of Agriculture (MOA) or Department of Agriculture is the major institution responsible for soil conservation in both public and private agricultural lands. In many States, a Department of Forestry or a Forestry Unit is located in the MOA and takes responsibility for addressing soil erosion in forested lands. The ultimate responsibilities are with the Chief Agricultural Officer (CAO) or Chief Forestry Officer (CFO) who assign specific responsibilities to the appropriate units or officers. The units are named and structured differently in the MOA in the various territories e.g. Field Engineering Division (Trinidad and Tobago), or the Land and Water Use Unit of the Agricultural Engineering Services Division of the MOA (St. Lucia), or the Land Use Unit (Grenada). In some of the territories, a unit in the MOA dedicated to soil conservation does not exist but an agricultural engineer or agronomist is assigned the responsibility. All agricultural extension officers are expected to have some knowledge of soil conservation measures to be able to advise farmers. In the event of special internationally funded projects a specific project team is established.

Forestry Departments only occasionally have active programmes in soil conservation although conservation of soil is specifically stated as one of the reasons for declaring forest reserves. However, the preservation of forests, reafforestation and action against deforestation have always been important features of their work programme, which have contributed to the reduction of soil erosion.

Because soil erosion can affect water intake zones, surface water reservoirs and the quality of water supply, the institutions which regulate water resources development are concerned with soil conservation. In all the Caribbean islands there are functioning Water and Sewerage Authorities (WASA). They have broad powers for water conservation and protection of water gathering grounds. Generally, WASA have full power and authority over all public waters, to conserve, augment, allocate, distribute or redistribute, and monitor water resources. Catchment areas are required to be retained as forest reserves and imposes on the CFO the responsibility for their protection, conservation and maintenance. In St. Lucia, WASA power is limited to requesting the CFO to protect any water gathering grounds threatened by deforestation and since the CFO powers are restricted to the small area of Crown Lands the effect is insignificant.

The MOA through its CAO or CFO is generally represented on the Board of WASA and this representation should be used more positively to:

(i) foster interrelationships with other sectors e.g. Works, Drainage, Health which are also represented on the Board;

(ii) promote programmes for soil conservation awareness, adoption and enforcement.

WASA should use their authority and power and the importance of water to the nation to enforce proper soil management and the protection of the soil against erosion.

The institutional arrangements cannot always be separated from the legislation and these are considered in some detail at Appendix A. The institutional arrangements for soil conservation in Barbados is of particular interest and is discussed.

Legislation and Related Institutional Arrangements

The separate administration of the Caribbean in colonial times and post independence has led to the development of non-unified legislation. This has usually been developed in the context of the particular economic, social and political environment. A substantial amount of legislation that relates to activities in the watershed which affect soil erosion and conservation has been enacted decades ago and has not been amended or repealed to reflect the changes which have occurred. There are also institutional deficiencies. Consequently, some of the legislation is outdated, ignored and generally unenforceable due to inadequate technical personnel for monitoring and enforcing compliance, and sometimes lack of political will. Sometimes, the institutional roles and jurisdictional competencies are not clearly defined in several resource management areas e.g. development control and planning approval; allocation and use of public lands; conservation and protection of watersheds and water supply; pollution control and the maintenance of water quality.

In addition to legislation which directly pertains to agriculture, there are numerous Acts pertaining to town and country planning, forestry, water and sewerage (the aspects dealing with management of water runoff, storage and quality) and Crown Lands protection, are relevant to soil conservation. All territories have a Town and Country Planning Act, a Water and Sewerage Act and many have a Crown Lands Ordinance.

The Town and Country Planning Act is intended to ensure the orderly development of the towns in particular, and generally excludes jurisdiction over agricultural lands. The Act does not specifically address land use planning. The Water and Sewerage Act aims at protecting water resources through forestry protection and the prevention of inappropriate land use in water intake zones. This legislation should be extended to enforce the proper use of land in the watershed. The Crown Lands Ordinance protects these lands against misuse and often includes the rights of land acquisition for the Crown or of declaring forest reserves.

Although there are many Acts which, if enforced, can contribute to soil conservation, there are relatively few which focus specifically on soil conservation. Three of the more significant ones are:

Soil Conservation (Scotland District) Act (Barbados);

Barbados Agricultural Development Corporation Act (Barbados);

Forest, Soil and Water Conservation Act (Grenada).

These and the other pertinent legislation are presented in Appendix A.

APPENDIX

Key Articles of Legislation

APPENDIX

The key articles of legislation which have relevance to soil conservation are presented below for several Caribbean countries.

ANTIGUA AND BARBUDA

Forestry Act (1941) focuses on the prevention of deforestation and encouragement of reforestation. It requires that a permit be obtained from the CFO to clear land for cultivation, pasturage or other purpose, or to cut, lop or fell any timber or burn any wood or charcoal within the forest reserve. It empowers the Governor General to declare any estate or part thereof to be under the operation of a reforestation scheme, or to make regulations for the management and control of activities in the forest reserves. Provision is also made for compensation to estate owners carrying out afforestation schemes.

Land Development and Control Act (1977) provides for the orderly and progressive development of land in urban and rural areas and the preservation and improvement of the amenities of such areas. It requires permission to develop any land but expressly removes the development of land for agricultural purposes.

Antigua Agricultural Development Corporation Act (1978) establishes the corporation whose functions are to stimulate, facilitate and undertake the development of agriculture in the State; to develop and manage, on a commercial basis, such plantations and other agricultural land as may from time to time be vested in it; and to administer such agricultural development schemes. It defines agriculture to include forestry, but it does not specify the requirement for good husbandry and soil management.

Agricultural Small Holdings Act requires tenants of small holdings to practise good husbandry.

The Crown Lands (Regulation) Act (1917) entitles the competent authority to establish conditions for the lease of State lands. This can therefore be structured to accommodate the objectives of good land management and management policy.

Draft Forestry and Wildlife Act if enacted into law it will supersede the existing Forestry Act (1941). It provides, *inter alia,* for the conservation, management and development of forests; protection of water reserves and promotion of proper soil and forest conservation practices.

BARBADOS

In Barbados most of the soil conservation effort has been concentrated in the Scotland District. The Soil Conservation Unit (SCU) established in 1957 to control and reverse soil erosion problems in the Scotland District is perhaps the best institutional arrangement for soil conservation in the Caribbean. The programme is directed and monitored by the Scotland District Soil Conservation Board comprising the Deputy CAO (Chairman), Senior Agricultural Officer, Chief Technical Director, General Manager of the Water Authority, Chief Town Planner and four others nominated by the MOA to include representatives of the agricultural community. Functions include advising the CAO on land utilization to prevent soil erosion. The CAO after consultation with the Board may prepare conservation proposals. The legal authority for carrying out the work of the Unit was provided by the **Soil Conservation (Scotland District) Act (1958)** which gave wide powers to the CAO in consultation with the Soil Conservation Board. The 1991 Soil Conservation (Scotland District) Amendment Act now empowers Government through the Board to enter private lands for soil conservation, can charge the owners for work done and can restrict or dictate the use of the land. The SCU is managed by a soil conservation specialist and a deputy and they are supported by supervisory and field staff.

This institutional structure for soil conservation should be considered as a model for the Caribbean. It has the potential for integrating the inputs of relevant technical sectors and the farming community to achieve the multidisciplinary approach to soil conservation. A successful institutional arrangement requires that the executing or responsible agency be fully aware and that there is interaction between the relevant Government organizations, research and academic institutions and private interests. The Governments role would be management, public education, regulation and enforcement; research and academic centres would be concerned with data gathering, information processing and dissemination; and the public would voice demands and assist in implementation and awareness. These other aspects can be included in the Barbados model for greater effectiveness.

The Barbados Agricultural Development Corporation was established to facilitate and stimulate agricultural development and to develop and manage government plantations. It provides for soil conservation within the coral region (non-Scotland District) of Barbados by the establishment of grasslands and soil and water conservation works.

Specific focus on the environment is being initiated in some of the territories. In Barbados, an Environmental Unit is located in the Ministry of Labour, Consumer Affair and the Environment. Proposals have been made to create a Department of the Environment within the Ministry. It would rationalise the current diverse institutional framework for environmental management and formulate an Environmental Act.

The other legislative instruments which pertain to agriculture and can be used to support the soil conservation effort are:

- **Cultivation of Trees Act:** promotes and provides incentives for cultivation of approved trees;

- **Tree Preservation Act:** prohibits the cutting down of any tree of a defined size without approval;

- **Security of Tenure Small Holding Act:** provides for terms of tenure and reasonable security for the tenants of land 10 acres or less;

- **Cane Fires (Prevention) Act:** prohibits lighting of fires in conservation areas and the destruction or interference with trees, shrubs and plants in these areas;

- **Land Acquisition Act:** Crown Lands (Vesting and Disposal) Act - make provision in the public interest for compulsory acquisition, vesting in the Crown or disposal of land;

- **Livestock (Control of Strays) Act; Animal Act:** caters for the trespass of animals on land and damage to land.

DOMINICA

Forest Ordinance 1959, the original forest legislation, deals with the designation of forest reserves and the control over forest produce. It authorises the designation of private land as protected forests for water and soil conservation and other public purposes. The Forest Rules (1972) made under the Ordinance specify the actions that are prohibited in a forest reserve and give details for issuing licences and permits to harvest forest produce (including timber and charcoal) and for clearing and cultivation in a forest reserve. The Rules prohibit any exploitation of forest products, squatting, setting of fires, livestock grazing, land clearing and hunting in all Forest Reserves, unless a licence has been issued by the CFO.

Land Acquisition Ordinance gives the President the power to acquire any private land for a public purpose by making a declaration to that effect. A Board of Assessment will determine compensation if the sale price cannot be agreed.

Crown Lands Ordinance (1960) gives power to prevent trespassing and contains provision for the grant, sale, exchange, and lease of Crown Lands.

Water and Sewerage Act (1989) makes provision for a national policy for water and the granting of exclusive licence to the Dominica Water and Sewerage Company (DOWASCO) for the development and control of water supply and sewerage facilities. All existing gathering grounds shall either be retained as forest reserves or protected forests or be declared controlled areas. To protect gathering grounds from deforestation or animals DOWASCO may request the Ministry of Finance or Ministry of Health to take action, or restrain, impound or shoot such animals.

Town and Country Planning Act of 1975 is the substantive planning and development legislation. Subject to exemptions made by the Minister, planning permission is required for any land development, excluding the use for agricultural purposes. Zoning of land for various forms of agricultural development is needed. Currently, unsuitable areas are being farmed while more suitable lands are underutilized.

The Development and Planning Corporation Act of 1972 creates a corporation to be responsible for physical planning. It, however, does not meet and has delegated its functions to a small technical committee under the Planning Division of the Economic Development Unit, Ministry of Planning.

Dominica Land Management Authority Act of 1973: the primary purpose is to establish a Land Management Authority to promote agriculture and related activities. The Act is, however, not in use.

Agricultural Small Tenancies Ordinance of 1953 covers tenancies of cultivated and pasture land under 10 acres but more than 0.5 acres. It lists the several natural resource related conditions to which the tenant must agree e.g. good husbandry to include soil conservation, and fertility maintenance. The Ordinance is not apparently in use.

GRENADA

The Forest, Soil and Water Conservation Ordinance 1949 amended by **The Forest, Soil and Water Conservation (Amendment) Act (1984)** provides for watershed protection, permanent reservation of lands, designation of prohibited areas and procedures against squatting and illegal grazing. It provides for the declaration of lands other than State lands to be protected forest. The Act also provides for the appointment of a Chief Forestry Officer responsible for the management of all lands belonging to the State.

The forest policy which was followed until 1984, addressed issues relating to forest reservation, forest management, utilization, research, education, private forestry, forest industries and recreation. Forest reservation proposes permanent preservation of a tree crop cover on such areas of land as are required for the prevention of soil erosion and flooding, and the preservation of water supplies. It also proposes lands that are unsuitable for agriculture to be exploited for the economic production of timber crops.

The Land Development (Control) Act 1968 amended by **The Land Development Control (Amendment) Law of 1983** relates to the carrying out of building, engineering and mining or other operations on any land. It is broad enough to encompass silviculture but not agriculture. A draft agricultural land development policy which makes recommendation on a range of issues addressing the protection, use and development of agricultural land and land zoning, is under consideration by the Government. Approval of the policy is a necessary precursor to the formulation, approval and implementation of legislation for the development of agricultural lands.

The National Water and Sewerage Authority (NWASA) Act 1990 established NWASA with full power and authority over all waters. Section 38 requires catchment areas to be retained as forest reserves and imposes on the CFO the responsibility for their protection, conservation and maintenance.

The other relevant legislative instruments are:

- **Agricultural Fires Act:** requires a licence to set fires;

- **Agricultural Small Tenancies Ordinance:** defines the rules of good husbandry and observe the rules;

- **The Crown Lands Ordinance:** establishes the conditions for the alienation of State lands.

JAMAICA

The Watersheds Protection Act 1963 was enacted in 1963 to provide for the protection of watersheds and adjoining areas. It established a Watershed Protection Commission with power to acquire, hold and dispose of property and to do all things necessary for the purpose of the Act. It empowered the Commission to undertake watershed work. Between 1963 and 1974, areas to be treated and works to be undertaken had to be declared for approval by the Commission.

In 1974, the Natural Resources Conservation Division (NRCD) of the Ministry of Agriculture and Forestry was established and in June 1991 **"The Natural Resources Conservation Authority (NRCA) Act"** was enacted to amend the 1963 Act. In 1983 all 33 watersheds in Jamaica were made 'declared watersheds' so that work could proceed in all of them, and in 1985, NRCD was required to undertake purely investigation and monitoring. The investigation was to be carried out in conjunction with the Forestry Department which would undertake implementation.

The new Act of 1991 is wider and provides for Environmental Impact Assessment (EIA). There is also provision for increased penalties and stricter monitoring to control such activities as charcoal burning, mining of sand and marl, and logging. However, lack of staff for enforcement, deficiency in training, public awareness, and education are major shortcomings.

The Rural and Physical Planning Division (RPPD) of the Ministry of Agriculture is the custodian of agricultural lands and an important agency for ensuring appropriate land use. It undertakes land reform using the physical capability of the land as the main criteria. It updates the data base of land resource and provides data to many sources concerned with land use.

The Soil Conservation Department (SCD) was established in the Ministry of Agriculture in 1973 under the 7 year FAO project entitled **"Forestry Development and Watershed Management in the Upland Regions"** which began in 1968 (FAO, 1990). In 1980, the SCD was amalgamated with Forestry as the Forestry and Soil Conservation Department.

Land Authorities (LA) are also important institutional arrangements for carrying out soil conservation. They have conducted soil conservation on public and private lands in collaboration with SCD (FAO, 1983).

ST. KITTS

The National Conservation and Environmental Protection Act (NCEPA) 1987 is the centre piece of federal legislative regulation of forestry matters and provides for the establishment of protected areas e.g. national parks, nature reserves, marine reserves, botanic gardens, historic and scenic sites. It deals particularly with Forestry, Soil and Water Conservation in six sections and, in this regard, it:

- prohibits cutting and felling of timber without the consent of the Director of Agriculture;

- confers power on the Minister in consultation with the National Conservation Commission (NCC) to make regulations for

    - establishment of forest reserves and the prohibition of the grazing of livestock in such reserves;

    - national exploitation of forest resources;

    - conservation of threatened species of flora;

    - promotion of reforestation;

    - regulation of charcoal burning;

    - procedures and exemptions in regard to felling or cutting of timber.

NCEPA mandates the Minister of Development in consultation with the NCC to "*provide regulations for soil conservation including the identification and* *protection of critical watershed areas and natural drainage systems and the encouragement of scientific farming techniques by means of physical and biological soil conservation designed to prevent soil erosion".*

All ghauts (natural drainage channels) declared a protected area are "*to be managed in the public interest as stable and production natural drainage*", with ancillary power of the Minister, in consultation with the NCC, to make regulations requiring "*special land use rehabilitation, management and conservation measures*".

NCEPA directly prohibits without requiring the making of regulations, unauthorized cultivation, cutting, burning or clearing of land or vegetation, grazing of livestock, construction of structures, removal of sand in any area of special concern.

With regard to water resources, NCEPA requires the Minister in consultation with the NCC and the Water Boards to make regulations to conserve and develop the nation's water resources or reduce soil erosion and thereby meet the present and future water needs for domestic, agricultural, commercial, industrial and other beneficial uses. It provides for the donation or exchange of land of an owner for designation as a protected area, and for the prohibition of unauthorized wilful damage to any tree, shrub or grass planted or laid out. Finally, NCEPA prohibits the unauthorized deposit of waste, rubbish or litter in a protected area or forest reserve.

The extensive regulation-making powers of NCEPA are yet to be exercised except in relation to the Brimstone Hill Fortress National Park Regulations 1991. Regulations to supply the detailed prescriptions of the Act have not been enacted. This Act has the promise of becoming a model for the other Caribbean States.

A major omission of the NCEPA is the failure to grant permission to enter estate owner's land to execute required works without the owner's consent. There is also no tax waiver on land being reforested. These provisions were included in the Forestry Ordinance of 1904 which was repealed by the NCEPA.

The multiplicity of other legislative instruments in St. Kitts relate to land tenure, land use, and agricultural development. These instruments can be summarised as follows:

Land Tenure

- The Limitation Act - provides for a time limit for acquiring possessory title to land;
- The Prescription Act - provides for a time period for the acquisition of easements of water or watercourse or use of water;
- The Land Acquisition Act - provides for compulsory acquisition of land by the Crown;
- The Title by Registration Act.

Land Use

Some of the relevant legislation include **NCEPA**, **The Town and Country Planning Act, The Agricultural Development Act, The Land Development (Control) Act, The Building Act, The Planting of Sugar Canes Prohibition Act, The Frigate Bay Development Corporation Act, The SouthEast Peninsula Land Development and Conservation Act.**

Agricultural Development

The dominance and history of agriculture in the economy of St. Kitts is evidenced by much statutory regulation of agriculture. There are at least 12 Acts which deal with agricultural activity but none of the Acts addresses soil conservation specifically. There is need to revise the multiplicity of statutes in order to eliminate duplication and overlap of jurisdiction and to clarify the hierarchy of decision-making authority where duplication is unavoidable.

ST. LUCIA

The major relevant legislation relating to agricultural land management is as follows:

The Land Conservation and Improvement Act which empowers its Board to **inter alia** (1) advise the on matters relating to the general supervision of land and water resources; (2) advise the Development Control Authority and any other agency involved in land use on matters concerning land conservation and improvement and (3) offer, in conjunction with government agencies, **technical advise** in field and land management to land owners and/or occupiers.

The Agricultural Small Tenancy Act which is restricted to land not more than five acres in one or more parcels. This area of land could be controlled for proper soil and water conservation practices. The tenant is required to follow good husbandry practices defined generally to mean the application of measures for soil conservation, maintenance of soil fertility and the preservation of the capital value of the holding.

Forest, Soil and Water Conservation Ordinance: under this amendment act, there are possible incentives to encourage the allocation of private lands for protected forest. Compliance with the rules by owners of the protected forest entitles the owner to remission of any land tax that may exist and monetary compensation or compensation by exchange of land.

The Crown Land Act which authorises the Government to make rules and regulations concerning the sale, occupation and allocation of government lands. The Forestry Department has drawn up a policy for Crown lands, which was revised by the management of the CIDA Forestry Project and submitted to Cabinet.

The Town and Country Planning Act which is a broad policy instrument in terms of land development and does not specify the development of farm lands.

The Water and Sewerage Authority Act which is concerned with water conservation and protection of water gathering grounds. Under this new Act the Authority may request the Chief Forestry Officer to take action to protect any water gathering grounds that may appear seriously threatened by deforestation.

While the above policy instruments may have served as a useful means of achieving their stated objectives, they are only broad policy measures and are not specific to the utilization and management of agricultural lands. It is therefore evident that a policy on agricultural and management is of utmost importance.

An Act entitled "**Land Conservation and Improvement Act,** 1987" to provide for land conservation and the establishment of a Land Conservation Board was placed before Parliament as a Bill but has not been passed as yet. It is believed that the political implications of the Act and the proposals for formulating and implementing Protection Orders may be obstacles. The proposed Act is fairly comprehensive and would provide for proper land use and the protection against soil erosion and other forms of land degradation.

ST. VINCENT AND THE GRENADINES

Ring's Hill Enclosure Act 1791 and **Land Acquisition Act 1947** both empower the competent authorities to acquire land for public purpose subject to compensation.

The Agriculture Act 1954 requires owners to practice good husbandry, which has been expressed to involve the terracing of steep land, soil conservation and preservation of vegetative cover and forests on slopes and ridges. The Act authorizes the CAO to take over the supervision of agricultural land whenever the owner/occupier is not perceived to be practising good husbandry.

The Agricultural Small Tenancies Act 1957 regulates tenancies of 10 acres and less and requires tenants to practise good husbandry in order to maintain the capital value of the land through employment of protective and conservationist practices. This Act and the previous one, if properly employed, can become important policy instruments for good soil management.

Central Water and Sewerage Authority (CWSA) Act 1978 vests every body of water in the Government to be held in trust for its citizens and confers control on the Authority. The Act identifies various functions of the Authority, some with implications for activities in the forestry sector and for protection of the water resources. It empowers the Authority to purchase by private treaty or to acquire compulsorily any land or interest in land, or other property in accordance with the provisions of the Land Acquisition Act. Private forests can be acquired for watershed management or water resources conservation.

Crown Lands Act and Regulations 1983 pertain to the declaration, reservation and protection of Crown Lands.

Forestry Resource Conservation Act 1992 makes provision for the establishment of a Forestry Department headed by a Director with specified functions which relate to the conservation, management and development of forestry. It clearly requires the Director to promote agroforestry in agriculture and proper soil and water conservation practices, and to prepare at intervals not exceeding ten years a national forest resources conservation plan. The Act declares certain areas forest reserves and empowers the competent Minister to declare other areas forest reserves for the sustained production of timber and water, the conservation of soils and the preservation of flora and fauna. The Minister is accorded power to regulate or prohibit the use of chemical or organic compounds used for agriculture; to control soil erosion and sedimentation; to establish standards and land classification systems to guide land use in erosion-prone areas; to manage and protect water resources, watersheds, streams and rivers.

The Town and Country Planning Act 1992 repeals **The Town and Country Planning Act 1976** and is designed to enable the orderly and progressive development of land, the proper planning of town and country areas, and the control of development including change of land use. The Act establishes the Physical Planning and Development Board. The Board may prohibit the destruction of trees, forests and woodlands and has the power to require the submission of environmental impact assessments.

Implementation of Legislation

It is evident that all territories have adequate legislation and institutional arrangements which provide the policy framework for regulating soil conservation and other aspects of soil management. The deficiencies, limitations and constraints to the implementation of legislation are:

(i) multiplicity of legislation with overlapping jurisdiction and no clear hierarchy of authority;
(ii) failure to develop regulations to give effect to the legislation;
(iii) inadequate penalties for breaches of the legislation which do not deter violation;
(iv) lack of political will to implement because of political expediency;
(v) failure to provide adequate budgetary allocations to support implementation;
(vi) inadequate technically trained staff to monitor and enforce compliance with the legislation;
(vii) inadequate and insufficient educational programmes and public awareness activities;
(viii) lack of incentives to farmers to encourage compliance;
(ix) need for technical assistance to farmers in tree crop cultivation, soil conservation and other soil management techniques, crop production and marketing.

Existing legislation can address a range of activities which influence soil conservation e.g. illegal fires, forest preservation, squatting, uncontrolled grazing, poor crop husbandry practices. The legislative framework exists. However, the implementation of the legislation, management planning, and soil conservation technology appropriate for the Caribbean are required for successful soil conservation. Appropriate soil conservation technology and the methods of implementation are presented in Volume II.

VOLUME II

Farming Systems Approach and Methodologies

INTRODUCTION

The soil erosion status in the Caribbean, and the sociological, institutional and legislative factors which influence soil conservation were considered in Volume I.

Volume II deals with the practical measures or methodologies for integrating soil conservation into farming systems in the agricultural context of the Caribbean. It therefore considers the requirements for successful adoption and implementation of the farming systems approach, and the physical data which are required for making decisions on the actions to be taken. It is with regard to the later that the information to be collected in baseline surveys, and land capability and land use are considered.

The methodologies emphasise the agronomic or biological approach. They focus on methods that are within the capability of small farmers. Gullies are common features of farmlands in the Caribbean and these are therefore considered even though the control of the large gullies is often beyond the capability of the small farmer. Most farmers clear the land at one time or the other and therefore it is important for them to be aware of the most appropriate methods of land clearing.

Volume II examines existing systems of soil conservation which are integrated into farming systems but does not examine proposed models. The Hillside Agricultural Project in Jamaica is also discussed as a practical example of an attempt to integrate soil conservation into farming systems based on a tree crop system of farming. Some of the shortcomings of this effort are also considered. Finally in the Appendices it presents Case Study Exercises for the student of soil conservation to work through using the principles considered in the book.

CHAPTER 6

FARMING SYSTEMS APPROACH TO SOIL CONSERVATION

6.1 Farming systems: Requirements for successful adoption and implementation

A farming system can be defined as a reasonably stable arrangement of farming enterprises that are managed according to well defined practices in response to the physical, biological and socio-economic environments and in accordance with defined goals, preferences and resources. The integration of soil conservation into the farming systems therefore means that soil conservation methods must be sustainable in the physical, biological and socio-economic environments.

Clearly visible techniques like terraces and contour drains have become synonymous with soil conservation but there are many agronomic practices which are not generally associated with soil conservation but which reduce soil erosion or can be used to enhance soil conservation. The farmer, however has to take a conscious, deliberate and organized approach to ensure that soil conservation is one of the objectives of the farming system. With this approach, the farmer may not be required to make radical changes to his practices or significantly increase his inputs but may benefit from increased production.

6.1.1 Farming systems research and extension

Appropriate farming systems can be developed or improved and successfully adopted by farmers through the Farming Systems Research and Extension (FSR/E) methodology. FSR/E is an applied farmer oriented, agro-biological approach to research informed by socio-economic considerations in a team effort that includes extension responsibilities. It is an approach to generating, evaluating and delivering technology which is appropriate to the social and economic environment. If the technology is not to be rejected, changes must not be drastic and the profitability of the farm, which is a business, must not be decreased by the new technology.

To minimize the chance of rejection, the farmer must participate from the planning through to the implementation, evaluation and recommendation stages. The FSR/E approach can be used to select or develop the most appropriate soil conservation techniques to fit into the farming system with or without modifying the farming systems and to get farmers to adopt the systems. The emphasis here is on adoption and continuity.

Four stages are required for the FSR/E methodology and for the successful integration of soil conservation into farming systems. These are:

Diagnostic
Planning and Design
Implementation
Evaluation and Recommendation

Diagnostic Stage

Existing farming systems, soil conservation practices and the biological, physical and socio-economic environment are characterized and analysed. The information is obtained in two steps. The first is the review of existing literature of all pertinent information. The second is to carry out surveys which can be through formal, informal, quantitative or qualitative data collection procedures. Formalized and quantitative surveys for data collection can take time and be costly. However, recent trends are towards informal methods with complementary and focused formal surveys to verify informal results or to explore some particular aspect in greater detail. A popular method of collecting information quickly and cheaply is the *Sondeo* method which was originally formulated at the Institute of Agricultural Science and Technology (ICTA) in Guatemala by Hidlebrand 1981 (cited by Dolly and Young 1991). In this process information on the major constraints and problems limiting the productivity of a defined agricultural system is obtained and analysed. A rapid reconnaissance survey or appraisal of the farming system is conducted among representative farmers in a specific area within the system to obtain the relevant information. The information obtained by this method is later verified and strengthened by conducting a Baseline Survey which is a more formalized method of data collection. Diagnosis does not take place only at the beginning of the programme but is a continuous process and the information can be used to make modifications. An important element of this stage is consultation and involvement of farmers who need to be an integral part of the process.

Planning and Design Stage

In this stage, the information gathered during the diagnostic stage is analysed and farmers are actively involved in design. Problems are identified and prioritized and appropriate farming and soil conservation systems designed or soil conservation systems adapted to fit into the existing or modified farming systems. The appropriate expertise required to design and implement the systems must be put in place or consulted as necessary. The plan must be developed and finalised in consultation with the farmers. Provision must be made to monitor or to test the systems to be implemented.

Implementation Stage

All inputs required for the programme must be identified and made available on a timely basis, in accordance with the implementation plan. Staff must be fully aware of all aspects of their job and fully trained. If the programme involves testing or formulating of technologies, experiments are established in farmers' fields under farmers' conditions which are appropriate and therefore adaptable by farmers. The design of these experiments should be simple so that farmers will be able to understand and manage them with less supervision during the verification and evaluation stages. In this stage, the normal farmers' practice must also be carried out as a control for comparison.

Evaluation and Recommendation Stage

In this stage, the results of the on-farm experiments or testing are assessed. The researchers and extensionists must discuss the results with farmers to obtain their opinion of the treatments. The results must also be subjected to both an agronomic evaluation and statistical analysis. This assessment of the results from the farmers point of view is most important and must be clear before decisions on the treatments to be recommended to farmers or to be tested further. If one or two treatments show greatest promise they can be further tested in farmer-managed trials referred to as *validation stage*. This gives the farmers themselves the opportunity to manage and evaluate the treatments.

After evaluation or validation, treatments can be recommended for dissemination by extensionists through suitable communication systems. The dissemination process only starts when farmers begin to accept or adopt the technologies and when they begin to pay the cost of inputs and accept the risks of the intervention.

6.2 Baseline surveys and farm planning

In planning any enterprise, including farm planning, it is absolutely necessary to have the required data. In farm planning, data will be required to evaluate the capability and suitability of land for the current and proposed use under the given set of physical, social and economic conditions. The relevant data can be obtained by baseline surveys. These surveys provide the physical, social and economic data for developing the farm plans and the associated soil conservation methods appropriate to farming system and the physical and social environment.

The database which would provide the information for planning would include the following:

6.2.1 *Physical data*

Geographic location and elevation. This is needed to be able to locate the land on a map and to assess the implications of the proposed activities to the surrounding areas.

6.2.2 *Climatic conditions*

The important climatic factors are temperature, rainfall, relative humidity and wind. In the Caribbean, rainfall and wind are frequently the more important factors. These four-climatic parameters would determine the crops that are most suitable for specific locations.

Temperature: Some crops perform better under cool conditions e.g. solanum potato in the Christiana area of Jamaica; while others perform poorly under the cool and humid conditions of the high elevations eg. banana, mango, papaya in the elevated Montreal area of St. Vincent.

Rainfall: Data on the amount, intensity and duration of rainfall are very useful for the development planning of the farm. It determines, whether annual crops can be grown without irrigation in the dry season and the need for soil conservation on sloping soils.

Relative Humidity: The quality of some crops (e.g. Blue Mountain coffee) is improved but the incidence of pests and diseases is increased by high humidity.

Wind: Wind causes damage to crops and animals during storms and hurricanes. The banana crop is particularly sensitive. In addition high winds increase evapotranspiration and irrigation requirement. The information would help in identifying the most appropriate location for crops and in determining the need for windbreaks.

Evapotranspiration: This factor when compared with rainfall distribution would indicate whether irrigation would be required and would provide an estimate of the timing and amounts of irrigation.

6.2.3 *Soils*

Soil type: The classification, texture, fertility status and other soil properties, and area of the soil types are important. They help us to infer the behaviour, capability and appropriate land use of the soils. They play a vital role in the design of suitable farming systems.

Topography and Slopes: The physiography or land form in the project area help in the design of the farm plans, the location of crops, the infrastructural needs and soil conservation methods. The land forms may include alluvial plains (flat areas), terraces at different elevations, undulating, rolling and steep areas and each may have different soil types. The classification of slopes qualitatively by terms such as flat, gentle slopes, moderately steep, steep and very steep, or quantitatively into per cent or degree of slopes, aid planning.

Erosion Hazard: A map showing eroded areas, the degree of erosion which has occurred and the potential erosion hazard helps to determine the soil conservation measures which will have to be instituted to reduce the risk of erosion and to enable sustainable use to be made of the land.

Hydrology and Drainage: The amount and location of surface and subsurface sources of water, the present use and availability for irrigation are useful data. The availability and distribution of pipe-bourne water are also important.

Drainage of the soil is affected principally by slope, texture and structure. Low lying areas with poor or imperfect external or internal drainage, can become flooded or waterlogged for prolonged periods. These areas should be known and included in the data collected so that proper drainage can be effected.

Present Land Use: The present land use provides the necessary background for future planning. It also gives an indication of the capability of the land, although in some cases farmers may be persisting in activities that are degrading the environment. Natural vegetation is particularly useful in indicating the fertility status of the soil and specific soil factors as pH, salinity and excess or deficiency of ion species.

6.2.4 *Infrastructure*

The accessibility to the farm and to market and social amenities are essential for efficient and successful farming and must be assessed or included in the development plans.

6.2.5 *Socio-economic data*

Social infrastructure: These include schools, hospital or clinic, post office, churches, community centres, and determine whether the farmer will live on farm or elsewhere.

Factories: The presence or absence or processing facilities will determine the corps to be grown and therefore the land use in relation to the capability of the land.

Labour Availability: It is very important to know if an adequate supply of quality labour is easily available. This would influence the systems that can be introduced in light of the competition for the available labour.

Capital Availability: The availability of funds from lending agencies (such as banks) at attractive interest rates frequently determine the success of agricultural enterprises or lift the level of farming above subsistence. This factor is as important, in modern farming, as land, labour and management. Information on capital availability and conditions of lending influence the choice of systems to be implemented.

Preference of Farmers: Farmers often show preference for certain commodities or activities even though they may not be the most economical or appropriate for the environment. They usually have good reasons for their choices and these must be determined and considered in preparing the farm plan.

Markets: Markets must be available for farmers to sell their produce if the venture is to succeed. Knowledge of market demand or studies to provide the information, and marketing arrangements are all essential to the planning process and the success of the farming enterprise.

Technical Services and Farm Supplies: Advice through the Extension Service should be easily available to the farmers particularly to those small farmers who lack technology know-how or the resources to purchase the services. Other technical support services e.g. equipment repair and tractor rental are also important. Farm supplies needed for running the business successfully must be available in adequate quantities for the community of farmers or steps must be taken to expand the supply.

After all the data are collected, they should be carefully analysed and evaluated so that the appropriate land use and farming systems suitable for the physical and socio-economic environment can be selected. Computer programmes have been developed which would allow soil properties to be matched against crop requirements to give suitability ratings. Jamaica has developed the Jamaica Physical Land Evaluation System (JAMPLES) computer programme for rating the suitability of soils for specific crops. However, to develop farming systems which include soil-conservation measures for a particular project areas, all the physical and socio-economic factors must be integrated and this requires a team of people with the appropriate expertise.

6.3 Land Capability and Land Use

6.3.1 *Land Capability*

The demand for land for the various uses (residential, industrial, commercial, recreational, agricultural and nature reserves) continues to rise and to put pressure on a finite resource. It is therefore essential to make the optimum use of the resource without causing it to deteriorate. Proper land use planning is critical. Soil and land use surveys provide the information which allows planners and decision makers to know the potential or capability of the land. The surveys involve an inventory of the soils and vegetative cover of the land. Soils are classified according to defined criteria and this classification is used to assist in the determination of land capability or suitability.

Different soil classification systems for agriculture have been developed and many are specific for some countries. Two international systems are now used widely or universally, the 1974 FAO/UNESCO soil map of the world, and the 1975 United States Department of Agriculture (USDA) "Soil Taxonomy". The latter is the twelveth "Approximation on Soil Classification" developed by the USDA over a number of years. In addition there are many national classification systems in use.

The current agricultural land capability system in the Caribbean is based mainly on degree of slope as the dominant factor and to a lesser extent on factors of erosion, drainage, rainfall and soil fertility. This system of land capability classification is based on the former system of the USDA in which the suitability of the land for mechanised agriculture is of prime importance. This system was adopted by the Regional Research Centre (RRC) of the Imperial College of Tropical Agriculture (later UWI) and the classification of soils for each territory was published in a series of Soil and Land Use Surveys between 1958 and 1974. The relevance of this system to the Caribbean is questionable because (a) complete mechanisation is not possible due to size of farm, topography and sometimes crop type; (b) manual cultivation is often the only practical and suitable form of land management on most of the hillsides. This historical system is still referred to in many reports and is therefore briefly outlined below. However, if farmers only cultivated slopes as recommended, production would be reduced considerably. Therefore a more pragmatic, treatment-oriented approach is recommended which links slope classes to the conservation treatments required to avoid erosion.

In the RRC system soils are classified into seven land use slope classes shown in **Table 6.3.1**. Based on these slope classes, the risk of soil erosion and difficulties of management, the soils have been classified into seven land capability classes which indicate the most intensive suitable use as shown in **Table 6.3.2**. In some cases an eighth class is added for the extremely steep land, beach sand and mangrove, characteristics which preclude their agricultural use.

A broad grouping of the land in this manner into seven land capability classes is useful for some purposes such as determining a country's available arable acreage. It is not, however, adequate for specific land management recommendations. Between the extreme generalisation into seven broad land classes and the extreme detail of the soil survey, certain intermedial groupings are necessary in order to compile land capability classification.

Slope class is in many cases the primary factor in determining land capability, but the need to align this assessment with the detailed soil survey requires further subdivision within each land capability class. Four principal limiting factors are considered significant in this respect and they are shown by a small letter following the land capability numeral: "e" if the principal limiting factor is slope and erosion risk; "w" if it is excess water in the soil, seasonally or otherwise, giving poor natural drainage; "s" if it is a soil factor implying usually shallow or droughty soil; and "c" for the climatic factors.

TABLE 6.3.1 Slope classes and gradients

Slope class	**Gradients**	
	Degree	Percent
A	0-20	0-3
B	2-5	3-9
C	5-10	9-18
D	10-20	18-36
E	20-30	36-58
F	Over 30	Over 58

Source: Soil and Land Use Surveys carried out by the Imperial College of Tropical Agriculture (1958-1974)

TABLE 6.3.2 Land Capabilities Class, Slope Limits and Recommended Land Use

Land capability class and slope limits	Most intensive suitable use
I Slope limits 0-5° A and B slopes of good soils	Suitable for cultivation with almost no limitations.
II Mainly C slopes of good soils, and level land of less favourable soils	Suitable for cultivation with moderate limitations.
III Mainly D slopes of good soils, and gentler slopes of less favourable soils	Suitable for cultivation with severe or strong limitations
IV Mainly E slopes, some D slopes	Marginal for cultivation due to erosion risk but suitable for tree crops, pasture and forest.
V Mainly E and F slopes	Unsuitable for cultivation, but suitable for planted forest, tree crops and pastures.
VI No slope limit but shallow soil over hard rock (includes all steep rock land)	Unsuitable for cultivation due to erosion risk but suitable for tree crops, pasture and forest.
VII Mainly F slopes of deeper soils; No slope limit of soils with rock outcrop; river wash.	Unsuitable for agriculture should be left in natural vegetation.

Source: Soil and Land Use Surveys carried out by the Imperial College of Tropical Agriculture (1958-1974)

6.3.2 *Land Suitability*

This term is now used more often and refers to the suitability of the land for specific use and provides more details than Land Capability, particularly in qualitative economic terms. The details of this system are provided in the FAO Framework For Land Evaluation (FAO 1976). The term land evaluation is sometimes loosely used but the FAO Framework For Land Evaluation is quite specific. It provides a standard set of principles and concepts on which evaluation systems can be constructed. It emphasizes the importance of explicitly stating the intended land use, the level of management and whether it is based on current or potential suitability of the land.

6.3.3 *Land use and soil erosion*

A first defence against soil erosion is to use the land within its capability and to use the soil conservation practices that are appropriate for the capability class. The returns to inputs, including soil conservation, decrease from Class II to Class VII. Therefore it is not cost effective to use a conservation practice which is suitable for Class V in a Class II soil situation. It is also necessary to have soil conservation treatments which can fit into the socio-economic environment and allow maximum use of the land.

6.3.4 *Proposed Treatment-Oriented Land Capability Scheme*

In the Caribbean farmers are forced to cultivate soils outside of the historical capability classification proposed by the RRC because of scarcity of land, market demand and better prices for certain commodities. If the authorities were to enforce land use in accordance with this scheme many farmers would be forced out of farming and the nations would be unable to meet their food production expectations.

A treatment-oriented land capability scheme is needed. This would allow crop production on the steeper slopes provided it is associated with appropriate crop and soil management. A treatment-oriented land capability scheme would permit marginal lands to be used beyond the capability proposed by the RRC in their Soil and Land Use Surveys, through the introduction of suitable crop and soil management systems. It would bring more soils in Classes IV - VII into greater and sustainable agricultural production.

The scheme being proposed would classify soils in each slope category into different classes of fragility based on soil factors, for example, depth of soil, erodibility, and fertility status. Appropriate soil management treatments would then be proposed for crops or crop combinations on the soil. A treatment oriented or management scheme which would permit steeper slopes to be more intensively cultivated is presented in Table 6.3.3.

TABLE 6.3.3: Recommended Soil Conservation Practices Guidelines

SLOPE		TYPE OF CROPS OR CROPPING SYSTEM	RECOMMENDED PHYSICAL SOIL CONSERVATION PRACTICES
Degree	Percentage		
0 - 4	0 - 7	Best lands for intensive annual production; mechanized mono-cropping	Good crop husbandry; Contour farming
4 - 10	7 - 18	Good for intensive annual crop production; mixed cropping on erodible, fragile soils	Vegetative barriers; Hillside ditches
10-20	18 - 36	Semi-permanent crops; Annual crops suitably intercropped with semi-permanent or permanent crops	Storm water diversion and downhill drains; Vegetative barriers; Hillside ditches; Mini-terraces; Narrow ridges and furrows; Mulching
20-30	36 - 58	Permanent crops, for example, fruit trees in pure stands with grass ground cover, or mixed with food crop on the less fragile soils; agroforestry	Hillside ditches; reversed sloping narrow terrace; Tree basins especially at the higher slopes; relay cropping of food crops
30 - 45	58 - 100	Production Forest; Agroforestry on the less fragile soils *(Forest species and permanent fruit trees only)	Full ground cover always; soil conservation measures in association with agroforestry depending on crop mix
45+	100+	Forest for watershed protection	Full ground cover always

Some fruit trees, for example, mango, papaya, are not suitable for the high wet elevations because of disease problems.

The above general and summary guidelines should be used to develop specific recommendations for the different soils on various slopes and climatic conditions.

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

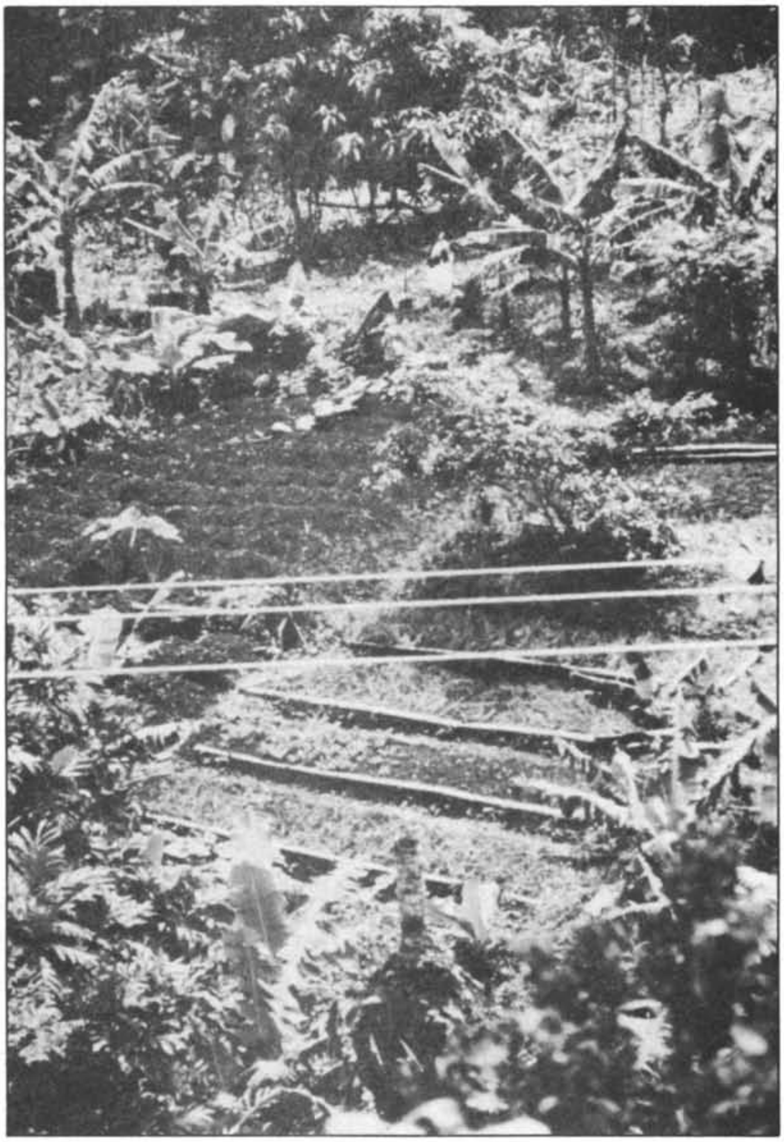

Figure 7.4 Bamboo barrier

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.

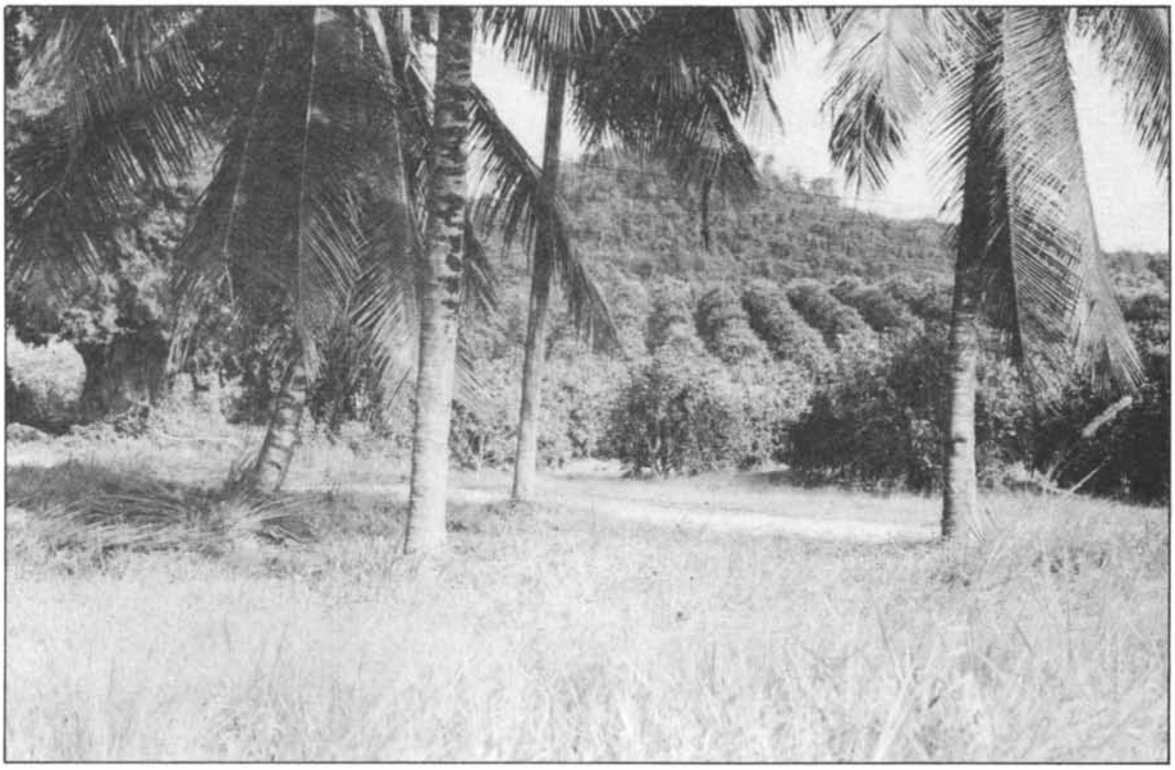

Figure 7.6 Citrus on the contour with rows unstaggered

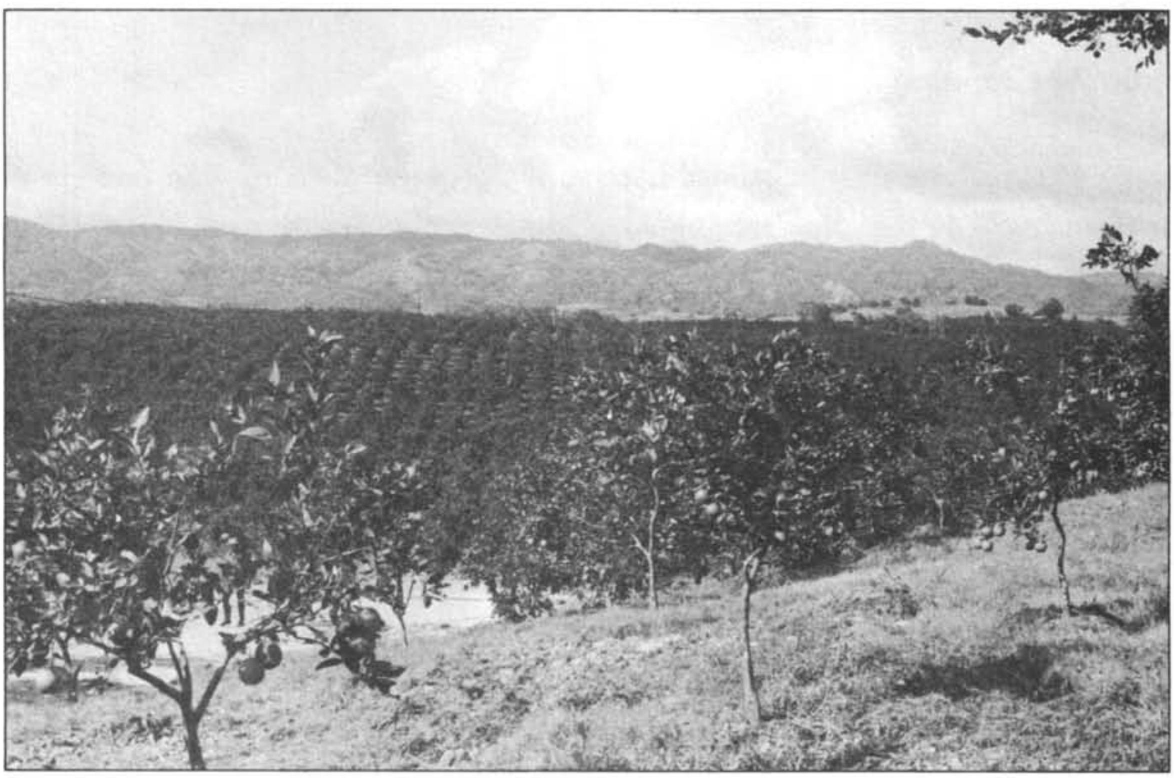

Figure 7.7 Citrus on the contour and grass cover in young citrus

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

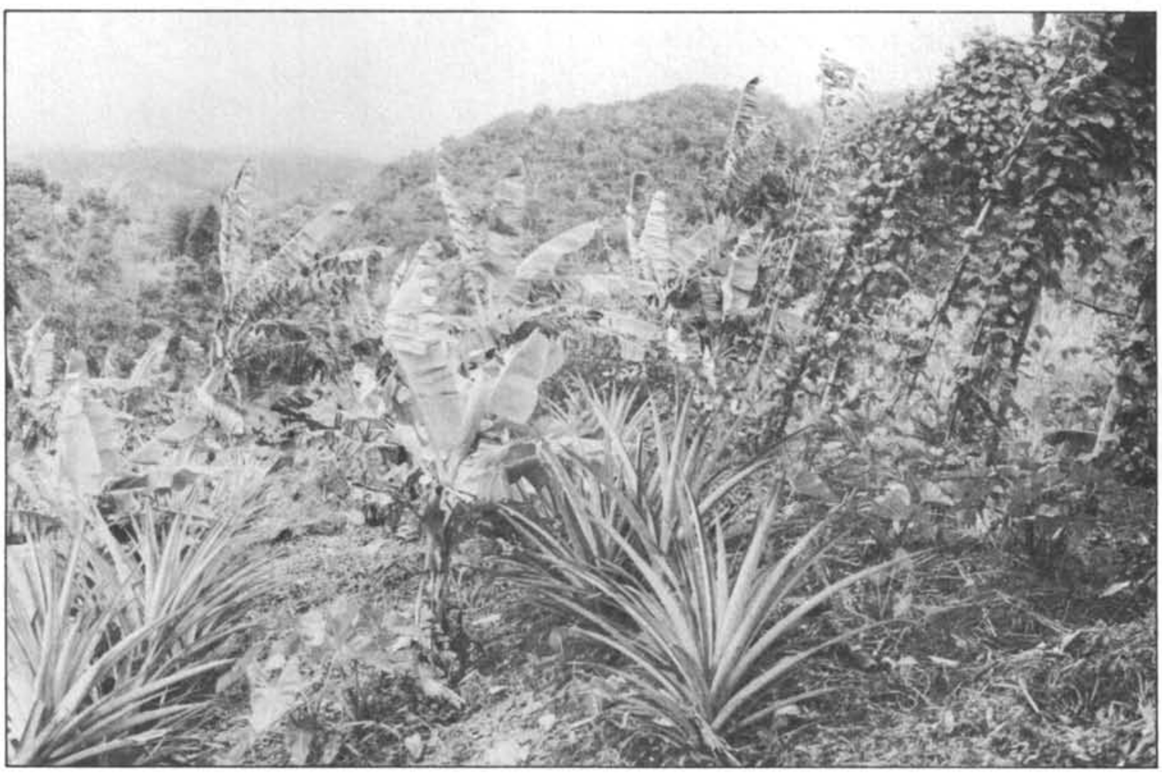

Figure 7.9 Row intercropping with several crops

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

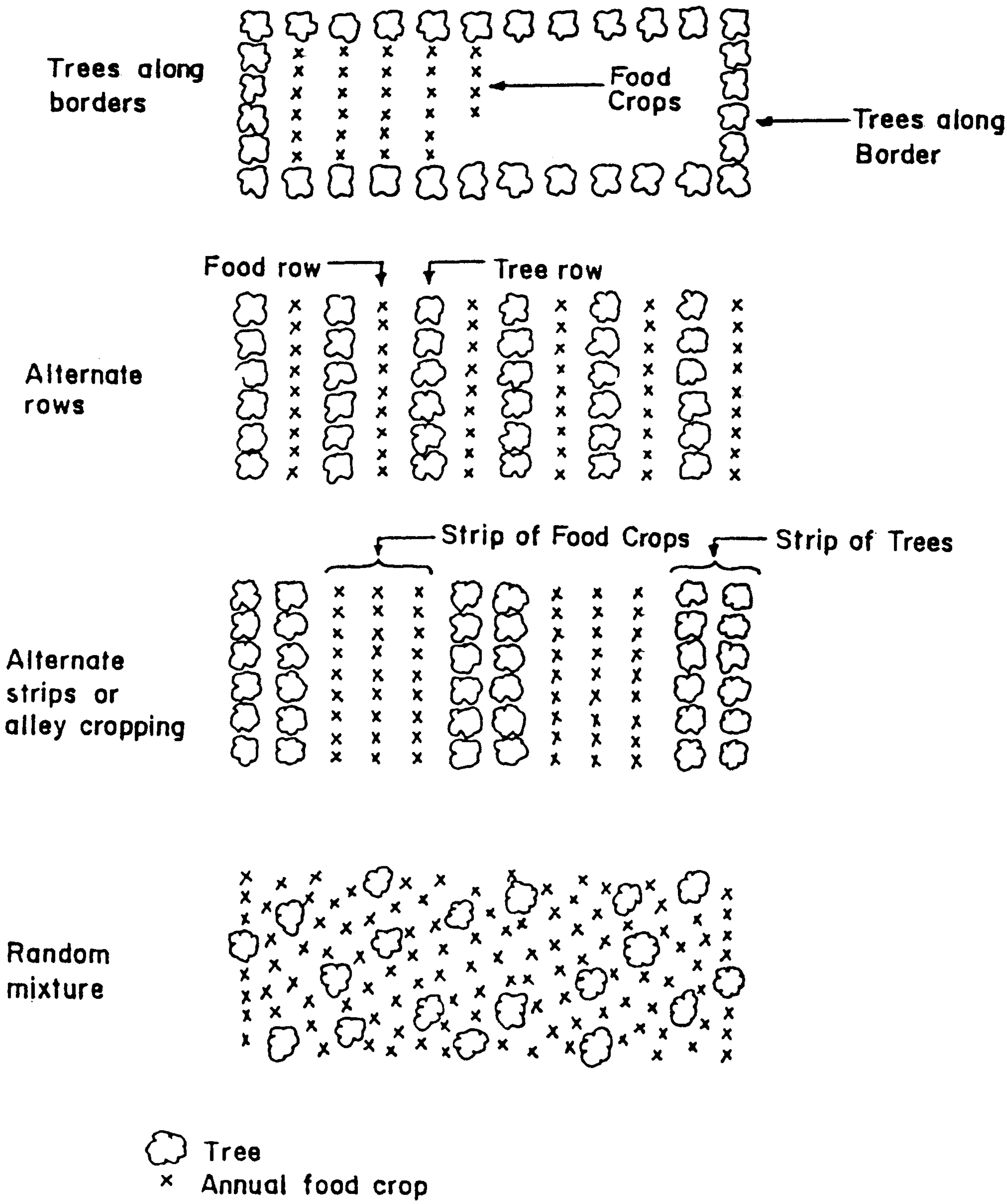

Figure 7.10 Spatial arrangements of agroforestry systems

Figure 7.11 Agrisilviculture system with several tiers of crops

Figure 7.12 Agrisilviculture system of citrus and banana

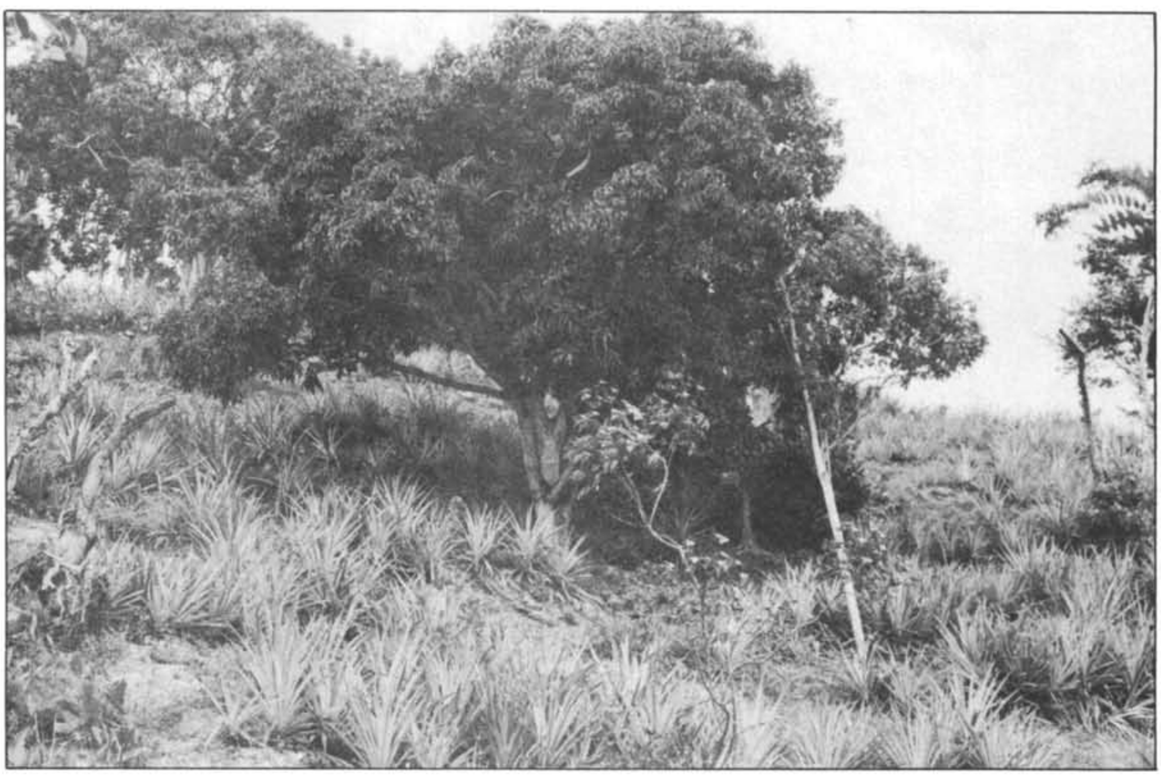

Figure 7.13 Pineapple planted on land without removing all trees

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

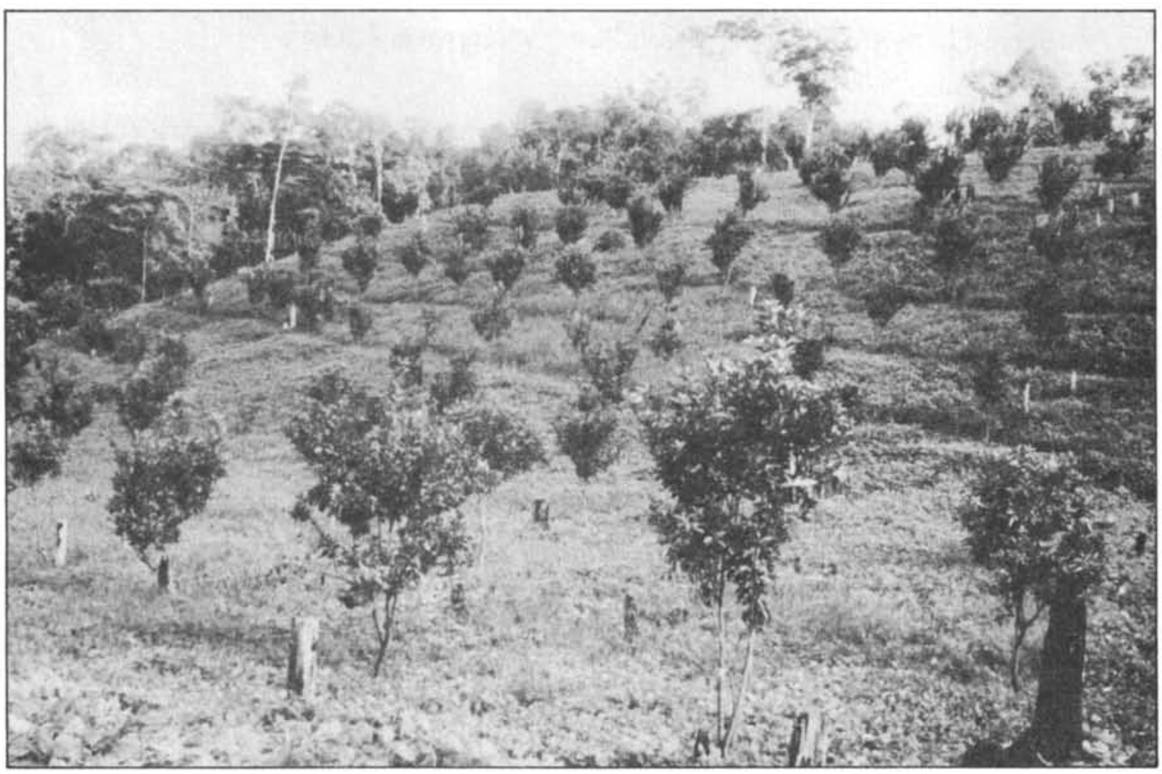

Figure 7.17(a) Mini-terrace or Hillside ditch with citrus (Orchard terrace)

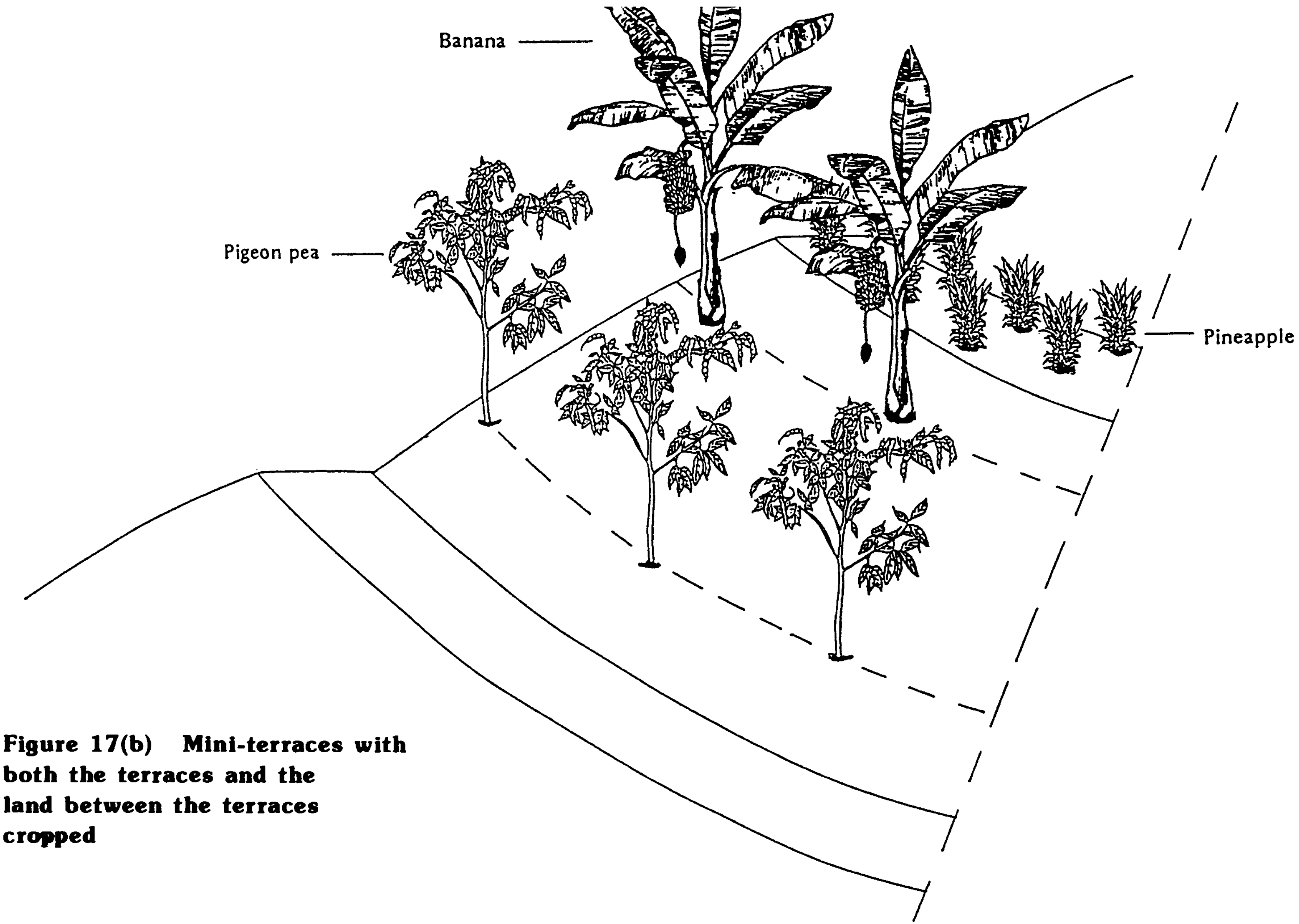

Figure 17(b) Mini-terraces with both the terraces and the land between the terraces cropped

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

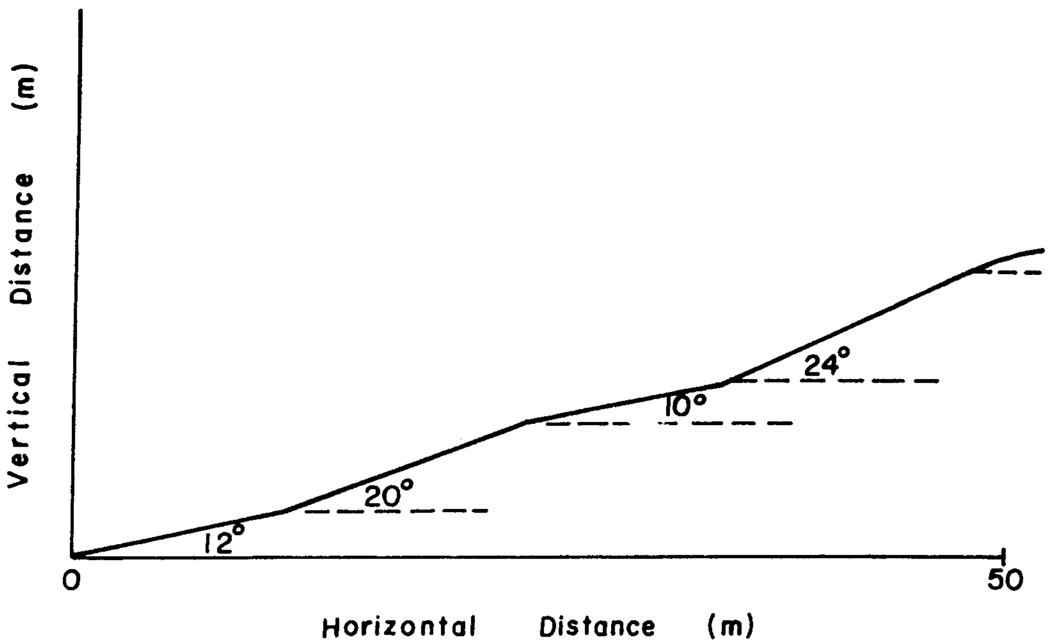

Figure 7.18 Longitudinal profile of gully bed

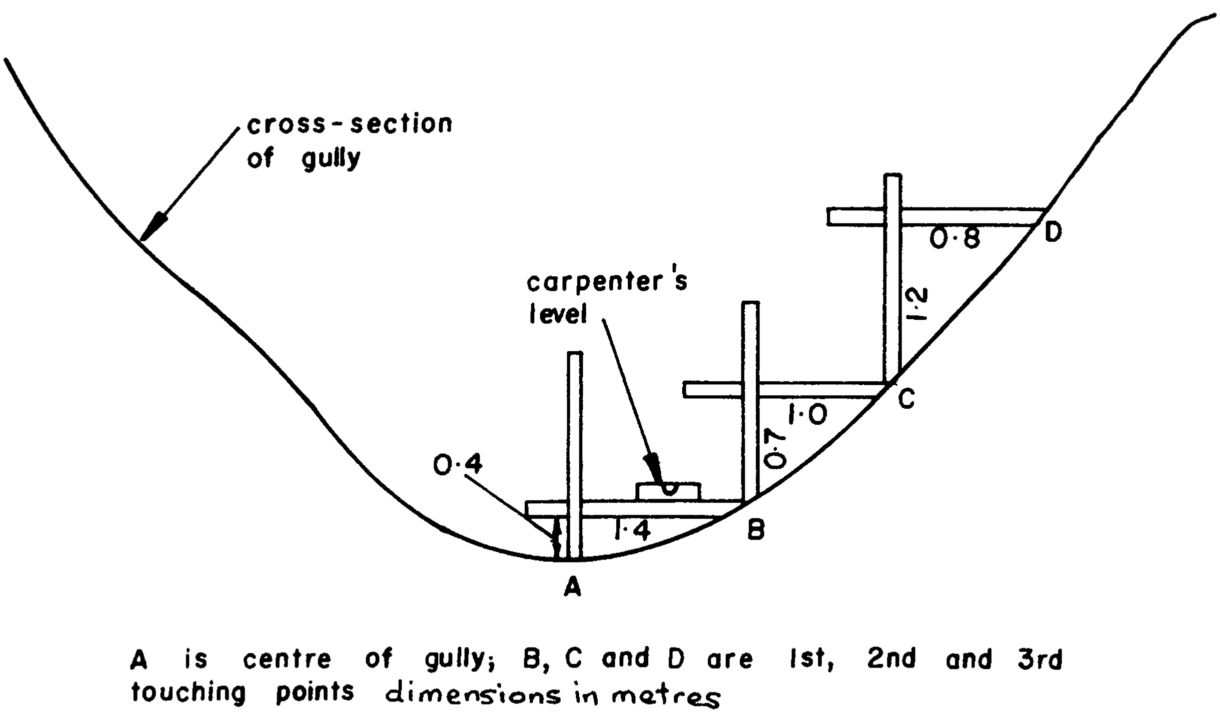

Figure 7.19 Measuring the profile of the cross-section of the gully

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.

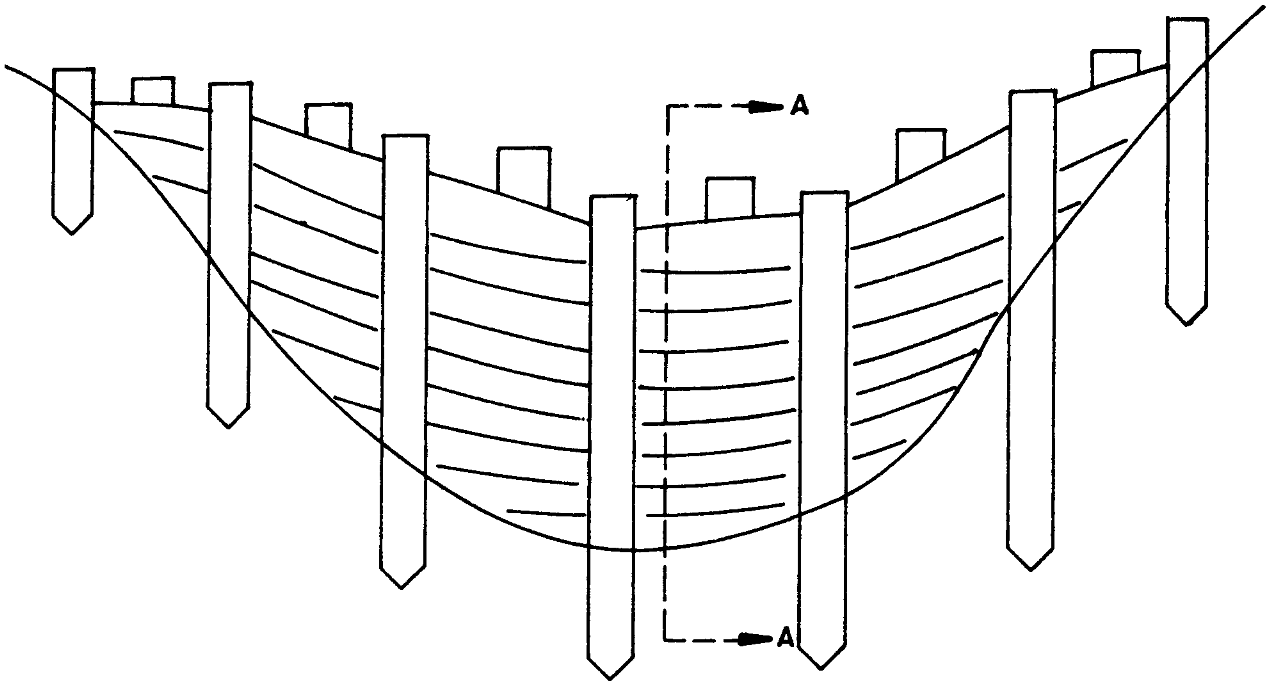

Figure 7.20(a) Brushwood Check Dam

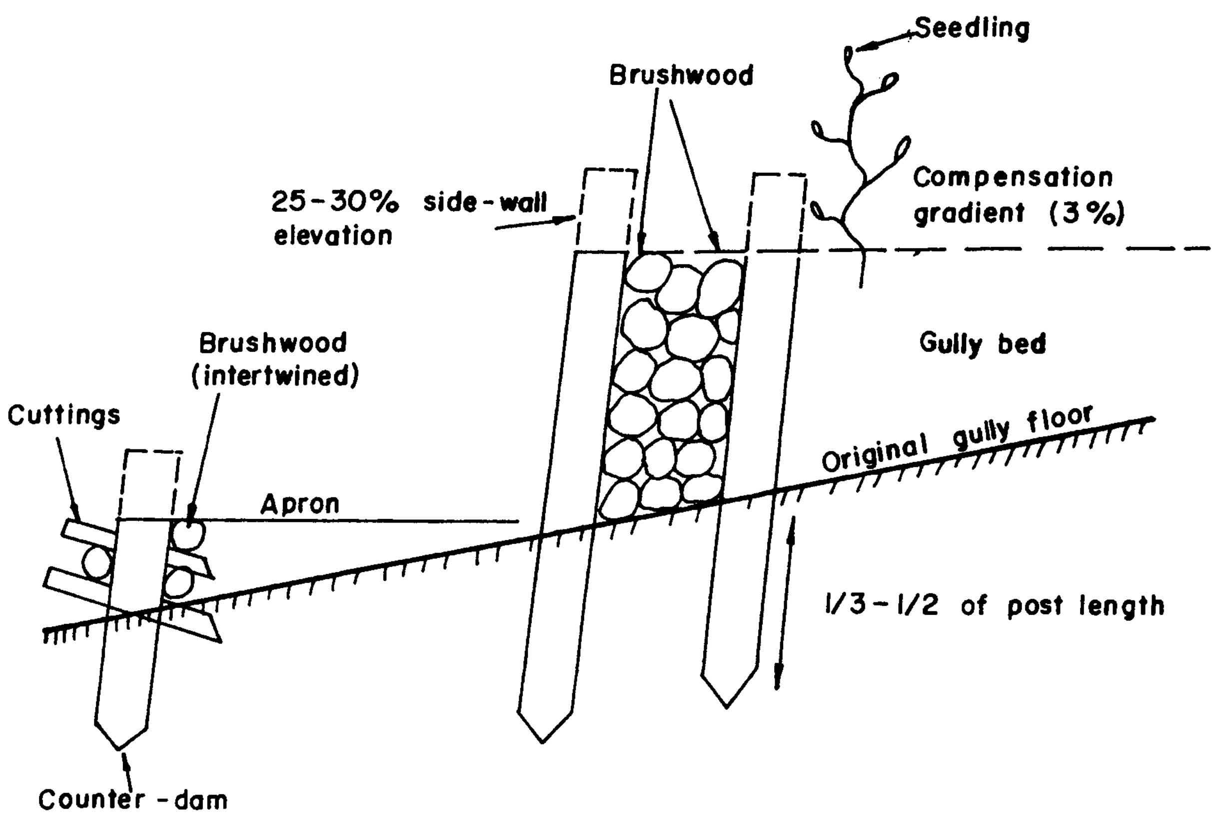

Figure 7.20(b) Cross-section of Brushwood Check Dam

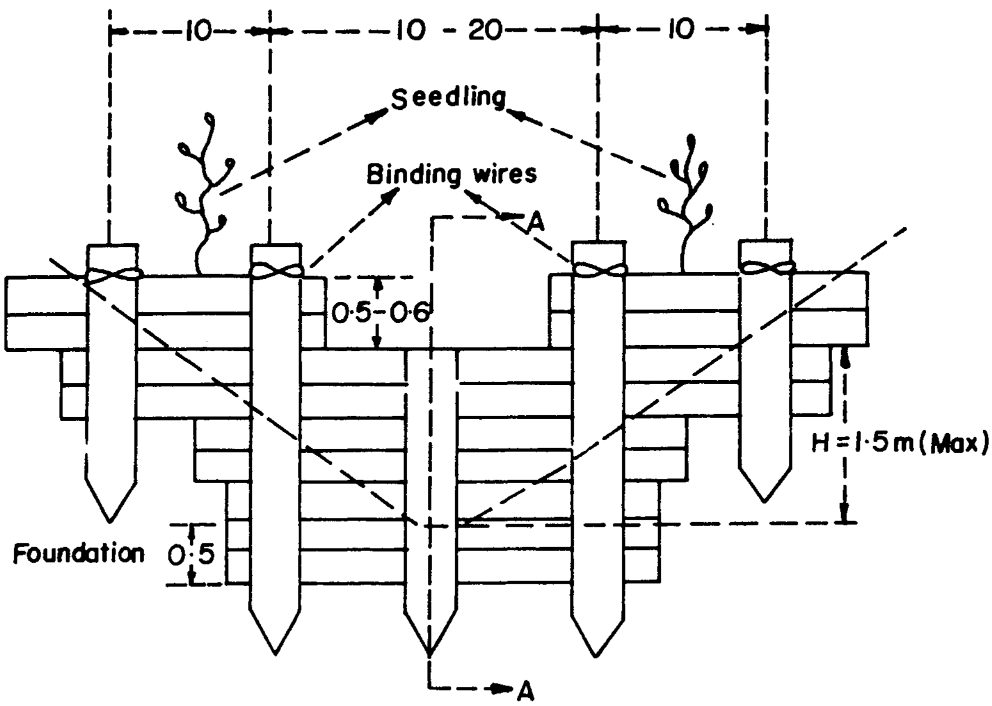

Figure 7.21(a) Log Check Dam

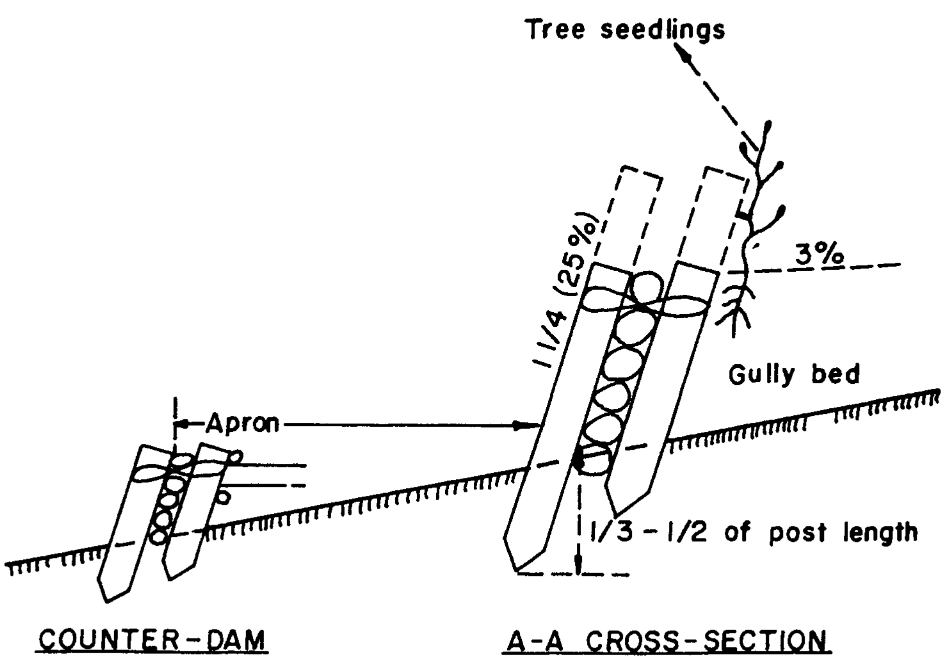

Figure 7.21(b) Cross-section of Log Check Dam

- 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:

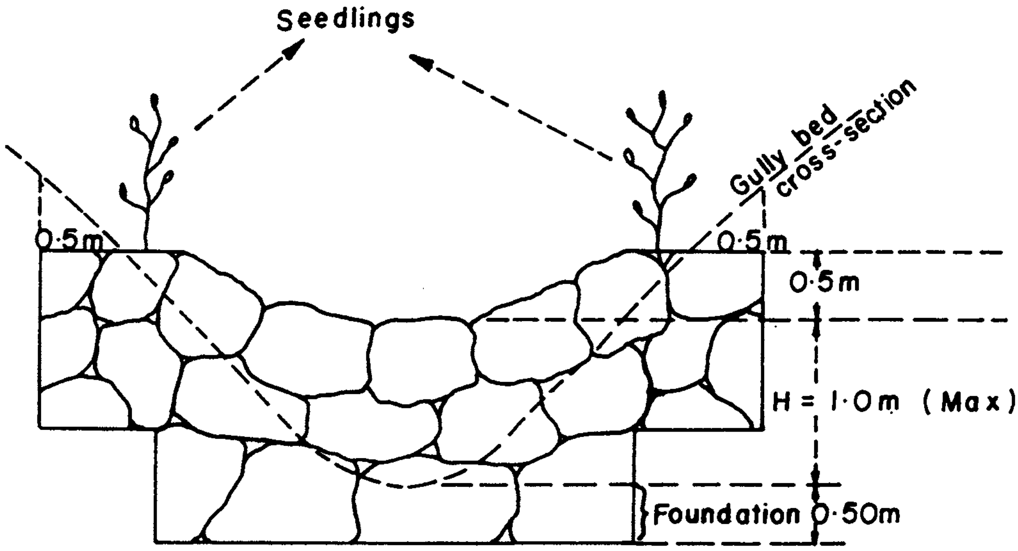

Figure 7.22 Loose Stone Check Dam

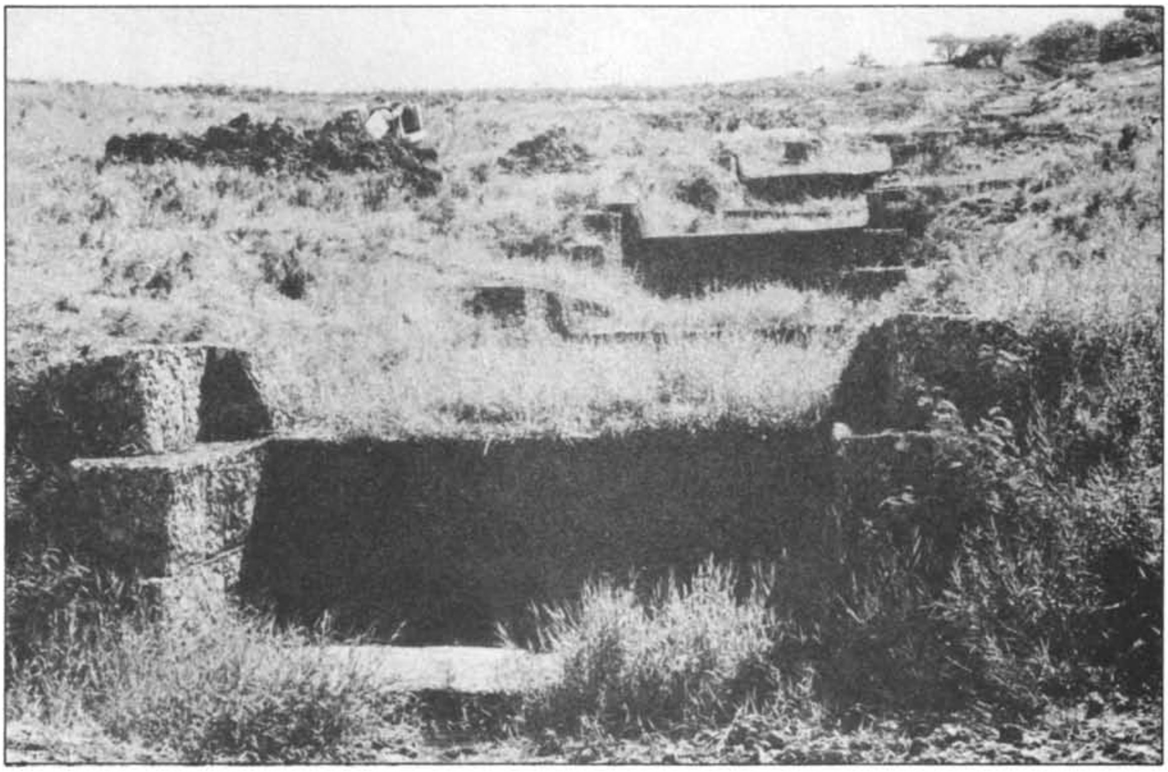

Figure 7.23(a) Gabion Check Dam

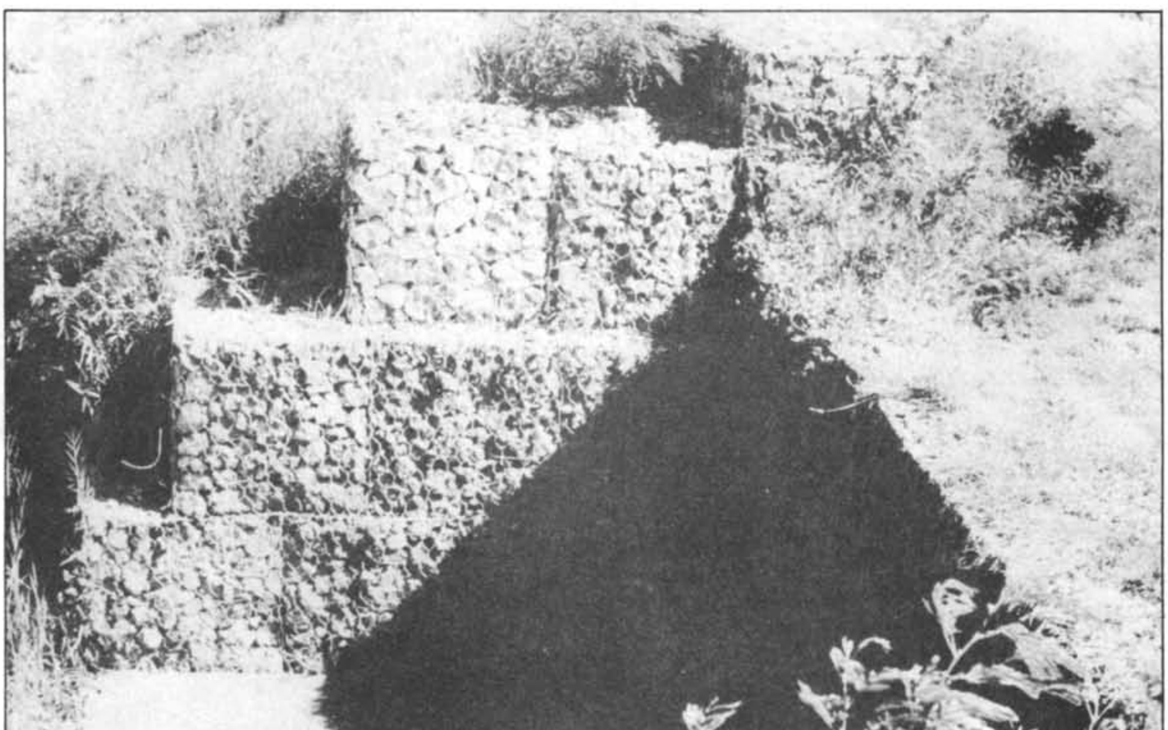

Figure 7.23(b) Close-up of Gabion Check Dam

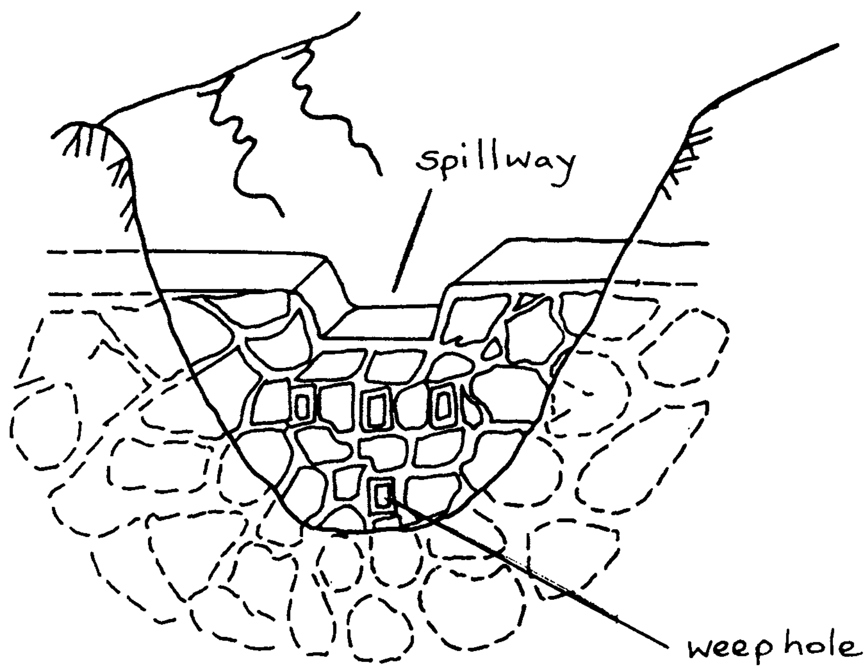

Figure 7.24 Masonry Check Dam

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.

CHAPTER 8

INTEGRATED SOIL CONSERVATION SYSTEMS

The preceding chapters provided the principles and considerations which must be taken into account to successfully integrate soil conservation into farming systems. This chapter:

- firstly, examines the experience of the Hillside Agricultural Project (HAP) of Jamaica where an attempt was made to involve farmer and community participation in project design and implementation: and

- secondly, examines broadly the existing systems in the Caribbean where soil conservation has been integrated into farming systems;

Exercises which the student of soil conservation should carry out using the principles outlined in the book to gain some practical experience are given in the Appendix.

8.1 Hillside Agricultural Project (HAP), Jamaica

The overall goal of HAP is to increase the economic well-being of the residents of the hillside lands in two watersheds, Rio Minho and Rio Cobre, in a manner that promotes rational land use patterns.

The project was initiated in February 1987 and is due to be completed in February 1994. It is funded by USAID at a cost of US$10 million. HAP itself is not a project implementing agency. It consists of a core staff of a Project Manager and Deputy Project Manager and office support staff. It funds self-managing sub-projects (Hillside Agricultural Sub-Projects or HASP) that promote the production and productivity of perennial tree crops. Between 1987 and 1991, 16 sub-projects were approved and two were pending. Fourteen of the 16 sub-projects were similar in nature and were concerned with farm improvement. The other two were a Watershed Inventory sub-project and a Baseline Study sub-project. The

HAP has certain defined objectives and criteria and the sub-projects have to satisfy these conditions before they are approved.

It should be made clear that HAP was not a soil conservation project per se and this was often not the primary objective of a sub-project. However, because erosion must be controlled if the improvement of farms on hillsides is to be sustained, soil conservation is recognized as an important aspect of the project. However HASP did not emphasize soil conservation and this can be considered to be a deficiency in some cases.

The purpose of the project is to increase productivity and expand the area of both export-oriented and domestic perennial crops. This targeted increase in agricultural production is expected to result in an increase in the productive employment of hillside residents and in disposable income. The specific goals and objectives of the sub-projects varied and included: increasing tree crop production and farmer incomes, improving crop development by introducing improved technology, controlling soil erosion and land degradation, increasing community participation and strengthening local institutions.

At the sub-project level specific targets or outcomes had to be set and quantified. An important consideration is that the detailed goals and objectives should reflect local specific needs. All sub-projects had to list a set of local constraints which would be addressed. Formal detailed case assessments of local constraints through farmer interviews, walk over surveys, or rapid rural appraisal were to be undertaken but these were not frequently achieved. In some cases, the major problems common to an area were assessed through individuals or organizations with experience of previous work in the area e.g. extension officers, NGOs.

The 16 sub-projects approved and implemented are:

- St. Mary Cocoa Growers Support Sub-project (S-p)
- IICA/MINAG Farming Systems S-p
- Agro-Forestry Promotions S-p
- N.W. St. Catherine Coffee S-p
- UNITAS S-p

- Upper Clarendon Processing Company
- Manchester Rural Agricultural Development Agency (RADA) S-p
- Rio Minho Cocoa Expansion S-p
- Guys Hill Coffee Sop
- Blackwoods S-p
- Elgin S-p
- Windsor S-p
- Mango Top-working S-p
- Above Rocks S-p
- Watershed Inventory S-p
- Baseline Survey S-p

The first 14 sub-projects listed above had different specific objectives and targets but they were all concerned with perennial or tree crops. It is not feasible to outline for each project the specific objectives and targets, and the constraints to production which the projects sought to overcome, but the general approaches to project design, implementation and evaluation promulgated by HAP will be considered. The detail project proposals and progress reports are located at the HAP office.

The key pillars to HAP strategy were:

- Community participation in all phases of the project cycle or the "bottom-up approach"
- Strengthening of local institutions
- Project implementation through a sponsoring organization
- Non-monetary incentives to farmers
- Extension service to farmers
- Crop improvement through agronomic and cropping systems approach
- Inclusion of soil conservation in the sub-projects
- Sustainability of sub-projects

Community Participation

The HAP strategy calls for community participation from the problem identification or planning stage, through project design, implementation, monitoring and evaluation i.e. the "bottom-up approach" in the true sense. Except for the IICA/MINAG Farming Systems sub-project, the projects have been weak in community participation in the first two stages of the project cycle. The HAP proposal preparation involves some discussion with farmers in targeted districts but a more in-depth process is required. In many cases this information is supplemented by information from NGOs and extension officers with experience in the area. A preliminary needs assessment is obtained during the process. Farmers and the community have not really been involved in project planning.

There has however been greater success in community involvement in project implementation. All sub-projects have incorporated this approach by establishing local management committees (LMC) which include representatives of local farmer organizations and other community representatives. The Farmer Action Committee Team (FACT) of the IICA/MINAG sub-project is the best example of farmer mobilisation and community participation in HAP. (This was discussed in Chapter 3 Volume I.) FACT has functioned in all stages of the project cycle and should be adopted by other sub-projects. Apart from FACT, communities of other projects have not participated in project monitoring and evaluation. The strategy therefore needs to be implemented more fully if it is to achieve the objective of project adoption and sustainability.

An alternative to the FACT strategy is to use existing local organizations that are functioning efficiently e.g. cooperatives, select Jamaica Agricultural Society (JAS) branches. In some cases these may need strengthening to improve their effectiveness.

Strengthening Local Institutions

One of the aims of the HAP is to strengthen the capacity of local community organizations, such as JAS branches, Coffee and Cocoa Cooperatives, and youth organizations, to initiate and implement projects. This would encourage farmer participation in project implementation and ensure sustainability. The success depends on the presence of existing functioning organizations which can benefit from the sub-project. This is not always the case.

Sponsoring Organizations or Implementing Agencies

The implementation of sub-projects through permanent organizations with suitable experience has the advantage of permanence as regards future institutional support. Organizations have different strengths, resources, capabilities and effectiveness. These must be carefully assessed in relation to the requirements of the project and the capacity of the organization to deliver efficiently.

Non-monetary Incentives

For sustainability, the project does not offer cash incentives or cash subsidies for soil conservation because farmers come to depend on cash support and never take full responsibility for soil conservation. The experience of the HAP has been that soil conservation declines or ceases with the removal of subsidies.

Extension Service to Farmers

Similar extension approaches are used by the sub-projects. District meetings are held to inform farm families of the assistance to be provided by the sub-project and to distribute applications. The applications are reviewed by the Local Management Committee and the farms are visited by the staff to decide if the farmers qualify for participation.

Training sessions are held by way for field days, seminars, demonstrations and workshops. Field visits are the primary method used to ensure that farmers utilise the appropriate cultural methods and soil conservation practices. The Socio-economic Impact Study revealed that 92% of all respondents were visited. The demonstration plots on farmers' fields are the focus of the training days which provide the mechanism for farmers both within and outside the sub-projects to learn the particular production technology. The demonstration plot was an important extension methodology but it did not cover all the techniques that needed to be demonstrated. Fertilizer application, pruning and plant spacing were the main practices demonstrated. This may be because cocoa and coffee were the primary focus and the extension message seem to be the promotion of the practices recommended by the Cocoa and Coffee Boards.

The report on the Comparative Analysis of the Hillside Agricultural Project and Sub-Projects by the Caribbean Agricultural Communications Services Ltd (CACS) revealed that soil conservation techniques received the least attention of the five primary extension messages promoted by the sub-projects. On average a third of the farmers received some instruction in soil conservation. The Above Rocks sub-project was the lowest with only 10% receiving soil conservation advice. According to the farmers, the most effective extension approach was the extension worker visits (49%); field days next (17%); group meetings (9%); and demonstration plots last with 3%. About a quarter (23%) felt that they were all equally important.

The extension service was rated as good by 80% of the respondents while the remainder felt that there needs to be better communications.

Agronomic Approach/Cropping Systems Approach/ Soil Conservation

The HAP's concept is that the most suitable form of development for small holder hillside agriculture is a perennial crop regime incorporating sound conservation practices. The perennial crops were mainly cocoa, coffee, forestry species and other tree crops (e.g. coconut, mango, avocado).

The agronomic approaches were concerned mainly with planting new trees to adjust or increase previously low plant populations and with rehabilitation by pruning fertilization and shade control. Generally, it represented the implementation of the package of practices recommended by the commodity boards, and tested over many years.

Cropping systems included the use of banana, plantains, root crops, legumes and vegetables. Many were associated with cocoa and coffee which were frequently the main crops. The improvement in the performance of the minor crops was not monitored and therefore conclusion on the effectiveness of the project on these crops could not be drawn.

Specific attempts to address soil conservation were not common in cocoa fields. There were very few gully plugs/check dams, hillside ditches, barriers. The principle applied was that the establishment or presence of trees addressed the high priority placed on soil conservation by most sub-projects.

There was, however, sensitivity to the greater need for imposing soil conservation practices for coffee, where leaf accumulations did not parallel the cocoa situation. There was a widespread occurrence of contour grass, stone or bush barriers, as part of the cultivation system. The imposition of minimum tillage, strip cropping and mulches were emphasised on demonstration plots.

The sub-projects which have emphasised agroforestry, nursery development with youth participation, integration of fruit tree development with processing, mango top-working to convert non-commercial mangoes into exportable varieties, are commendable but the technical competence, management on a continuing basis, and marketing are not always in place and have to be given serious attention for sustainability of the activity.

8.2 Existing integrated soil conservation systems in the Caribbean

In the Caribbean many different mixed cropping or mixed farming systems exist. The systems are usually designed specifically for economic reasons but some are associated with specific agronomic or land management practices for the purpose of soil conservation. The existing farming systems have not been fully assessed economically and technologically. The Caribbean Agricultural Research and Development Institute (CARDI) attempted to address the improvement of agricultural production and productivity through a Farming Systems Research and Development (FSRD) Project. A major objective was to improve the systems employed by farmers through the incorporation and integration of appropriate technologies in the systems.

Consideration is given here to the systems on hillsides which can be grouped as follows:

- Monocropping of tree crops
- Systems based on tree crops
- Systems based on banana
- Systems without tree crops

Monocropping of tree crops

Pure stands of cocoa, citrus, coconuts, forest species and, to a lesser extent, fruit trees are the main tree crops cultivated. Grass is often associated with coconuts for grazing of livestock. These tree crops stabilize the soil, especially if leaf litter is present or allowed to accumulate. This system effectively conserves the soil on all classes of slope against erosion. Small and large livestock are sometimes introduced into the system. Large stock (cattle) can damage the soil in the wet season and increase erosion. Therefore the numbers and the system have to the carefully managed.

Systems based on tree crops

The dominant tree crop may be cocoa, citrus, spices, coconuts and coffee (at higher attitudes). The farmer then chooses from a multiplicity of cash and food crops such as vines, bushes and ground crops for filling appropriate spaces. The times of planting and harvesting are such that the ground is always covered or occupied by crops, and consequently is very effective in conserving the soil against erosion. The random distribution of the crop mix prohibits mechanization. If inorganic fertilizers are used these are applied to individual crops in relation to the time of planting.

If the tree crop is not sufficiently dominant to prevent the soil from eroding, log or trash barriers are used to reduce erosion.

Systems based on banana

Banana may be grown as the dominant crop with a tree crop (e.g. citrus, coconut) and/or one or more cash or food crops as intercrop. The favourable price of bananas over recent years has led to the gradual replacement of the tree crop which may have been the dominant crop to the point where banana is dominant or exists as pure stand. In these systems the ground is always covered or largely covered by a crop or is associated with contour drains or barriers to reduce erosion.

Systems without tree crops

A random or systematic mix of several cash or food crops is common. The farmer may choose as many as six to ten different crops in his mix mainly to spread his risk and income distribution. The mix of crops is generally randomly distributed and serves, incidentally, to ensure that the ground is always partly or completely covered by a crop and to reduce the spread of disease. Sometimes one of the crops (e.g. pigeon pea, yam, pineapple) is grown at intervals on the contour and the other crops occupy the spaces between these contour crops with or without vegetative or trash mulching.

CONCLUSIONS

Soil erosion is a serious problem in the Caribbean. Several efforts have been made and continue to be made to reduce or minimize soil erosion but it has been recognised that historically farmers do not often adopt soil conservation methods on their own volition or even when the methods are demonstrated to them. This failure has been due to the use of soil conservation methods that are not appropriate to the physical, social and economic environment. Therefore, the social context and methods of extension are critical.

In the Caribbean most of the farmers on hillsides are resource-poor small farmers who do not have a soil conservation culture, and who have limited formal education and training. Therefore, the methods of soil conservation must be simple, inexpensive and must preferably give an economic benefit quickly and must not compete seriously for scarce labour. In the past the focus has been on physical or engineering methods but adoption of these methods has been limited. A different approach is therefore needed. There are many practices which are not normally associated with soil conservation but which can reduce erosion. In this regard the agronomic or biological methods are very important.

The two volumes of this book have considered the institutional, sociological and technical factors which are necessary for the successful implementation and adoption of soil conservation projects. Experience in the Caribbean has shown that the following factors are essential:

- strong institutional base to promote soil conservation;
- enforcement of existing relevant legislation;

- active, knowledgeable and adequate numbers of extension workers with good communication skills;
- identification of critical behavioural factors at the project design stage to ensure that changes are sustained;
- early identification of farmers with the project (from the design stage) and active involvement throughout the project i.e. the bottom-up approach;
- identification and involvement of community leaders in bringing about change;
- public awareness and education;
- proven inexpensive or cost effective technologies.

The institutional and sociological factors have been considered in Volume I while Volume II has concentrated on the technical requirements. The second volume has emphasised that agronomic or biological methods which can be integrated into the farming system are more cost effective than physical or engineering methods and more readily adopted by farmers. Since gullies are common problems on farms located on hillsides, appropriate methods for their control are given prominence. The methods of control inevitably involve some simple engineering techniques but the methods presented are simple, and sufficient information is given to be of practical benefit.

It is hoped that this approach of integrating soil conservation into farming systems would be widely appreciated and adopted and that this book would contribute to this process.

APPENDIX

APPENDIX

STUDENT CASE STUDY EXERCISES

The following exercises are given so that the student of soil conservation can gain experience in designing programmes of soil conservation activities as case studies. The case studies should take into consideration the principles outlined in the book and the socio-economic context of the Caribbean.

Project Profile

A soil conservation programme is to be developed in a project area with the following features:

Area : 18km^2

Terrain: Hilly with varying slopes including steep slopes; large number of gullies and ravines.

Soils: Two major soil types.

(1) loose erodible, shallow or shallow and bouldery in places;

(2) loose friable erodible, deep profile

Present Cropping

High percentage of cocoa and coffee
Banana
Some food crops
Few scattered fruit trees
Forest trees

Farm Sizes

Small farms 0.5 - 5 hectares

Tenure

(1) Owner occupied (2) Short term leases

Constraints: low yield of crops because of low technology; low or no use of suitable fertilisers; high incidence of disease; low crop husbandry.

Specific Objectives:

- Increase productivity of farms
- Increase farmers' income
- Improve land-use practices, particularly the adoption of appropriate sustainable soil conservation methods
- Strengthen producers organizations
- Strengthen extension services

Soil conservation practices are to be developed for the following farm situations:

No.	Farm Size	Slope	Gullies/ Ravines	Cropping	Tenure	Soil
1	Small	G/M	Small	Banana and Food Crops	Lease	1
2	Large	S	Large	Cocoa, Coffee, Food Crops	Owner	2
3	Medium	S	None	Free choice	Lease	1
4	Small	S	Small	Coffee	Lease	2
5	Large	S	Small	Food Crops, Fruit Trees, Banana	Lease	1
6	Medium	G/M	Moderate	Vegetables, Banana, Cocoa	Owner	2

Soil conservation practices are to be developed for the following farm situations:

No.	Farm Size	Slope	Gullies/ Ravines	Cropping	Tenure	Soil
7	Small	G/M	Large	Vegetables,	Owner	2
8	Large	G/M	Small	Vegetables, Banana, Tree Crops	Owner	2
9	Medium	S	Small	Cocoa, Food Crops	Lease	1
10	Small	S	None	Vegetables, Banana, Food Crops	Owner	2
11	Large	G/M	Moderate	Free choice	Owner	2
12	Medium	S	Large	Vegetable, Tree Crops	Owner	1

Farm Sizes		Slopes	
Small	0.5 - 1.5 ha	G	gentle
Medium	1.5 - 3.0 ha	M	moderate
Large	3.0 - 5.0 +	S	steep

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Regional Research Centre of the British Caribbean at the Imperial College o Tropical Agriculture (now faculty of Agriculture, The University of the West Indies Trinidad.

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Tropical Forestry Action Programme (TFAP) 1991-1992

Reports of the consultants on Legislation

Reports of the consultants on Land Use and Watershed Management (Antigua and Barbuda, Barbados, Dominica, Grenada, Montserrat, St. Kitts/Nevis, St. Lucia, St. Vincent and the Grenadines).

This volume complements a report published by the Commonwealth Secretariat in 1992 entitled, 'Integrating Soil Conservation into Farming Systems in the Commonwealth Caribbean'. Other reports published by the Commonwealth Secretariat deal with issues of interest to Commonwealth countries in the natural resources field and cover topics in forestry, fisheries, livestock, and various aspects of agriculture in all regions.

The research work for this study was assisted by a grant from the Overseas Development Administration (ODA), of the United Kingdom.

ISBN 978-1-84859-572-9

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