International Centre for
Integrated Mountain Development

Asian Rural Life
Development Foundation

# SLOPING AGRICULTURAL LAND TECHNOLOGY (SALT)
## A Regenerative Option for Sustainable Mountain Farming

**Tej Partap**

and

**Harold R. Watson**

## ICIMOD OCCASIONAL PAPER NO. 23

**Kathmandu, NEPAL**
**1994**

# ICIMOD Occasional Papers

No. 1 **EROSION AND SEDIMENTATION PROCESSES IN THE NEPALESE HIMALAYA**
Brian Carson (1985)

No. 2 **INTEGRATED RURAL DEVELOPMENT PROJECTS IN NEPAL: A REVIEW**
Bharat B. Pradhan (1985)

No. 3 **SUSTAINING UPLAND RESOURCES: PEOPLE'S PARTICIPATION IN WATERSHED MANAGEMENT**
Anis Dani and J.G. Campbell (1986)

No. 4 **DECENTRALIZED ENERGY PLANNING AND MANAGEMENT FOR THE HINDU KUSH-HIMALAYA**
Deepak Bajracharya (1986)

No. 5 **GLACIAL LAKE OUTBURST FLOODS AND RISK ENGINEERING IN THE HIMALAYA**
Jack D. Ives (1986)

No. 6 **OPERATIONAL EXPERIENCES IN FOREST MANAGEMENT DEVELOPMENT IN THE HILLS OF NEPAL**
G.B. Applegate and D.A. Gilmour (1987)

No. 7 **FORESTRY-FARMING LINKAGES IN THE MOUNTAINS**
T.B.S. Mahat (1987)

No. 8 **ROAD CONSTRUCTION IN THE NEPAL HIMALAYA: THE EXPERIENCE FROM THE LAMOSANGU-JIRI PROJECT**
Urs Schaffner (1987)

No. 9 **MOUNTAIN ENVIRONMENTAL MANAGEMENT IN THE ARUN RIVER BASIN OF NEPAL**
John R. Dunsmore (1988)

No. 10 **HILL AGRICULTURE AND THE WIDER MARKETING ECONOMY: TRANSFORMATION PROCESSES AND EXPERIENCE OF THE BAGMATI ZONE IN NEPAL**
Mahesh Banskota (1989)

No. 11 **HIGHLAND-LOWLAND INTERACTIONS IN THE GANGES BRAHMAPUTRA RIVER BASIN: A REVIEW OF PUBLISHED LITERATURE**
L.A. Bruijnzeel and C.N. Bremmer (1989)

No. 12 **MICRO-LEVEL ENVIRONMENTAL MANAGEMENT OBSERVATIONS ON PUBLIC AND PRIVATE RESPONSES IN KAKANI PANCHAYAT, NEPAL**
Saroj K. Basnyet (1989)

No. 13 **MOUNTAIN ENVIRONMENTAL MANAGEMENT: NYEMO COUNTY (TIBET), CHINA**
Zhang Rongsu (1989)

No. 14 **NATURAL RESOURCE MANAGEMENT IN THE MOUNTAIN ENVIRONMENT: EXPERIENCES FROM DOON VALLEY, INDIA**
J. Bandyopadhyay (1989)

No. 15 **LANDSLIDE MANAGEMENT IN THE MOUNTAIN AREAS OF CHINA**
Li Tianchi (1990)

No. 16 **MINI- AND MICRO-HYDROPOWER IN NEPAL**
Jean-Marion Aitken, G. Cromwell, and G. Wishart (1991)

No. 17 **AGROFORESTRY IN MOUNTAIN AREAS OF THE HINDU KUSH-HIMALAYAN REGION**
Jeannette Denholm (1991)

No. 18 **HYDROLOGICAL ASPECTS OF THE HIMALAYAN REGION**
Donald Alford (1992)

No. 19 **SUSTAINABILITY OF THE ENVIRONMENTAL RESOURCE BASE AND DEVELOPMENT PRIORITIES OF A MOUNTAIN COMMUNITY: BHARDEO, NEPAL**
Kk Panday (1992)

No. 20 **SEABUCKTHORN: A MULTIPURPOSE PLANT SPECIES FOR FRAGILE MOUNTAINS**
Lu Rongsen (1992)

No. 21 **THE LAND, THE FARMER, AND THE FUTURE: A SOIL FERTILITY MANAGEMENT STRATEGY FOR NEPAL**
Brian Carson (1992)

No. 22 **DYNAMICS OF HIGHLAND AGRICULTURE IN LHASA DISTRICT, TIBET**
Liu Yanhua (1992)

# SLOPING AGRICULTURAL LAND TECHNOLOGY (SALT)

## A Regenerative Option for Sustainable Mountain Farming

**Tej Partap**

**and**

**Harold R. Watson**

**ICIMOD OCCASIONAL PAPER No. 23**

**Published by**
**International Centre for Integrated Mountain Development**
**Kathmandu, Nepal**

Cover photograph: Top
i) Managing sloping agricultural land through planting grass and *Leucaena* on the contours - the TAHASD Project for hill tribes, Thailand (Tej Partap)
ii) A farmer trimming hedgerows in the field, Ningnan County, Sichuan, China (Tej Partap)

Bottom
i) The terrace formation constructed by SALT hedgerows is indicated by the hands of two persons. Photo of MBRLC experimental plot at Mindanao, the Philippines (HR Watson).
ii) This farm family in Ningnan county, Sichuan, China, is obtaining better crops from their degrading sloping lands after adopting SALT (Tej Partap)

Published by

International Centre for Integrated Mountain Development
G.P.O. Box 3226,
Kathmandu, Nepal

**ISBN 92-9115-323-0**

Typesetting at ICIMOD Publications' Unit

# FOREWORD

The population in many parts of the Hindu Kush-Himalayan Region has more than doubled over the past thirty years as a result of improved health care; off-farm employment and income opportunities have not been able to keep abreast of this increase. This has, in turn, led to excessive pressure on land resources, leading to a deterioration in both the quality and productivity of land and resultant unsustainability in areas where the population has steadily increased.

The human response to increased population pressure in terms of resource use has been of three types, namely,

i) intensified use of existing agricultural land leading to double/triple cropping not only on flat land, where this is sustainable, but also on lands with different gradients where it leads to a decline in soil fertility, to erosion and landslides, and ultimately to abandonment of the land;

ii) forest clearance for agricultural use; often of a too intensive type, leading in turn to a decline in soil fertility, soil erosion and landslides, and ultimately to the abandonment of the land when cultivation is no longer financially viable; and

iii) excessive and exploitative use of public forests and common property resources (both grasslands and forests), causing soil fertility and yields to decline, leading to further deterioration in the quality of the land, and ultimately to its abandonment.

The above comparisons make it abundantly clear that small farmers in the hill and mountain areas are in desperate need of farming systems and technologies that will enable them to produce sufficient and reliable yields from their sloping lands, but which will not deplete the resource base on which they depend.

Agricultural resources and extension workers in many parts of the world have made efforts to overcome the problems of slope stabilisation and erosion control, and to restore and enhance the fertility of the soil and its productivity. Among the many solutions that have been proposed, one stands out, on account of its capability to provide an answer to the problems of both erosion control and soil fertility enhancement.

The solution concerned is the so-called Sloping Agricultural Land Technology, or "SALT", which has been developed and perfected by the Baptist Rural Life Centre at Kinuskusan, Bansalan, on Mindanao Island in the Philippines, operating internationally under the name, Asian Rural Life Development Foundation (ARLDF).

Under the SALT system, the degraded slopes are divided into strips of land for cultivation (4-6m wide, depending on the gradient), separated by double hedgerows of nitrogen-fixing trees or bushes planted along contour lines. These hedgerows are the key element of the entire system. They act as erosion barriers and stabilisers for hill slopes. The hedgerows also contribute to soil fertility through nitrogen-fixation, and the biomass of the hedges is either used as mulch for soil cover and soil moisture conservation, or as animal fodder to be recycled back into the soil as compost.

SALT, as a biologically-based system, has to be designed to suit location-specific ecological conditions, as far as annual and perennial crops for production strips are concerned. SALT works best under tropical and sub-tropical conditions with even rainfall distribution, which permits multiple-cropping in production strips. Because the island of Mindanao, in the Philippines, is located in the tropics, the work of the researchers, under the Reverend Watson at the Baptist Rural Life Centre at Kinuskusan, concentrated on perfecting SALT for tropical conditions during the initial years (late 1970s and early 1980s). Subsequently, ARLDF and other agencies, including the German Technical Cooperation and Australian Aid, introduced SALT not only to other Southeast Asian countries but also to areas having sub-tropical and warm - temperate conditions.

SALT was incorporated into the ICIMOD Mountain Farming Systems' Programme on "Replication of Successful Experiences as Low Cost Options for Sustainable Mountain Agriculture" in 1992. ICIMOD's interests in this technology received encouragement from the active cooperation extended by the Asian Rural Life Development Foundation which shared its knowledge and experiences. During the past two years, several joint initiatives have been carried out by the two institutions, and these led to the organisation of training, the production of a video film on SALT, and the establishment of prototype models of SALT at the Godavari ICIMOD site and in other areas in the HKH countries.

This Occasional Paper is another result of the joint efforts of ARLDF and ICIMOD. It is primarily intended to meet the information needs of development planners/administrators, field researchers, and extension agencies. It should also be of interest to donors of agricultural development projects/programmes, scientists in research institutes, and local NGOs. The paper is meant to stimulate the readers' interest in SALT and also help them reorient their approaches so as to contribute to the emergence of sustainable forms of mountain agriculture.

Before concluding, I wish to express my most sincere thanks and appreciation to the two principal authors: the Rev. Harold R. Watson of the Asian Rural Life Development Foundation (ARLDF) and Dr Tej Partap of the Mountain Farming Systems' Programme of ICIMOD, for their joint efforts in producing this very valuable and useful publication. I also wish to thank others at ARDLF, ICIMOD, and GTZ and Australian Aid who contributed to this task.

E.F. Tacke
Director General
March 1994

# ACKNOWLEDGEMENTS

In ICIMOD, the Sloping Agricultural Land Technology (SALT) programme received the personal attention of Dr E.F. Tacke, the Director General. It was he who proposed that both of us should work together to produce a publication on SALT, combining the insights and experiences of ARLDF and analysing the potentials and constraints for its replication in the HKH Region. Right from its inception to the final stages of publication, Dr Tacke was a consistent source of inspiration in accomplishing this job. Both of us are greatly indebted to him and wish to thank him for his enthusiastic support.

Others also deserve our appreciation and thanks for their notable contributions: Dr Warlito A. Laquihon and Mr J. Jeff Palmer, senior staff members of ARLDF/MBRLC, who helped one of us (the Rev. Watson) to put the MBRLC experiences together; Dr M. Banskota, Dr N.S. Jodha, Dr P. Sharma, and Mr B.R. Bhatta, all senior staff members of ICIMOD, who reviewed the first draft and suggested appropriate revisions to increase the usefulness of the publication; and Dr Uma Partap who volunteered to undertake the botanical editing of the document. The two external reveiwers, Dr M.D. Upadhya, Regional Director, International Potato Centre, South Asian Region, and Mr Badri Dahal, Director, Institute for Sustainable Agriculture, Nepal (INSAN), deserve appreciation for the speed and efficacy with which they performed their task.

The cooperation received in terms of sharing information and experiences from the SALT cell of the Chengdu Institute of Biology, headed by Dr Tang Ya and Wei Taichang, and the Ningnan County leadership, Sichuan, China; the SALT Project of the Chittagong Hill Tracts' Development Board (CHTDB), Bangladesh; the Mountain and Desert Research Cell of Pakistan Agricultural Research Council; the Institute for Sustainable Agriculture, Nepal; and the GB Pant National Institute for Himalayan Environment and Development, Almora, India; also deserves mention here. In preparing this document, we have also benefitted from the experiences of the sloping lands' management programme of the International Board for Soil Research and Management; the Thai-Australia Highland Agriculture and Social Developement Project (TAHASD) - specifically for grass strip technology; and the Upper Mahaweli Watershed Development Project (UMWP), Sri Lanka. The UMWP was kind enough to share with us their findings on hedgerow species, which are included in Chapter 4. The Alley Farming Network for Tropical African Nations (AFNETAN) supplied information on the activities related to alley farming ( SALT) in Africa. We have liberally quoted the work and experiences of these and other organisations, while giving due credit to them, wherever it was necessary.

We would also like to record our appreciation of the Asian Development Bank, Manila, for supporting the whole SALT programme of ICIMOD, including this publication. Finally, the commendable job performed by the Publications' Unit of ICIMOD, in publishing this document so speedily, is duly acknowledged.

Tej Partap

Harold R. Watson

# Contents


| | | Page |
|---|---|---|
| 1. | MOUNTAIN AGRICULTURE IN TRANSITION: THE CHALLENGES | 1 |
| 1.1 | Unsustainability Symptoms | 1 |
| 1.2 | The Common Problems of Mountain Farmers | 3 |
| 1.3 | Major Contributing Factors | 9 |
| 1.4 | Traditional Systems of Resource Management: Limits and Breakdowns | 10 |
| 1.5 | Summary | 14 |
| 2. | SUSTAINABLE USE OF SLOPING LANDS | 21 |
| 2.1 | Search for Innovative Approaches | 21 |
| 2.2 | Regenerative Technologies for Soil Erosion Control on Sloping Farm-lands | 21 |
| 2.3 | Regenerative Technologies for the | 24 |
| 3. | SLOPING AGRICULTURAL LAND TECHNOLOGY (SALT) | 29 |
| 3.1 | Background to the Evolution of the Technology | 29 |
| 3.2 | The SALT Philosophy and Rationale | 31 |
| 3.3 | The Four Salt Systems (SALT - 1, 2, 3, and 4) | 32 |
| 3.4 | Characteristic Features of the SALT Farming System | 34 |
| 3.5 | SALT Experimental/Demonstration Models Maintained at MBRLC | 35 |
| 4. | THE CRITICAL ROLE OF HEDGEROWS | 43 |
| 4.1 | Principles and Functions of Hedgerows | 43 |
| 4.2 | Opting for NFTs in the Hedgerows | 45 |
| 4.3 | Limiting Factors of NFT Legumes | 46 |
| 4.4 | Promising Hedgerow Species | 48 |
| 4.5 | Hedgerow Evaluation System | 50 |
| 4.6 | Hedgerow Experiences of ICIMOD and Others | 52 |
| 4.7 | Hedgerows, Agroecological Zones, and Information Needs | 53 |
| 5. | THE PERFORMANCE EVALUATION OF SALT | 59 |
| 5.1 | The Biophysical Appropriateness of SALT | 59 |
| 5.2 | The Socioeconomic Acceptability of SALT Farming | 67 |

| | | |
|---|---|---|
| 5.3 | Overall Economic Assessment of SALT Systems | 71 |
| 5.4 | Comparative Experiences of Related Technologies | 74 |
| **6.** | **REPLICATION OF SALT: BENEFITS, PRECONDITIONS, AND PROGRESS** | 79 |
| 6.1 | Potential Reasons for Advocating the Replication of SALT | 79 |
| 6.2 | Farmer-level Concerns for the Adoption of SALT | 87 |
| 6.3 | Progress in the Wider Application of SALT | 92 |
| **7.** | **SCOPE AND INITIATIVES FOR REPLICATING SALT IN THE HKH** | 99 |
| 7.1 | Scope for SALT in the HKH | 99 |
| 7.2 | ICIMOD Initiatives and Outcomes | 101 |
| **8.** | **SUMMARY AND CONCLUSIONS** | 109 |
| 8.1 | The State of Sloping Land Resources | 109 |
| 8.2 | Search for Sustainable Land Use Options | 109 |
| 8.3 | Wider Application of SALT | 110 |

**ANNEXES**

| | | |
|---|---|---|
| 1: | Ten Basic Steps for Setting up the SALT System | 115 |
| 2: | The Critical Considerations for Evaluating SALT | 127 |

**REFERENCES** 133

**List of Tables**

| | | |
|---|---|---|
| 1.1: | Indicators of Unsustainability/Decline of Mountain Agriculture (Timeframe 1954-91 = 37 Years Approx.) | 2 |
| 1.2: | The Extent and Causes of Land Degradation in the Countries of the Hindu Kush-Himalayan Region | 3 |
| 1.3: | Overview of Soil Erosion from Sloping Farmlands* (T/ha/yr) | 4 |
| 1.4: | Estimated Soil and Nutrient Losses by Rainfall Erosion under Different Land Uses | 5 |
| 1.5: | Economic Valuation of Soil Erosion for Level Terraces Growing Monsoon Paddy (1987/88) | 7 |
| 1.6: | Economic Valuation of Soil Erosion for Sloping Farmlands Growing Monsoon Maize (1987/88) | 7 |
| 3.1: | Simple Comparisons between SALT and Non-SALT Farms | 30 |
| 3.2: | Land Use Characteristics of Different SALT Systems | 33 |

| | | |
|---|---|---|
| 4.1: | Promising Hedgerow Species Tested at MBRLC | 48 |
| 4.2: | Biomass Production Evaluation for Contour Hedgerows (1982-92) | 49 |
| 4.3: | Hedgerow Biomass Production Evaluation Under Different Treatments (MBRLC) | 51 |
| 4.4: | Growth Characteristics of Seven Hedgerow Species | 53 |
| 4.5: | Recommended SALT Hedgerow Species for Tropical Highland Areas | 54 |
| 5.1: | Land Uses under SALT-farmed and Traditionally-farmed Sloping Lands | 59 |
| 5.2: | Soil Loss from SALT-farmed and Traditionally-farmed Sloping Lands | 60 |
| 5.3: | Physical Indicators of Change in the Soil Properties of SALT and the Traditionally-farmed Sloping Land Data from MBRLC test plots | 61 |
| 5.4: | Rainfall, Sediment Load, and Water Runoff from SALT and Traditionally-farmed Plots over a Period of 17 Months (Aug 1991 - Dec 1992) | 63 |
| 5.5: | Maize Yields from SALT Plot and Control Plot (Sloping Land) | 64 |
| 5.6: | Comparison of Maize Crop Yields on SALT and Control Plots, with and without Fertiliser Inputs | 66 |
| 5.7: | Study of Nutrient (NPK) Deficiency in SALT Farming | 66 |
| 5.8: | Cost Return Analysis of the One-hectare SALT Farm (MBRLC) (Data of12 years - 1980 to 1992 in US$) | 69 |
| 5.9: | The Cost Return Analysis of SALT-2, 1987-1991 | 72 |
| 5.10: | Cost Return Analysis of SALT-3, 1987-1991 (Per ha in US$) | 73 |


**List of Figures**


| | | |
|---|---|---|
| 1.1a: | Relationship between Topsoil Depth and Maize Grain Yield | 6 |
| 1.1b: | Relationship between Topsoil Depth and Soil Productivity | 6 |
| 2.1: | Relative Yield Trends of Crops under Three Different Cultivation Practices | 26 |
| 5.1: | Bi-weekly moisture readings at a six-inch depth in a SALT and Traditional Farmer's farming system. | 62 |
| 5.2: | Productivity Changes due to SALT and NPK Inputs | 65 |
| 5.3: | Comparison of Net Incomes from SALT and Non-SALT Farming | 69 |
| 5.4: | Comparison of Labour Requirements between SALT and Non-SALT Farming | 70 |
| 5.5: | Comparative Soil Loss for Different Cultivation Practices | 75 |

# 1. MOUNTAIN AGRICULTURE IN TRANSITION: THE CHALLENGES

## 1.1 Unsustainability Symptoms

Agriculture in the mountains, broadly defined to cover all land-based activities such as cropping, animal husbandry, horticulture, forestry, and their linkages and support systems, is a primary source of sustenance for most of the mountain populations. It is a dominant user of the natural resource base and the production environment. Thus, the future of the majority of people living therein as well as the future of the environment of mountain ecosystems are closely linked to the nature and performance of agricultural activities. Sustainable agricultural strategies for the mountain ecosystems, therefore, require that conditions be created for a production system that can ensure an enhanced but stable flow of products and services without degrading or depleting the potential of the natural resource base of agriculture in the long run.

However, barring few exceptions, the current situation is contrary to it, reinforcing a process of poverty - resource degradation - scarcity-poverty. The importance of agriculture as a source of sustenance for the people, is rapidly declining, be it from the perspective of agricultural productivity, per capita product and resource availability, the economic conditions of the majority of hill farmers, or the environmental resource situation. This is happening because of declining per capita availability of usable land resources and their falling productivity, or carrying capacity.

The general symptoms of decline in the agricultural sustainability of the Hindu Kush-Himalayas (HKH), as listed by Jodha and Shrestha (1993), include:

(a) increased population and resulting pressure on farmland in terms of declining per capita availability of cultivated land;
(b) decline in the biophysical resource base of mountain agriculture to sustain the pressure of an increasing population;
(c) decline or stagnation in the productivity of croplands due to erosion and land degradation, visible through poor crop yields; and
(d) decline or discard of diversification and resource-regenerative farming practices.

A long list of emerging indicators of unsustainability of mountain agriculture was prepared, based on studies conducted mainly under ICIMOD's Mountain Farming Systems' Programme on 'dynamics of unsustainability' (Shrestha 1992). The more important indicators among those identified by the study are presented in Table 1.1.

These negative changes in mountain agriculture reveal that, barring a few exceptions of improvement, the conditions of mountain habitats and their people are steadily deteriorating, although the pattern and magnitude do vary from area to area and among regions.

Poverty, both ecological and economic, prevails among a large percentage of mountain farmers. An increasing number of people find fewer and fewer accessible resources to meet their needs for food, fodder, fuel, and fibre. Environmental problems, such as the accelerated degradation of agricultural, forest, and pasture lands, have increased considerably over the years.

In sum, degradation and unsustainability of mountain agriculture are taking place, as

**Table 1.1: Indicators of Unsustainability/Decline of Mountain Agriculture (Timeframe 1954-91 = 37 Years Approx.)**

| Indicators | Range of Changes | Indicators | Range of Changes |
|---|---|---|---|
| I. RESOURCE BASE | | II. PRODUCTION FLOW | |
| 1. Landslides | + 100 - 300% | 18. Average crop yields on sloping lands<br>(a) maize and wheat<br>(b) millet | <br>- 9 - 15%<br>- 10 - 72% |
| 2. Gully formation on sloping lands | High - Medium | 19. New land under cultivation | + 5 - 15% |
| 3. Soil erosion rates on sloping lands | +20 - 30 % | 20. Human population | + 60 - 65 |
| 4. Abandonment of agricultural land due to decline in fertility | + 3 - 11% | 21. Application of compost (organic manure) | - 25 - 35% |
| 5. Appearance of stones/rocks on cultivated land | + 130 - 200% | 22. Labour demand for falling productivity | + 35 - 40% |
| 6. Size of livestock holding per family (LSU) | - 20 - 55% | 23. Forestry-farming linkages | Weak - Weak |
| 7. Area of farmland per household | - 30 - 10% | 24. Foodgrain purchases from shops | + 30 - 50% |
| 8. Forest area | - 15 - 85% | 25. External inputs' needs for crop production | High - Medium |
| 9. Pasture/grazing area | - 25 - 90% | 26. Fuelwood fodder scarcity in terms of time spent in collection | + 45 - 200% |
| 10. Good vegetative cover on common property lands | - 25 - 30% | 27. Fodder supply from<br>(a) common land<br>(b) private land | <br>- 60 - 85%<br>+ 130 - 150% |
| 11. Fragmentation of household farmland (in number of parcels) | + 20 - 30% | III. RESOURCE MANAGEMENT | |
| 12. Size of land parcels of families | - 20 - 30% | 28. Emphasis on monocropping | High - High |
| 13. Distance between farmland parcel and home | + 25 - 60% | 29. Steep slope cultivation (above 30%) | + 10 - 15% |
| 14. Foodgrain production and self-sufficiency | - 30 - 60% | 30. Weed and crop herbaceous products' use as fuelwood | + 200 - 230% |
| 15. Permanent outmigration of families | None - 5% | 31. Conversion of marginal land into cultivation | + 15 - 40% |
| 16. Seasonal migration | High - High | 32. Fallow periods | From 6 to 3 month |
| 17. Conversion of irrigated land into dry farming due to water scarcity | + 7 - 15% | | |

Source: 'CRISIS AREAS' STUDY' conducted by ICIMOD's Mountain Farming Systems' Programme (MFS Discussion Paper No. 32, S. Shrestha 1992).

Note: A positive sign (+) means increase and negative (-) means decline/decrease evidenced by reduced quality and range of options, increased degree of desperation, and reduced level of flexibility which are manifaested in several ways (Jodha and Shrestha 1993).

The more important contributing factors and issues, among the whole range of causes and symptoms of decline, are further elaborated upon in the following section.

## 1.2 The Common Problems of Mountain Farmers

### i. *Degradation of Land*

Land degradation is a quiet crisis that is unfolding gradually in the hilly and mountain areas. Over time, people have used land resources haphazardly, either by converting most marginal and sub-marginal lands, including forest and pasture/grazing lands (which can be considered as supportland for farming), into cultivated land, or by over-exploitation of the vegetation resources on these supportlands. The scale and dimension of degradation have been further enhanced by the natural fragility and marginality of the steeper lands brought to the plough by the expanding number of marginal/small upland farmers. Within the HKH Region, an alarming trend in and extent of land degradation are apparent as shown in Table 1.2 (Plates 1.1 and 1.2).

**Table 1.2: The Extent and Causes of Land Degradation in the Countries of the Hindu Kush-Himalayan Region**

| Country | Extent of Land Degradation | Causes of Degradation |
|---|---|---|
| Afghanistan | 39.8 million ha of mountainous land seriously affected | **Natural Factors**<br><br>High potential for degradation - steep slopes, unstable geology, short periods of heavy rainfall, high speed winds, flooding, drought<br><br>**Demand Factors**<br><br>Rapid increase in human and livestock populations<br><br>**Unsound Management Practices**<br><br>Uncontrolled and excessive grazing, poor soil management practices, improper forest harvesting, unmanaged mining activities<br><br>**Harmful Practices**<br><br>Setting fires to forests, environmentally unsound infrastructural activities<br><br>**Macro-policy Related Factors**<br><br>Land ownership problems, unplanned urbanisation, inappropriate land-use practices, lack of environmentally sound guidelines for land use |
| Hilly areas of Bangladesh | 1 million ha of hill area affected | |
| Bhutan | 1.6 million ha of hill area affected | |
| Chinese Himalayas | 209 million ha of northern hill area affected | |
| Indian Himalayas | 17.3 million ha affected | |
| Uplands of Myanmar | 17.6 million ha of land area degraded | |
| Nepal | 1.8 million ha estimated to be degraded | |
| Northern mountains of Pakistan | 20 million ha estimated to be degraded | |

Source: Bhatta 1990

*ii. Magnitude of Soil Erosion*

There is a lot of evidence (Shrestha 1992, Banskota 1992, and FAO 1991 & 1993) to indicate that soil erosion from agricultural activity on sloping lands has been, by and large, the major contributor to land degradation. This is further exacerbated by excessive animal pressure on grazing lands and from the degradation of forests. Data recorded for soil erosion rates, from different agricultural lands (Table 1.3), are indicative of the dimensions of the problem. What is being observed in these areas is an evolving process of non-sustainable production systems.

**Table 1.3: Overview of Soil Erosion from Sloping Farmlands* (T/ha/yr)**

| S. No. | Site/Area | Type of Land Use | Soil Erosion T/ha/yr |
|---|---|---|---|
| 1. | Throughout Nepal | - Sloping farmlands under farmers' practices | 20.0 |
| | Nepal | - Grazing lands (supportlands) | 100.0 |
| | Nepal | - Rainfed terraces | 5.0 |
| | Nepal | - Irrigated terraces | 0.0 |
| 2. | Jhikhu Khola (redsoil), Mid-hills of Nepal | - Sloping farmlands under farmers' practices | 38.0 |
| 3. | Eastern high mountains | - do - | 2.8 |
| 4. | Pakhribas, Nepal | - do - | 3.6 |
| 5. | Southern Bhutan | - do - | 1.0 |
| 6. | Eastern Himalayas, India | - do - | 54 |
| 7. | Uplands of NE Myanmar | - do - | 55 |
| 8. | South China, Uplands (red soil) | - do - | 57.0 |
| 9. | Highland areas of Northern Thailand (Chiang Mai) | Traditional farming<br>Terraced farming<br>Grass strips<br>Strip cropping | 120<br>1.9<br>1.6<br>16 |
| 10. | Upland areas of Malaysia | Sloping farmlands under farmers' practices | 101 |
| 12. | Upland areas of Mabini, the Philippines | - do - | 100 |
| 13. | Upland areas of Tamay, the Philippines | - do - | 36 |
| 14. | Upland areas of Indonesia | - do - | 88 |
| 15. | Upland areas of Vietnam | - do - | 3.3 |

Source: Compiled from various sources (project reports and documents of IBSRAM, ICIMOD, and IDRC)

The gravity of the soil erosion problem in the HKH Region is highlighted here with an example from Nepal - a typical mountain country of the HKH Region. The erosion processes in the hill and mountain areas of Nepal are complex and include natural (geological) and man-induced erosion. In addition to the natural forces, increasing population on limited land resources has played a contributing role in forest clearance, over-grazing, and poorly maintained marginal arable lands. The most serious problem is the loss of topsoil from the increasing sloping farmlands and grazing lands. As topsoil erodes, fertility declines and the soil is less able to maintain its productive capacity. Estimates of soil erosion and associated loss of nutrients are provided in Table 1.4. Notably, nutrient losses through soil erosion are more significant against the background of the prevailing system of low inputs.

**Table 1.4: Estimated Soil and Nutrient Losses by Rainfall Erosion under Different Land Uses**

| | Irrigated Rice Land | Level Terraces | Sloping Terraces | Shifting Cultivation |
|---|---|---|---|---|
| Proportion of Total Land (%) | 69.2 | 8.9 | 20.6 | 1.3 |
| Soil Depth (cm) | 0.0 | 0.4 | 1.6 | 8.0 |
| Soil Loss (kg/ha/yr) | 0.0 | 5000.0 | 20,000.0 | 100,000.0 |
| Organic Matter Loss (kg/ha/yr) | 0.0 | 150.0 | 600.0 | 3,000.0 |
| Nitrogen Loss (kg/ha/yr) | 0.0 | 7.5 | 30.0 | 150.0 |
| Phosphorous Loss (kg/ha/yr) | 0.0 | 5.0 | 20.0 | 100.0 |
| Potassium Loss (kg/ha/yr) | 0.0 | 10.0 | 40.0 | 200.0 |

Source: LRMP 1986

The loss of topsoil has affected the ability to grow food in two ways. First, it has reduced the inherent productivity of land, both through the loss of nutrients and the degradation of the physical structure (Figures 1.1a & b). Second, it has also increased the cost of food production. Increasingly, farmers losing topsoil are trying to increase land productivity by substituting energy in the form of fertilisers. Hence they are facing either a loss in land productivity or a rise in the cost of agricultural inputs. In cases in which farmland productivity has become too low or in which the agricultural costs have become too high for farmers to afford, farmlands are being abandoned (Scheewe 1993 and LRMP 1986) (Plates 1.3 and 1.4).

An indicative economic evaluation (Banskota 1992) of topsoil loss, showing the erosion and corresponding nutrient losses from the soil for different categories of agricultural land in Nepal, revealed soil erosion to be one of the most critical environmental problems and that available soil resources are being lost at an alarming rate (Tables 1.5 and 1.6.).

When these nutrient losses are compared with available arable land, the results show an interesting trend. The total amount of nitrogen lost from level terraces (3,65,000ha) and sloping farmlands (8,16,000ha) is about 27,000 metric tonnes, whereas the total amount of nitrogen-fertiliser used in 1987/88 was only 24,320 metric tonnes. The total loss of combined nutrients exceeded the level of inputs used in 1987/88.

The value of nutrient loss has been estimated at over Rs 6.0 million for paddy and at over

**Figure 1.1a: Relationship between Topsoil Depth and Maize Grain Yield**

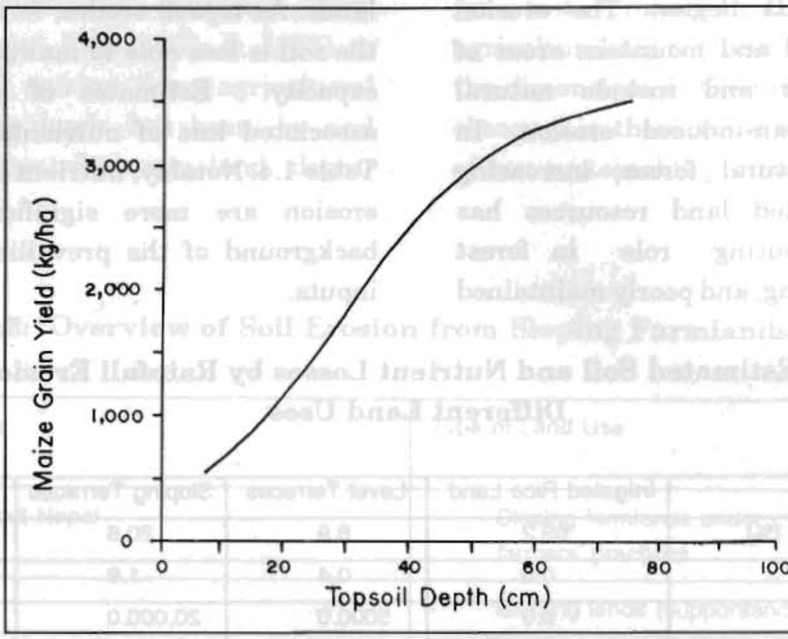
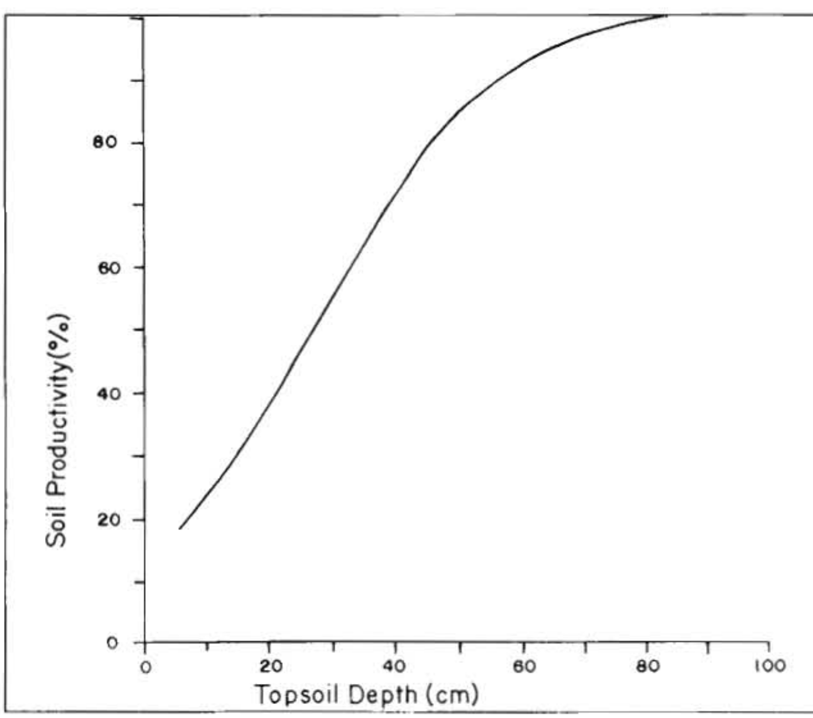



**Figure 1.1b: Relationship between Topsoil Depth and Soil Productivity**




Source: Computed from MBRLC findings

**Table 1.5: Economic Valuation of Soil Erosion for Level Terraces Growing Monsoon Paddy (1987/88)**

| Type | Losses | Total Losses from 365,000ha (T/yr) | Prices of Inputs (Rs/T) | Total Value of Inputs (Rs/T) | Recommended Input and Output Levels for Paddy (kg) | | Equivalent of Paddy Lost because of Soil Erosion (T) |
|---|---|---|---|---|---|---|---|
| | | | | | Input | Output | |
| Soil | 5000.0 | 1825000.0 | - | - | - | - | |
| Organic Manure | 150.0 | 4750.0 | 16.0 | 876000.0 | 2052.0 | 792.0 | |
| Nitrogen | 7.5 | 2750.0 | 867.0 | 2372979.0 | 60.0 | 1185.0 | 54055.7 |
| Phosphorous | 5.0 | 1825.0 | 867.0 | 1582275.0 | - | - | - |
| Potassium | 10.0 | 36.5 | 333.0 | 1214450.0 | - | - | - |
| Total | | - | - | 6046704.0 | - | - | - |

Source: Banskota 1992

**Table 1.6: Economic Valuation of Soil Erosion for Sloping Farmlands Growing Monsoon Maize (1987/88)**

| Type | Losses Equiv. | Total Losses from 365,000ha (T/yr) | Prices of Inputs (Rs/T) | Total Value of Inputs (Rs/T) | Recommended Input and Output Levels for Maize (kg) | | Equivalent of Maize Lost because of Soil Erosion (T) |
|---|---|---|---|---|---|---|---|
| | | | | | Input | Output | |
| Soil | 20000.0 | 16320000.0 | - | - | - | - | |
| Organic Manure | 600.0 | 489600.0 | 16.0 | 7833600.0 | 6080.0 | 712.0 | 57334.7 |
| Nitrogen | 30.0 | 24480.0 | 867.0 | 21224160.0 | 689520.0 | | |
| Phosphorous | 20.0 | 16320.0 | 867.0 | 14149440.0 | 30.0 | 1,690.0 | - |
| Potassium | 40.0 | 32640.0 | 333.0 | 10869.0 | 120.0 | | - |
| Total | - | - | - | 54076320.0 | - | | 746854.7 |

Source: Banskota 1992

54.0 million for maize, at 1987/88 market prices. The implications in terms of equivalent foodgrain loss are even more significant. The total losses were equivalent to about 75,000 tonnes of paddy and 7,47,000 tonnes of maize. These large losses indicate the difficulties experienced in sustaining food production when soil fertility is being depleted at massive rates. It is further argued (Banskota 1992) that, the extent to which the nutrients supplied from outside can offset these losses is at best limited, particularly in the maize-growing hill areas.

*iii. Declining Crop Yields*

Available reports confirm that the overall soil fertility status throughout the Himalayan Region is very poor (Shah and Schreier 1991). This is compounded by the fact that farming is generally practised on sloping farmlands, aggravating soil erosion and associated nutrient losses. Further, in red soils, which occur throughout large areas of the Himalayas, soil acidity and phosphorous availability are of particular concern with respect to maintaining a good nutrient pool (Shah and Schreier 1991).

A more serious dimension of the situation is that, for several reasons related to land degradation, the productivity of farmlands in the upland areas has been recording either a steady decline or stagnation in crop yields. For instance, average crop yields declined within the range of 5 to 30 per cent during the past few decades in a number of mountain watersheds in the Indian Himalayas, in Nepal, and in the Tibet Autonomous Region of China. (Banskota 1992, Shrestha 1992, Bajracharya 1992, Singh 1992, Yanhua 1992, and Swarup 1991).

In rainfed uplands, where maize and millet are dominant summer crops, soil fertility is maintained mainly by the application of compost or manure. Other methods of maintaining soil fertility include the trapping of flood water, 'cutting and carrying' natural green manure species into rice paddies, planting grain legumes in rotation, slicing weeds and soil from terrace risers and spreading them on the field, a short fallow period, burning of crop residues, and mulching with forest litter (Riley 1991 and Sthapit et al. 1989); nevertheless there are indications of weakening forestry-farming linkages (Yadav 1990 and Shrestha 1992), blocking the flow of nutrient cycling from forest to farmland.

Bhutan is a case which is considered by some to be a typical example of an area maintaining better balance between agriculture and the environment, simply because there still are ample forest areas. Here agriculture is the main source of livelihood, and only 30 per cent of the agricultural land is terraced and irrigated - the remaining 70 per cent with slopes exceeding 30° falling under the dryland category. The per capita cultivated land varies between 0.57ha to 0.13ha and the country average is 0.28ha. The visible manifestations of upland degradation in Bhutan are similar to those in other parts of the Himalayas (Thinley 1991). The loss of fertile topsoil from the limited cultivated land in the country has caused many Bhutanese farmers, to abandon their traditionally cultivated land and to move on to other marginal lands. Thinley (1991) argues that this is happening because of decline in the productivity of farmlands.

*iv. Increasing Food Insecurity*

An ICIMOD study in the mid-hills of Nepal (Panday 1992) highlights the increasing food insecurity situation among mountain farmers in resource poor areas. The study revealed that 86 per cent of the households in Bhardeo village were experiencing food deficits to varying degrees. Among them, over 50 per cent suffered food deficits for at least six months each year. It further concluded that the production of adequate amounts of food on small landholdings, with ever-declining farm productivity, is almost impossible. Bhardeo is an example of a food deficit area with its resulting chain of reactions. It depicts the increasing trend of food insecurity in resource poor, heavily populated mountain areas.

In a number of other countries, the related concerns for local food security and rapid agricultural growth are being pursued through the promotion of intensive cropping of both food and cash crops by using high external inputs. The farm economies of these areas have resulted in food security of a kind, but in these strategies the value of diversification, local resource regeneration, and recycling, essential for sustainable agriculture, has been undermined (Jodha 1993). These foodgrain-focussed strategies have led to the extension of cropping on to sub-marginal lands and steep slopes not suited for annual cropping and have also increased cropping intensity on traditional croplands. This has resulted in increased physical degradation of fragile lands, and the cost of maintaining production on these lands is increasing.

*v. Biomass: Gaps in Demand and Supply*

The decline in productivity is not seen only on farmlands, but one finds a wide range of shortages in biomass production, e.g., in the form of fodder, fuelwood, or other forest products, on which the sustenance of the mountain people depends. Small farming families facing food deficits try to extract their sustenance from supportland resources. This is mainly accomplished through an increasing depen-dence on livestock or through products and services offered by supportland resources.

An average person in Nepal uses 640kg/yr of firewood. The estimated yield of firewood per capita from the forests of the country is about 479kg per year, i.e., 75 per cent of the actual demand (Banskota 1993). The demand gap may vary, but there are unmistakable symptoms (Table 1.1) indicating an increase in the shortage of fuelwood.

Keeping in mind all the basic requirements of farm families from the supportlands, Wyatt Smith (1982) calculated that about three to four hectares of supportland (forests and grazing land/pastures, etc) are required to maintain one hectare of cultivated land for normal production in the middle mountains of the central Himalayan region, notably in Nepal. Studies indicate (Shrestha 1992) that in many areas this supportland to agricultural land ratio has gone down to 0.5ha:1ha from 4ha:1ha.

Further, assuming that an average of 2.5ha of supportland is needed to maintain one hectare of agricultural land, the degradation of 1.5 million ha of agricultural forests will affect more than 0.5 million ha of agricultural land. If this is further calculated in terms of foodgrains, the magnitude of loss is likely to be enormous.

## 1.3 Major Contributing Factors

The trends of degradation in several spheres of mountain agriculture, in particular, and the environment, in general, are invariably attributed to a number of causal factors. However, the two main causes, related to the topic under discussion in this paper, are increased population in the uplands, leading to a deficiency in arable land resources, and the promotion of non-regenerative technologies to improve farming. These two issues are discussed below in more detail.

*i. Population Pressure*

Rapid growth in population during the past decades is clearly the most crucial factor leading to unsustainability. The HKH Region, for example, is home to 117 million people (1991 estimates) and its overall population density is 34 persons/sq.km. The data for some of the areas show quite clearly that the current population of the HKH is almost double that of five decades ago (Sharma and Partap 1993). The increase in population density is likely to continue, especially in habitable areas of the mountains.

Furthermore, most people sustain themselves through agriculture and its different land-based activities (cropping, animal rearing, forestry, horticulture, etc). This is indicated by the fact that from approximately 56 to more than 80 per cent of the working population of the region are engaged in agriculture (Sharma and Partap 1993). This figure increases further if agriculture is taken as a composite of multiple land-based activities and only rural areas are considered.

An important indicator of the pressure on land is the size of cultivated landholdings. The average size of per capita cultivated land in 1980/81, was 0.097ha in the Chittagong Hill Tracts of Bangladesh and 0.272ha in the State of Sikkim in India. The situation in the remaining areas fell within this range. In most areas, the per capita cultivated land declined by 30 to 45 per cent between 1960 to 1980. This occurred despite the extension of agriculture to sub-marginal lands/steep slopes. The main indicator of the unsustainability of mountain agriculture is the fact that, wherever there is an increasing demand of, or dependency on, arable land resources, the availability is shrinking rapidly (Sharma and Partap 1993).

*ii. Technological Gaps*

Owing to strong linkages among the various, traditionally existing components of mountain farming systems (crops, livestock, forestry, and pasture), agriculture in the uplands was usually self-supporting. Over time, these linkages weakened, partly due to the new technological interventions focussing on fossil fuel-subsidised agricultural systems. This set off a chain of reactions leading to external dependency for farm inputs. But, because of inherent mountain characteristics, such as inaccessibility, marginality, fragility, and their imperatives (Jodha 1992), these technological approaches had only limited success in more favourable areas. Improved seeds, fertilisers, pesticides, and regular, or assured, irrigation facilities, are generally not available in the mountains/uplands to complement these technologies. Studies conducted by the Mountain Farming Systems' Programme of ICIMOD revealed that, over the past few decades, a general environment created for promoting these new technological options for improving farm production further accelerated the discontinuation of traditional biomass-centered, local resource-based, regenerative production options (Jodha et al. 1992 and Jodha and Partap 1993).

### 1.4 Traditional Systems of Resource Management: Limits and Breakdowns

*i. Terracing*

Terracing has been a critical aspect of sloping farmland management, because of its ability to reduce erosion substantially. The scale of terracing can be gauged from the fact that 30 per cent of the arable land (3,65,000ha) in Nepal (LRMP 1986); 30 per cent in Bhutan (Thinley 1991); and almost an equal percentage in India, Pakistan, and the Chinese Himalayas (Das and Maharjan 1988) is under various forms of terracing. In general, sloping farmlands are managed by forming a variety of terraces, each reflecting the physical and socioeconomic attributes of the village lands on which they occur. Irrigated rice terraces are flat, and rainfed terraces tend to be gently outwards or sideways sloping so as to join terraces at different levels. Thus, different production systems within different climatic zones of the HKH have adopted distinct terrace forms (Das and Maharjan 1988). They usually reflect local soil conditions, regional climatic conditions, cropping preferences, local productivity, and the profitability of the farming systems (Plate 1.5).

Within the middle mountains of the central Himalayan region, terracing is essential for arable cultivation on slopes of over 20 degrees. As one moves higher into the mountains the rainfall intensity drops, and the terrace system becomes less developed on even steeper slopes. In the Siwaliks, surface runoff control is an unsurmountable problem because of high intensity rains and the low infiltration capacity of the soils that occur there. Consequently, terrace systems are uncommon.

A prerequisite for terrace systems is that the farmer should be able to maintain soil fertility, and this is where the system is no longer functioning. The lack of terrace management, apparent in many areas of Nepal today, is a reflection on the overall decline in productivity of the marginalised areas of most farms. Carson (1992) felt that, project interventions that include improving bench terraces are unlikely to have a positive effect, unless the productivity and profitability of the overall farming system are improved at the same time. In Nepal, the construction of new terrace systems is rarely seen today. Rather, thousands of hectares of abandoned terraces can be seen throughout the countryside. This abandonment is a direct result of decline in soil fertility (Carson 1992).

*ii. Swidden Farming*

Swidden farming is an agricultural system in which the area to be cultivated is cleared, usually by fire, and cultivated for a shorter period and then fallowed for a longer period over several years (10-15 years).

Shifting cultivation represented a response to the difficulties of establishing an agro-ecosystem in the tropical region and an extremely successful human adaptation to the rigours and constraints of the humid tropics. In an environment of fragile forests and soils, the integrated swiddeners have developed an agroecosystem that is diverse and is able to respond to environmental uncertainties (FAO 1991). The swiddener used his knowledge of the natural environment not only to make swiddens but also to successfully gather, hunt, and fish to provide food, fibre, and medicine for the household, and even for the external market. Knowledge of both the tropical environment and the needs of the tropical crop repertoire is used to develop and manage the micro-sites of his fields. Specific crop needs are matched to specific soils - a diversity of crops meshed with a diversity of micro-environments.

Shifting cultivation is the most widespread type of soil management technique and is practised over 30 per cent of the worlds' exploitable soils (FAO 1991).

<u>Swidden Farming in the HKH Region</u>. In several countries of the HKH Region in particular, and in South East Asia in general, the primary distinguishing feature of the uplands is shifting cultivation. It is also known as slash and burn agriculture, the *taungya* system, and *jhum* cultivation (Plates 1.6 and 1.7).

In Bhutan, a large proportion (32%) of cultivated land is still under shifting cultivation. In Eastern Bhutan, up to 79 per cent of the cultivated land was under *tsheri* (Upadhya 1985) or shifting cultivation. Practised either by individual households or groups of households dwelling in permanent houses, land lying fallow for three to eight years is cleared, burned, and then crops sown by dibbling into the soil or simply by broadcasting. Farmers were harvesting yields considered to be higher than those of dryland agriculture and which required less labour. The productivity of these lands, however, is reportedly on the decline due to heavy grazing on fallow lands, decreased fallow periods, reduced species' diversity, and depredation by animals.

In the north-eastern Indian Himalayas, shifting agriculture, or *jhuming*, is a predominant land-use system, supporting 1.6 million tribal people over an area of 426 million hectares (Castro 1991). In its typical form of a 20 to 30 years' cycle, *jhum* was a highly bioproduc-tive system, but increased populations and reduced acreage have reduced the *jhum* cycle to four to five years. In the Nagaland State of the NE Indian Himalayas, for example, as much as 42 per cent of the land is under shifting cultivation. An estimated 1,000sq.km. were brought under *jhum* cultivation during the last decade and the cultivation cycle, once 14 years or more, has been reduced to five years or so in many places. The shortened cycle is not enough to allow for restoration of soil fertility before the land is again cultivated, with the result that yields have declined over time. Families once totally self-sufficient in food are now barely able to produce enough food to last a year. Today, development agencies at regional and national levels are desperately looking for ways of putting a stop to shifting cultivation (Plate 1.8).

In the South Yunnan province of the Chinese Himalayas, swidden farming covered about 90 per cent of Xishuangbanna farmland, supporting 48 per cent of its population (Pei 1985). However, in recent years, the pressure of increased population, the need for cash crops, and the establishment of conservation parks have prevented these swiddeners from gaining access to sufficient land, resulting in the reduction of fallow periods (Pei 1985).

In Bangladesh, *jhuming* (shifting cultivation) is practised by 13 hill tribes living in the Chittagong Hill Tracts. Once, over 95 per cent of the area was covered with dense forests but today, apart from the 25 per cent reserve forests, all other areas have been converted into scrubland due to shifting cultivation. In this country too, development agencies introduced efforts a decade ago, with help from the Asian Development Bank, to find alternatives to shifting cultivation.

In Myanmar, hill farmers in the States of Kachin, Kayah, Karen, Chin, and Shan largely depend on swidden farming. Realising the problems associated with shifting cultivation in today's context, the Myanmar Agricultural Services - a government agency responsible for managing and providing agricultural services to the nation - has introduced a programme of sustainable hillside farming. The programme is intended to help shifting cultivators change over to sedentary forms of more sustainable agriculture.

The above reports are indications enough that, although swidden has been a sustainable agro-ecosystem in the past, it cannot serve as a model for the future of the tropics. Regeneration of forests is crucial for the long-term productivity and sustainability of swidden agroecosystems, and many swidden groups are no longer able to leave their fields fallow for the necessary period of time. This is not because the link between forests, soils, and productivity is no longer recognised by swidders, but because they are in a situation that makes the continuation of forest fallows impossible. The primary reasons for the shortened fallow periods are the classification of fallow land into forest reserves or logging concession areas, population growth, inmigration, and the impact of cash cropping (FAO 1991).

In many instances, all of these factors are interlinked. The swidden community, for example, may experience a constriction of its resource base as forested areas are reclassified by national authorities and reassigned to other sectors, or as laws prohibiting settlements from remaining in the forest reserves are enforced. It is not uncommon for swiddeners to be moved to a new site, far from their current fields and old fields during different stages of production.

It is in this context that swidden farmers and the agencies involved in their well-being are now looking for technologies to facilitate the transformation of the failing agroecosystem into a new system that will be sustainable. The challenge is to develop tropical agroecosystems that build upon the knowledge of the swid-dener and can be used by small farmers, not for a few years but for generations.

*iii. Agropastoral Farming*

The agropastoral system is a type of adjustment to the constraining factors of crop farming, e.g., marginal lands, high degrees of slopes, and unfavourable ecological conditions for profitable crop cultivation. Ecological conditions in uplands, where there are high mountain ranges, such as the HKH Region, rarely provide the conditions for crop farming; and agropastoral farming, which is broadly defined as an agricultural system dominated by livestock rearing, is more the norm. Crops may be an integral part of the agropastoral system but, in terms of both livelihood dependence and activities and output, livestock play a central role. To provide an overview of the structure and functional mechanisms of such systems, including the current sustainability trends, we will briefly highlight features from a study on the agropas-toral farming systems in Tibet conducted by a staff member of the Mountain Farming Systems' Programme (Liu Yanhua 1992).

Animal husbandry in the highlands of Tibet is not only an established tradition but also an important factor in the local economy. Livestock management here is characterised by semi-nomadic herding on extensive rangelands. In Lhasa district alone, the available rangeland of 26,600sq.km. is 94 times larger than the agricultural land, and on this vast rangeland pastoralism is practised with over 1.46 million head of cattle, including cows, yak, horses, mules, donkeys, goats, sheep, and swine.

Based on the economic importance of animal husbandry to the gross agricultural output value, elevation of the area, and management practices, three types of pastoral system exist in Tibet.

(a) **Auxiliary Pastoralism** is practised in valley basins where crop produc-tion accounts for 75 per cent of the agricultural output. Livestock is pastured on fallow lands, basin grasslands, and the surrounding valley slopes. Swine are the dominant livestock in this system.

(b) **Mixed Pastoralism** is prevalent on slopes, in between the highlands, and in the valleys. Here, seasonal range management is practised by driving the animals into highland pastures during summer and bringing them home during the autumn harvest.

(c) **Pastoralism-dominated System** is practised in the highland areas (above 4,200masl). Under this system, animal husbandry is the primary component of agri-culture. Herdsmen, living in shelters in the highlands, graze their herds on the surround-ing pastures during winter and spring but move to higher pastures still in summer.

In general, there has been an increase in the population of animals over the past decades (sheep-85%, cattle/yak-65%, goats-57%, horses/mules/donkeys-44%). One also finds that the composition of animals has changed since 1958. The main increase in numbers is in the case of sheep. This is because of the increasing commercial value of wool for carpet making, indicating that elements of commercialisation have been incorporated into the pastoral system.

The increase in livestock is, however, only in the highland areas because the focus of animal husbandry development has been shifting to the highland areas to harness the ecological 'niche' or comparative advantage afforded by the availability of plentiful resources for pastoralism. This is also reflected in the policy of the Tibetan Government which gives priority to animal husbandry development, followed by agriculture and forestry.

The situation of agropastoralism in the highlands, exemplified by the study in Tibet, is significant, in that, at a time when land resource availability and land conditions are disappointing in most other agroecological zones, this agroecological zone has still not been over-exploited. With rising consciousness about the environment and sustainability of farming systems, this may never happen.

Another point to be raised here is that most agropastoral systems in the HKH Region fall into the three categories and indications are that the two former categories are in good condition from the biological degradation perspective if not from the physical degradation perspective. Interventions in other mountain areas discourage agropastoral farming, even in areas where it is otherwise most suitable. Unlike Tibet, these relatively lower altitude areas are not fortunate in having large tracts of grassland, and, in whatever areas were available, there are unmistakable signs of biological impoverishment (increasing domination of unpalatable weeds, such as *Eupatorium* and *Lantana*, in the subtropical highlands) and declining livestock carrying capacities. Thus, barring a few exceptions, this system is also showing symptoms of decline in condition and carrying capacity.

## 1.5 Summary

To sum up, the following issues emerge.

(a) Population pressure in the uplands has caused extensive damage by creating resource scarcity in the otherwise marginal and fragile mountain ecosystems. Farmers are facing problems of smaller farmlands which are not big enough to feed them. Soil erosion and land degradation, causing fertility decline, are among the main contributing factors threatening the productive potential of already marginal lands. Because of these several associated contributing factors, mountain agriculture is facing a serious problem of unsustainability.

(b) The traditional systems of land management and adaptations to various ecological conditions were good under less population pressure, but the exigencies of today are rendering these traditional farming practices irrelevant, although the degree varies from one area to another.

(c) Technological interventions carried out in the past emphasised agricultural technologies that were based on external inputs and which could give maximum yields only under the most favourable conditions. This changed the direction of R & D initiatives towards maximising production-promoting external inputs, rather than focussing on the upgradation of and improvement in the productive potentials of the marginal land resources. However, decades of experience show that the experiment succeeded only partially, remaining limited geographically to more favourable areas.

(d) Further, a transition towards sustainable mountain farming, mainly based on the sustainable use of renewable resources, would require a thrust towards local resource use and regenerative technologies, reducing dependence on external inputs. Alternative regenerative options are also needed for the rehabilitation of degraded support-lands and better management of natural resources. Innovations that promote local resource management attract more attention. The alternative technological options are also expected to open up income opportunities for poorer groups such as marginal mountain farmers.

In the following chapter, our focus narrows to examine the relevance of various regenerative technological options for managing the problems of sloping farmlands and for improving the livelihood of small mountain/upland farmers.

Plate 1.1 These bare mountain agricultural fields are reminders of the increasing land degradation and weakened forestry-farming linkages, which adversely affect the productivity of farmlands in the HKH (Tej Partap).

Plate 1.2 The middle hills of Nepal. Grazing lands, also called supportlands, now provide little support to agriculture because of poor regeneration and reduced livestock carrying capacity (Tej Partap).

Plate 1.3 The Chittagong Hill Tracts of Bangladesh. Loss of topsoil and nutrients from agricultural land is resulting in poor growth and crop yields (Tej Partap).

Plate 1.4 Because of weakened forestry-farming linkages and decline in crop yields, abandonment, even of terraced lands such as those shown in the picture, is increasing (Tej Partap).

Plate 1.5 The Middle Hills of Nepal. Terracing is an important traditional adaptation mechanism for sloping farmlands in the upland areas of the HKH (Tej Partap).

Plate 1.6 Slash and burn swidden farming is common practice in the eastern Himalayan region comprising parts of India, Nepal, Bhutan, Bangladesh, Myanmar, and China (Tej Partap).

Plate 1.7 Because of land resource scarcity, swidden farming is being extended on to steeper slopes, resulting in soil erosion and decline in crop productivity (Tej Partap).

Plate 1.8 The Uplands of Myanmar. Upland farming communities, such as these people from a hill tribes of Myanmar, are compelled to replace swidden farming by sedentary agriculture (Tej Partap).

# 2. SUSTAINABLE USE OF SLOPING LANDS

## 2.1 Search for Innovative Approaches

The mountain economy is, to a great extent, based upon the use of sloping land resources. As discussed in the previous chapter, the prevailing productivity levels of these resources are not only low but are showing declining trends. At the same time, the limitations of the known traditional management systems of these sloping lands are being experienced more and more. This has necessitated the search for alternative approaches to facilitate sustainable use of these land resources.

One way of finding potential leads for evolving future strategies, that are responsive to the emerging problems/issues, can be found in the limited and sporadic success stories about regenerative agricultural technologies for the sustainable development of mountain areas, or sometimes one may find such leads through science and technology. The characteristics of these regenerative technologies revolve around the basic tenets of:

(a) diversification and higher productivity;
(b) intensification without resource degradation;
(c) resource focus, combining production and protection concerns; and
(d) integration of the inter-systemic linkages.

Further discussion on the search for sustainable options is narrowed down to approaches/options that are biological in nature (because of the regenerative focus) and are designed to meet the needs of the use and management of sloping lands. We are further limiting the discussion to such known methods or options in which formal science (R & D) has given some inputs to quantify its ecological and economic benefits.

## 2.2 Regenerative Technologies for Soil Erosion Control on Sloping Farmlands

Managing the slope constraint of sloping farmlands has received the attention of farmers and development agencies alike. The best-known mechanical system to release this constraint, as we know, is the terracing system. While looking for alternative botanical options, it was probably always kept in mind that the major problem with sloping land farming is soil erosion and that any method of controlling erosion which slowly leads to natural terrace formation may be more acceptable to farmers.

Exercises on the trial of vegetation as a barrier for soil erosion control have been going on for quite some time now. The findings show that biological soil conservation measures are quite effective in most cases. The failures are few, and in the cases of failure also one finds scope to overcome the problems. Experience has shown that vegetation-based soil erosion control measures need to be adapted to the sites and to the needs of the people. The implication of vegetation-based regenerative options for soil erosion and fertility management is that no one recipe can be applied as a blanket recommendation for all environments.

Mention should be made of the research efforts being carried out by the International Board for Soil Research and Management (IBSRAM) on the management of sloping lands for sustainable agriculture. Through its network, IBSRAM is testing a number of options to build a pool of potential biological soil conservation measures from which farmers from different agroecological zones, maintaining different farming systems, can select an option of their choice and suitability.

From the purely soil conservation point of view, the two options discussed below have been tested in the uplands of the tropics.

The benefit of maintaining soil productivity through these options is basically because of their ability to conserve nutrients.

*i. Vetiver Grass Contour Hedgerow Barriers*

The Board on Science and Technology for International Development (BOSTID) of the US National Research Council (1993) has come up with a publication on a little known tropical grass, vetiver, as a potential botanical solution for controlling soil erosion. Taken up for trial and testing only since 1985 by World Bank experts (Green Field), the document gives a high rating to the capabilities of vetiver for controlling soil erosion, cheaply, simply, and on a large scale, in both the tropics and the semi-arid regions.

Planted in lines along the contours of sloping lands, vetiver reportedly quickly forms narrow but very dense hedges. Its stiff foliage then blocks the passage of soil and debris, slows down runoff, and gives the rainfall a better chance of soaking into the soil instead of rushing down the slope. The experience gathered so far is that this deep-rooted, persistent grass has restrained erodible soils in this way in Fiji, India, and some Caribbean nations. It has recently been incorporated into conservation programmes in China, India, Nepal, the Philippines, Sri Lanka, Madagascar, Nigeria, and Zimbabwe (Plate 2.1).

The grass has a number of features that make it desirable, both from a farmer's and a project's point of view; the densely tufted perennial clumps of grass seem not to spread or become a pest and terraces rise as the soil accumulates behind the hedges, converting erodible slopes into stabilised terraces where farming can be carried out safely without threats of erosion. Greenfield (the patron of vetiver, the World Bank) recommended trials of vetiver in watershed projects and, after several years, observed that using vetiver as a soil erosion control measure is a technically sound and economically practical basis for the hedgerow/contour cultivation system.

Vetiver hedgerows can perform their functions while occupying a narrow strip of less than 50cm width per hedgerow and if kept pruned down below the crop level. This permits the introduction of hedgerow systems into the field with minimum change in current farming practices.

However, the initiative is still passing through an experimental phase and whether these limited experiences will present a practical possibility for erosion control on a wider scale is yet to be seen.

Several other vetiver-like, potential botanical alternatives have also been indicated by BOSTID (1993).

(a) Tropical grasses: several species of *vetiver*, Lemon grass, *Citronella*, Napier grass, *Pennisetum* grasses, Rhodes grass, Tropical Panic grass, and *Calamagrostis* species.

Temperate grasses: Switch grass, wheat grass (mentioned as a vetiver for the cool zone), pampas grass (*Cortaderia*), feather grass (*Stipa*), *Miscanthus*, bamboos (choice from among 1,250 species, e.g., *Bambosa oldhamii*, already used in New Zealand), giant reed (*Arundo donax*), and ribbon grass (*Phalaris arunonacea*).

(b) More promising trees and shrubs listed by BOSTID for their soil erosion control potential and which can be locally used are - seabuckthorn, *Hippophae L.* (Rongsen 1992), alder, *Leucaena*, asparagus, and Siberian pea shrub (*Caragana*).

**Box 2.1: Vetiver as a SALT Hedgerow Plant**

The excellent erosion control potential of vetiver is well acknowledged, but its use as a SALT hedgerow plant is not recommended, for it is not a nitrogen-fixing plant species. Therefore, its contribution in a hedgerow, if used, would be strictly for erosion control. Vetiver thus does not match with NFT legumes in making desired contributions to the improvement of soil fertility by way of nitrogen-fixation. Through farmers' choice and adaptation, vetiver, as a third row underneath the double hedgerow, has, however, found much favou: with the upper Mahaweli farmers in Sri Lanka as an effective soil erosion control measure and biomass source.

### ii. *Contour Grass Strips as an Erosion Control Measure*

Grass strips have been tested for their soil erosion control efficiency under some highland projects in Asia and the Pacific (IBSRAM 1992). The method was tried out extensively in the farmers' fields by the Thai-Australia Highland Agricultural and Social Development Project in the northern highland areas of Thailand (TAHASD 1993). The necessity for such trials arose from the unsatisfactory performance of other means of erosion control measures, because of the local soil (acid soils) and climatic conditions (Plate 2.2).

The system allows for establishing contour grass strips (*Setaria anceps* used in this case) up the slopes at a vertical interval of three metres. In between, the alleys are cropped as usual with the farmers' own choice of crops. Arguments favouring the adoption of this method over other possible options were based on the reasons given below (Plate 2.3).

(a) It is cheaper than terrace making and other biological options. There is less wastage of land, less land under strips, and no wastage of land if the grass is cut for animal fodder (efficient use of land wherever fodder is a much needed item).

(b) It is a labour-saving option; it uses 300 per cent less labour compared to terracing (Hoey 1993). Also, its simplicity allows farmers to readily adopt it.

(c) Crop yields are better because of effective soil erosion control. Comparative soil loss, from various methods studied by the project, showed surprising results. Seven-year averages showed that the average soil loss from traditional farming methods was 113 T/ha, from strip cropping, 16 T/ha, from *Leucaena* strips, 16 T/ha, from terraces, 1.9 T/ha, and from grass strips the least, i.e., 1.6 T/ha (Hoey 1993).

(d) An important point advocated in favour of grass strips is that they do not involve any infrastructural investment and if farmers have to leave the land, because of land tenureship problems as is found under shifting cultivation, they have nothing to lose. In other options, be they mechanical or biological, such a risk factor is much higher.

Apparently, grass strips and their multiple uses, rank among the potential options having comparative advantages for acid soils in many upland areas. However, experiences of using grass strips on a wider scale are limited and more experimentation under different agroecological conditions is required to generate sufficient convincing quantitative information.

Apart from these two methods, several other soil conservation techniques are also known (Plate 2.4). Many of them serve the twin purpose of soil conservation and soil fertility maintenance. A long list of such measures, still in the experimental stages, was presented at the 6th International Soil Conservation Conference and is included in a publication entitled "Erosion, Conservation, and Small-scale Farming" by Hurni and Tato (1992).

## 2.3 Regenerative Technologies for the Management of Soil Fertility on Sloping Farmlands

### *i. Agroforestry Systems and Transformation*

Some agroforestry-based farming practices constitute another kind of adaptation, evolved by upland populations through ages of trial and error. The organic integrity of mountain agriculture is based on the linkages and interactions of the various components of land-based activities (mentioned earlier in Section 1.1). The intentional manipulation of a piece of land to satisfy the subsistence needs for food, fuelwood, and timber and to protect the soil by cultivating annual and perennial crops is today known as agroforestry.

Historically, the system has evolved over a much longer time period and examples of the *taungya* system (cultivation of crops within forest areas) and swidden farming are two well-known examples of traditional agro-forestry systems, both designed exclusively for spatial and temporal management and use of the environment.

The traditional knowledge/practices and the current status of agroforestry in the HKH Region have been documented earlier by Denholm (1991), as part of the Mountain Farming Systems' Programme on agroforestry. The highlights of the HKH country experiences recorded by Denholm speak of numerous traditional and new initiatives in agroforestry, practised by farmers and as introduced by development agencies. Among these, some of the notable practices are of cash crop production in the forests and on grazing lands in Bhutan; the *dongya* system developed by farmers in Yunnan (a modified swidden farming system with four different stages and types of production system in a ten-year cycle); growing alder trees (a nitrogen-fixing tree) on farmlands by the hill farmers of the NE Indian Himalayas; and the most promising system of cultivating cardamon under the shade of alder trees in Sikkim in the Indian Himalayas and eastern Nepal. The combination of the cardamon cash crop and fertility-enhancing trees, which in today's context is both an ecologically and economically sustainable agroforestry option, is being adopted rapidly by farmers in eastern Nepal and the NE Indian Himalayas.

Similarly, numerous examples of traditional agroforestry systems, developed to meet the local needs and conditions, can be cited from almost every area of all countries of the HKH Region. However, many of these practices, such as the various forms of shifting cultivation found in several parts of the HKH, may no longer be considered as viable options of agroforestry. The factors and mechanisms behind the disintegration of the organic integrity of agricultural systems, of which these practices were part and parcel, include reduced areas and regeneration capacities of biomass production, forests, pastures, and grazing lands; reduced diversity of agricultural production systems; and increased erosion and land degradation, coupled with new forms of State interventions which obstruct further continuation.

However, the agrisilvipastoral system which combines elements of perennial and annual crops with animals or pasture is one of the most commonly known agroforestry systems in the HKH Region and holds promise for the future (Denholm 1991). Two key factors that will contribute to the acceptance of this last form of agroforestry are: (i) the crucial role of biomass derived from perennials, both in the farming systems and in the subsistence strategies of hill farmers and (ii) the changing patterns of availability and access to tree products, following increased pressure on communal lands producing perennials.

Further, the match between specific characteristics of mountain areas, vis-a-vis the attributes of this form of agroforestry as a system of land use and cropping, gives further credence to the point of view favouring the adoption of this latest form of agroforestry as a promising regenerative option for the upland farmers.

The agrisilvipastoral form of agroforestry, in a way, represents a compromise between extensive land use (possible with low population pressure) and intensive land use (necessary under current demographic pressure). Besides, this system helps to ensure the availability of and access to biomass in the absence of vast uncultivated lands. The system is derived from the farmers' traditional systems of soil fertility management through the use of biomass via livestock, provision of products to meet the subsistence needs of the family, and to supplement food supply with diversified products from perennials.

*ii. Influencing Forces behind Innovations in Agroforestry Systems*

The ongoing forces of change (discussed in Chapter 1), which are disrupting the institutional and technological arrangements conducive to uninterrupted supplies of biomass and involving land extensive and subsistence-oriented activities, are being rated as no longer feasible options.

In the changed scenario of mountain agriculture, the objective circumstances require increased use intensity of land resources. Thus there is an increasing demand for options that can blend biomass generation functions from the forests and pastures without having sufficient amounts of land under these land use categories.

It is in this context that agrisilvipastoral forms of agroforestry have emerged as one of the potential options. The promotion of appropriate forms of agroforestry, although so far small in scale and largely confined to the lowland areas of the HKH Region, could bring new hope to struggling mountain farmers.

*iii. Sloping Land Management-oriented, Specialised Forms of Agroforestry*

We shall focus here on more specialised forms of agroforestry designed for the management of sloping lands only.

**Box 2.2: Regenerative Sloping Land Agriculture**

Regenerative sloping land agriculture - the practice of improving the resource base of a sloping farmland while improving productivity and profitability; it is characterised by the increased use of abundant and renewable internal resources and the reduction in use of external inputs.

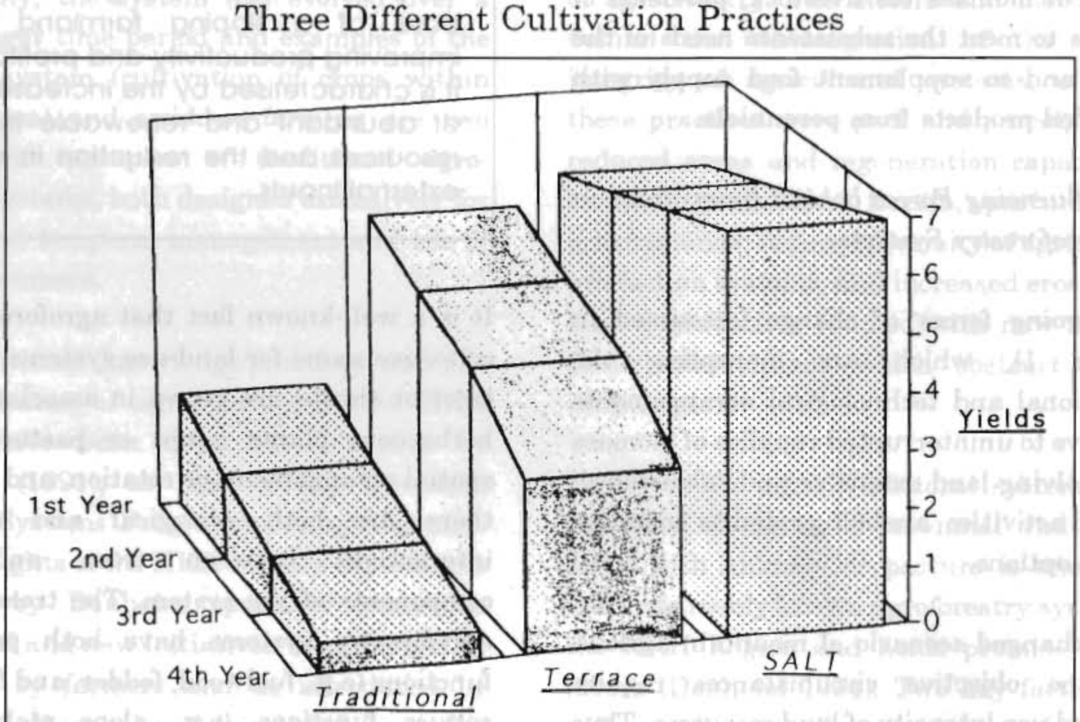
It is a well-known fact that agroforestry is a collective name for land-use systems in which trees or shrubs are grown in association with herbaceous plants (crops or pastures) in a spatial arrangement, or rotation, and in which there are both ecological and economic interactions between trees and other components of the system. The trees of such agroforestry systems have both productive functions (e.g., fuelwood, fodder, and fruit) and service functions (e.g., slope stabilisation, erosion control, fencing, and providing shade).

Recognising its functions of soil conservation and soil fertility maintenance, there have been a number of scientific initiatives in agroforestry (Young 1989). The fundamental approach of this form of agroforestry system is to plant the chosen nitrogen-fixing species in such a way as to form contour hedgerow barriers. In this way, both the functions of controlling soil erosion and making contributions to enhanced soil fertility are likely to be fulfilled. Alley farming is a broad approach with hedgerows as the principal component.

Sloping Agricultural Land Technology (SALT) is one form of the same approach but with standard norms: application on sloping lands only, double hedgerows using primarily nitrogen-fixing legumes, and designed in the form of models suited to small farmers. The suitability and performance efficiency of the hedgerow systems, including SALT, have been tested in a limited way, mostly in the tropical and subtropical highlands. The positive impact of these regenerative systems for upgrading the fertility of sloping lands, along with their stabilisation, has been well confirmed. A general scenario of comparative crop yield trends under different farming practices viz.; traditional farming on sloping lands, terraced agriculture, and the hedgerow systems, computed from different sources (Figure 2.1); highlights the fact that regenerative options give sustainable yields, unlike terraced farming and sloping land farming.

Detailed introduction and wider application of SALT is the subject of focus of this paper and, accordingly, the following chapters are devoted to explaining the philosophy, practice, performance, and scope of wider applicability of SALT in the HKH Region, in particular, and the upland areas, in general.

Figure 2.1: Relative Yield Trends of Crops under Three Different Cultivation Practices



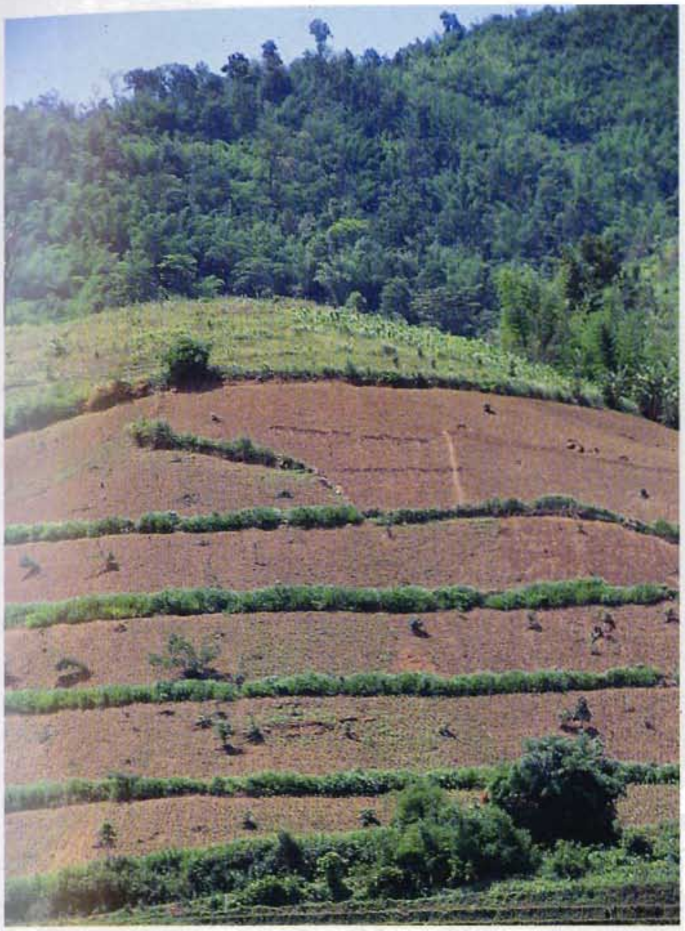


Plate 2.1 Chiang Mai, Thailand. Fresh plantation of a double hedgerow of vetiver grass in a sloping field, with maize crop in the background (Tej Partap).

Plate 2.2 Chiang Mai, Thailand. Sloping land management using contour grass strip method; farmers also cut this grass to meet their fodder needs (Tej Partap).

Plate 2.3 Chiang Mai, Thailand. Use of *Setaria* grass in contour grass strips has been promoted by TA-HASD for sloping farmlands with acidic soils (Tej Partap).

Plate 2.4 Myanmar. The hillside farming programme in Myanmar is trying out several ways to contain soil erosion. Among these, planting pineapples on the contour lines and collecting crop residues, etc on the upper side is one method (Tej Partap).

# 3. SLOPING AGRICULTURAL LAND TECHNOLOGY (SALT)

## 3.1 Background to the Evolution of the Technology

Sloping Agricultural Land Technology, or "SALT" as it is commonly called, originated as a result of the problems faced by the upland farmers of Davao del Sur, Mindanao Island, in the Philippines. The primary problem of these farmers was low and declining farm income. On one farm, the maize yield had decreased from 3.5 T/ha to about 0.5 T/ha in just ten years. Other crop yields had also decreased by 60 to 80 per cent in the same period.

As an alternative option, some farmers even tried planting permanent crops to augment their income, but yields of these were also very low. The main reason for this, which only became apparent later, was the depletion of soil and nutrients from sloping lands.

Traditionally dependent on a monocropping system, the farmers had also been trying out several options to achieve better distribution of income throughout the year. They had money after the harvest, but there were times during the year when they had neither money nor food; the problem of seasonal hunger was becoming a norm.

An equally common concern was the lack of capital for fertilisers, insecticides, and seeds of improved varieties of maize and other crops. New techniques for improving crop yields required expensive inputs. Farmers borrowed capital for these inputs, but each year the soil needed higher levels of fertiliser. This way, the continuous loss of topsoil reduced yields to below the break-even point between cost and return; thus, the farmers incurred debts they could not pay.

An NGO, the Mindanao Baptist Rural Life Centre (MBRLC), internationally known by the name of its sister affiliate, the Asian Rural Life Development Foundation (ARLDF), which works for the holistic development of the farming communities living in this hilly area, felt concerned about the difficulties faced by the farmers. Because of the strong local needs, the centre focussed on finding sustainable ways of managing sloping lands. The staff at the centre observed that the problems surrounding upland farmers was not so much a question of technology for growing maize and other field crops but rather one of severe soil erosion and the subsequently declining fertility of agricultural fields.

Obviously, a farming technology that could conserve the topsoil and, if possible, improve its fertility and productivity was needed for these uplands. Recognising this problem, from 1971 the centre started to conceptualise a system now known as "Sloping Agricultural Land Technology," or SALT.

### *i. The First SALT Model*

After testing different intercropping schemes and observing *Leucaena*-based farming systems, both in Hawaii and at the Centre, efforts to develop the first-ever SALT prototype model commenced in 1978.

A one-hectare test site was selected at the MBRLC to serve as a "testing ground" for the technology. Typical to the surrounding farms, the slope was greater than 15 degrees and it had been farmed for at least five years. The soils also were similar to those of most farms in the area.

After preparing a conceptual framework, MBRLC staff began establishing the project. Work was started at the top of the hill, locating the contour lines downwards, spacing them four to five metres apart. *Leucaena leucocephala* seeds, known locally as "*ipil-ipil*", were planted along the contours. Every other alley or strip between contour lines was planted with maize, leaving alternate strips uncultivated to help control soil loss until the *Leucaena* trees were large enough to hold the soil. The first maize crop was harvested later that same year.

A decision was taken not to promote an upland farming system until the basic objectives of controlling soil erosion and restoring the soil productivity were met. It was soon realised, however, that waiting for long drawn-out testing and experimenting would further delay solving the farmers' immediate needs for food and cash. MBRLC, therefore, decided that, if the comparison of the performance of the SALT model with that of non-SALT farming showed a marked difference in yield, and if observations also indicated that other goals were being met, it would proceed with the expansion and dissemination of the system simultaneously.

MBRLC proceeded to compare the crop yields derived by using its SALT model with the farmers' crop yields. It also compared the working hours required for one hectare of its model with the local farmers' working hours for one hectare of maize. The tools and equipment used for farming the SALT model were similar to the farming equipment used by local farmers. Soil losses were also monitored. The model was in operation for about one year before comparisons were made. Table 3.1 illustrates the comparisons.

**Table 3.1: Simple Comparisons between SALT and Non-SALT Farms**

| | SALT | Local Farmers' Method |
|---|---|---|
| Labour (First year) | 100% of working hours | 50% of working hours |
| Maize yields (2 crops/yr) | 2 T/ha/crop | 0.5 T/ha/crop |
| Tools needed | Same tools used by both | |

Source: MBRLC

The comparison showed that SALT requires more labour than the conventional farm methods in the first year, but the increase in yields outweighs this added use of labour. Tools needed to cultivate one hectare of SALT were the same as those used by local farmers (*carabao*, plough, harrow, and long knife for cutting grasses). The hoe was later introduced into the SALT system.

After comparing the prototype model with many other projects, it became clear that SALT as a farming system was simple enough for any hillside farmer to follow, was applicable to at least 50 per cent of the hillside farmers in Mindanao, required lower costs in comparison to making bench terraces or conventional terraces, and was discovered in time to save what little topsoil remained. By 1980, MBRLC had acquired the confidence that SALT could fulfill the objectives adequately. But, it took about four more years of testing and refining before SALT could be heralded as 'applicable' (Watson and Laquihon 1985).

## 3.2 The SALT Philosophy and Rationale

The SALT philosophy underscores the fact that sustainable land use is one which maintains an acceptable level of production and, at the same time, conserves the basic resources on which production depends.

A basic requirement for sloping land use systems is to retain productive potential over a period of time through the conservation of natural resources. Foremost among the requirements is that soil fertility should be maintained. Further, in order to achieve this goal, efforts should be directed towards a resource-based management system as opposed to an input-based approach.

SALT is a type of land-use system in which perennial plants, mostly trees and shrubs, are trained in a shrubby form to grow in association with annual or perennial crops in a spatial arrangement. The technology promotes planting of nitrogen-fixing trees and shrubs, maintained in the shape of double hedgerows at regular intervals on sloping lands. The package combines contour hedgerows as the main actors, along with other soil conservation and farming strategies, to ensure a sustainable production.

The technology aims at facilitating both ecological and economic interactions between the hedgerow species and other components of the agroecosystem. The Asialand programme of IBSRAM, a network on the management of sloping lands for sustainable agriculture, views the fundamental concept of the hedgerow technology as a biological soil conservation measure for the conservation and enhancement of the soil fertility of sloping lands.

**Box 3.1: Sustainable Production Systems on Sloping Lands**

Sustainable land use equation (Young 1989):

**Production + Conservation = Sustainability**

Subsequently, the soil conservation concept was redefined as follows:

**Soil Conservation = Control of Erosion + Maintenance of Fertility**

The benefits of the double hedgerows of the SALT system can be distinctly categorised into **service functions**, i.e., soil erosion control and soil fertility enhancement and maintenance; and **productive functions**, i.e., for fuelwood, fodder, mulch, fruits, etc. The broad goals of SALT are primarily aimed at the service functions. However, some features of SALT make it distinct from the general agroforestry practices as outlined in the next paragraph.

**Notably, in the application of SALT, a deviation is made from the general agroforestry approach, by accepting the fact that the mere planting of trees is by no means sufficient to control erosion; what matters is the way that the trees are arranged and managed.**

**Box 3.2: Principles/Norms for Adopting the SALT System**

After years of experimentation, the propounders of SALT defined the norms listed below for the adoption of the SALT system by farmers.

- The system must control soil erosion adequately
- The system must aid in restoring the soil structure and land fertility
- The system must enable efficient production of food crops
- The system must be applicable to at least 50 per cent of the hillside farms of an area
- The system must be replicable by upland farmers with local resources and, preferably, without taking loans
- The system must be culturally acceptable to the hill farming communities of the area
- The system must be oriented towards small family farms, and production of food crops must be the first priority with fruits, forests, and other crops as secondary options
- The system must be workable in as short a time period as possible and should be designed so as to require minimum labour
- The system must be economically feasible
- The system must be environmentally sound

Suitable modifications in the SALT system have been designed and tested in order to make it adaptable to different production systems, e.g., annual and perennial crops, mixed farming with livestock, forestry, and horticultural farming. Based on the combinations of these components, four broad categories of SALT models have been developed.

### 3.3 The Four Salt Systems (SALT - 1, 2, 3, and 4)

MBRLC has evolved four SALT systems, based on the production of food crops, some cash plants, forage species, and timber species, and raising animals within the farm biomass production cycle. SALT can be established on farmland slopes with a gradient ranging between 5 to 25 per cent or more. A concept of minimal tillage, use of organic fertilisers, and contour planting pervades all the four SALT systems.

The four SALT systems developed are:

(i) SALT-1, which focusses mainly on food crop production;

(ii) SALT-2, a system developed for farmers who would like to incorporate livestock with crop farming;

(iii) the SALT-3, a system developed, based on the assumption that the farmer has some additional marginal land that cannot be cultivated but which can be converted into economically productive forest to supplement production from other SALT components; and

(iv) SALT-4 places emphasis on orchard and plantation crops.

The salient features, in terms of design of these SALT systems, are summarised in Table 3.2.

**Table 3.2: Land Use Characteristics of Different SALT Systems**

| Production system | SALT-1 | SALT-2 | SALT-3 | SALT-4 |
|---|---|---|---|---|
| i. Base | staple crops | fodder | trees | horticulture |
| ii. Major product | foodgrains | meat/milk<br>manure | fuelwood<br>timber | fruits<br>plantation crops |
| iii. Planting area (%) | | | | |
| - Staple crops | 75 | 20 | 20 | 40 |
| - Food/cash crops | 25 | 20 | 20 | 60 |
| - Perennials/trees | | | | |
| - Forage/fodder | | 40 | - | - |
| - Private forestry | - | 20 | 60 | |

Source: Conceived, tested, and recommended by MBRLC/ARLDF

## SALT - 1

SALT-1 is a simple, applicable, low-cost, but effective agroforestry technology with agricultural crops and forestry in a ratio of 75:25. Based on the experiences of MBRLC/ARLDF, this technology decreases erosion substantially compared to the traditional, upland farming management practices. In addition, it increases crop yield five to six-fold. More details on crop yields are discussed in Chapter 5 (Plate 3.1).

## SALT-2

This simple agro-livestock technology is a modification of SALT-1 in the sense that it integrates livestock rearing with crop cultivation (SALT-1). Among the livestock species that can be raised under the system are cattle, sheep, and goats. Goats, however, are preferred, because they form an important component of the small farmers' farming systems. Goats have high fertility rates and short intervals between kidding. Although small in size, these animals are relatively inexpensive to stock. Goat/sheep manure is also a good source of fertiliser. Further, goats also are a potential source of milk and meat as well as hair and skin (Plates 3.2, 3.3, and 3.4).

## SALT-3

SALT-3 includes three types of component, i.e., SALT-1, SALT-2, and a separate plot of land to produce valuable timber, using hedge-rows and valuable timber crops in the alleys. Farmers owning landholdings of about two hectares can practise it (Plates 3.5 and 3.6).

## SALT-4

Recently, the focus has been on developing the horticulture and plantation crop-based SALT-4 system, popularly called the small 'agrofruit livelihood technology'. This system is based on the realisation that to improve hill economies, commercialisation of hill agriculture is required. In this respect, horticulture is a promising option with comparative advantages. To make it sustainable, technological improvements are required to raise productivity and to maintain soil fertility.

A good example of SALT-4, based on plantation crops, can be found in Sri Lanka, where SALT has been adopted to improve and maintain the fertility of tea-based plantations on a wider scale (UMWP 1993).

In general, the objectives of SALT-4 are to produce food and increase cash incomes while effectively conserving the soil on the farmlands.

### 3.4 Characteristic Features of the SALT Farming System

*i. A Biological Option for Soil Conservation*

The focus on biological soil conservation measures highlights the new thrust towards hill farmer-oriented, resource management options. In developing and applying SALT, the underlying philosophy was to bring the maintenance of soil fertility within the broad scope of soil conservation. From this perspective, control of soil erosion is a necessary but by no means a sufficient condition. Various physical and chemical components positively influenced by SALT include soil organic matter, the physical properties of the soil, enhanced nutrient status, and reduced toxicity.

While looking at the SALT system from a purely soil loss point of view, the technology seems to have a sound scientific rationale. It stands by the fact that SALT is designed to manipulate some of the factors of the globally acknowledged Universal Soil Loss Equation to contain soil loss.

*ii. An Alternative to Mechanical Terracing*

The contribution of the hedgerows in the SALT system, as an alternative to mechanical erosion barriers, is enhanced by its additional benefits as sources of soil fertility and biomass for mulching. It contributes towards its larger acceptability as an integral and permanent part of the farming system. From the fertility management angle, the efficiency is greatly enhanced because pruning simultaneously provides biomass for mulching; the biomass is placed on the ground surface of the cultivation strip areas. Soil builds up on the upperside of the hedges, resulting in the natural development of terraces.

A comparison of the effectiveness of SALT hedgerows and other forms of contour vegetative barriers and mechanical terracing (Figure 2.1) has reiterated the fact that aggregate hedgerows provide a more effective system for stabilising sloping lands. There is also evidence that the so-called "induced or controlled erosion terraces", that form behind the double hedgerows of SALT, show superior stability and result in higher crop yields.

In the long run, SALT has proved to be less labourious than traditional farming and is capable of enhanced gains compared to it; the income from SALT is six and a half times higher (US$65/HH/m) than from traditional farming (US$10/HH/m). The comparative benefits to farmers are discussed in more detail in Chapter 5.

*iii. A Promising System for Sloping Land Farming*

Today, on-farm soil conservation is losing its status as a free-standing pursuit, or project component. In its place, the focus is shifting to how farmers can manage their farms and maintain or restore the productivity of their soil. Soil conservation can be an additional benefit of good farming practices and, if adopted, increases the farm productivity and conserves resources.

SALT is a complete farming approach designed and developed for small farmers. Under the SALT system, sloping fields are divided into strips of land for cultivation by double hedgerows of leguminous trees and shrubs planted along contour lines. The hedgerows are the key element of the entire system. They act

**Box 3.3: How SALT Manages Soil Erosion**

Manipulating the Universal Soil Loss Equation (USLE)

**USLE = RKLSCP** (annual soil loss in tonnes/ha)

where, under a given condition,

R = rainfall factor,
K = soil erodibility factor,
LS = slope length factor,
C = cropping factor, and
P = cultural practices.

Since "R", "K", and " LS "are fixed values, given the climate, soil type, and positioning, the only two manipulable factors thus are "C" and "P".

SALT seeks to manipulate the latter two - the cropping factor & the cultural practices that farmers adopt while farming their sloping lands.

as erosion barriers; stabilise the slopes facilitating formation of terraces; increase soil fertility; and become the source of fodder, firewood, and mulching biomass. Using the same basic components and in a similar fashion, SALT has also been used for improving the productivity of sloping grasslands/pasturelands and private forestry.

As a proven system of upland farming, SALT has certain improvements over both the traditional techniques of slash and burn and conventional terrace farming. It protects the soil, restores soil fertility, is more efficient in food production, and is applicable over large areas of hilly land.

The first factor causing increased productivity under SALT is high yields *per se*, due to nitrogen fixation and enhanced nutrient and humus availability due to mulching. The second contributing factor is diversified farming with the cultivation and harvesting of different crops, spread more evenly throughout the year and complemented by livestock and forestry enterprises. This results in better utilisation and productivity of both land and labour. It also ensures sales and income generation throughout the year.

Farmers can easily replicate it on their farmlands and there is nothing to deter its cultural acceptance by farmers. Because of its focus on small farmers, it incorporates all ingredients of subsistence farming, unlike most other technologies. The technology has been shown to yield results over a relatively short period of time (refer to Chapter 5 ).

Wherever the technology has been demonstrated properly to farmers, results show that it has made a good impact as a promising soil conservation approach, compatible with farming systems. An additional attraction is that it is a potential source of a number of farm inputs from within the farm boundaries, protecting the farm's resource base and, ideally, sustaining and increasing yields at the same time. From a strict soil conservation point of view, it avoids the high per unit costs associated with the construction and maintenance of engineered systems; costs that most small farmers in the uplands cannot afford, unless heavily subsidised.

## 3.5 SALT Experimental/Demonstration Models Maintained at MBRLC

One of the important points in favour of Sloping Agricultural Land Technology (SALT) is that it is being constantly experimented with, evaluated, and modified for improved performance by its promoters at MBRLC/ARLDF, located in the village of Kinuskusan, in the Municipality of Bansalan, Davao del Sur Province, Mindanao, the Philippines.

**Box 3.4: Salient Features of SALT Farming**

- It is environmentally sound and ameliorating, because of the nitrogen-fixing capacity of the hedgerows, and protective because hedgerows are coppicing tolerant, can perform the mulching function, protect the soil from rain, and preserve soil moisture.
- It is economically rational because it facilitates maximum and efficient use of land and labour; it facilitates regular income generation and multiple benefits through marketable products, provided the plant species are carefully selected.
- It is developmentally desirable, for it has shown the potential to ensure security of food and income to farmers, diversity of products (food, cash income, and fodder), higher frequency of harvests, and reduced risk of price fluctuations compared to low-value, high-volume major crops, besides sustaining high productivity.
- SALT is more productive per unit of both land and labour than traditional farming practices, provided the system is set up and managed along the lines of the defined norms.
- SALT is technically a relatively simple system that can be replicated easily by upland farmers using local resources and without requiring costly external inputs.
- SALT is a diversified system and, as such, is less risky and more flexible than conventional farming practices
- SALT is cheaper than terracing in terms of both establishment and operational costs; in addition, it can be applied to situations in which terracing is not, or no longer, feasible

MBRLC is located in the foothills of Mount Apo, 400masl in the southern part of the Philippines. The local terrain is generally gentle to steep slopes. The slopes, which contain the SALT model and other test plots, range from 15 to 30 degrees. The local climate is marked by mild winters, hot summers, and fairly well-distributed rainfall (mean 2,500mm per year) throughout the year. The true periods of dry weather are for three months and usually last from January through March.

The soils in the area are of volcanic origin. They are locally called miral clay loam. They are typically, moderately acidic (pH 5.0 to 5.5), low in nitrogen and phosphorous content, moderately high in potassium, and low in organic matter (2.0%). According to the FAO World Classifications, they fall into the category of Dystric Nitosols.

At MBRLC, several permanent plots are maintained over 20 hectares of sloping land of varying degrees. These models feature in several experimental studies for the continued testing and improvement of SALT, and for the training-cum-demonstration of SALT systems. The main points of each experimentation are highlighted below. The whole centre gives the appearance of a comprehensive model of a SALT system being maintained strictly under the defined norms/principles, so as to serve as an appropriate example of proper management.

*i. SALT-1 Demonstration Model*

This one-hectare plot was established in 1978. As the first SALT model progressed, it became known as Demonstration SALT. The first few years of that model were spent in checking for the adaptability of crops, crop production, and soil erosion control and did not focus much on how much income could be made from the one-hectare plot. In 1982, MBRLC started to lay stress on income in its Demonstration SALT and began to plant crops that would yield the greatest financial return. The centre recognised that a farmer could understand and appreciate the economic benefits better than the biophysical benefits.

*ii. Experimental SALT System*

In 1980, a 0.5-hectare Experimental SALT plot was established for testing and development. It was established as a test site for evaluating the performance of major crops, monitoring the effects of permanent crops with improved practices, testing varieties of permanent row crops in the SALT system, monitoring pests and diseases in various crops, and for continuous monitoring of soil loss over long periods (Plates 3.7 and 3.8).

*iii. SALT and Non-SALT Comparative Testing System*

This comparative experiment was established in 1984 on one-third of a hectare of land area. It contains two SALT plots and two non-SALT plots for replicated comparison of the following aspects: labour inputs, crop yields (primarily maize), net income, soil loss, and the chemical and physical properties of the soil.

*iv. Contour Hedgerow Testing System*

The hedgerow performance evaluation system was established in 1984 on a 0.25 hectare site. It was established to test the adaptability of various leguminous and non-leguminous plants and their ability to grow and hold soil in a hedgerow-alley farming system. It is also used to test the ability of various selected species to produce organic fertiliser that can be used in a SALT-type farming system and as a seed bank for various types of legumes that have potential use as SALT hedgerows in hillside farming.

*v. Biomass Production Assessment System*

An experimental plot of one-tenth of a hectare, established in 1991, uses 24 different hedgerow treatments in triplicate random block design. Observations are being made to answer various questions relating to the management of hedgerows, such as:

(a) can more biomass be produced with closer in between row spacing ?
(b) can some species produce as much biomass if they are trimmed closer to the ground, as some farmers prefer?

*vi. Testing System for Hedgerow Spacing*

Such a system was established in 1992 for monitoring suitable distances for hedgerow spacing. Permanent experiments have been established to test the following hedgerow spacings; centre to centre -6-m, -5-m, -4-m, -3m, and -2-m. This experiment has four blocks of the above treatments spread in a random fashion. Simultaneous studies on weed suppression through spacing adjustments are also being carried out in this block.

Plate 3.1 SALT-1 hedgerows and alleys with legume crops on sloping lands check erosion from agricultural fields having red soils and enhance their productivity considerably (Tej Partap).

Plate 3.2 A view of a forage garden established under the SALT-2 model at MBRLC. Note the closer lines of shrubby hedgerows and the lopping style (Tej Partap).

Plate 3.3 A goat in an enclosure (SALT-2). This breed is preferred for milk and meat production (Tej Partap, MBRLC).

Plate 3.4 Livestock enclosure in the corner of a forage garden established under SALT-2 at MBRLC. The structure is designed in such a way that manure piles up underneath (Tej Partap).

Plate 3.5 Private forest of valuable timber trees, established on marginal land, under the SALT-3 model at MBRLC (Tej Partap).

Plate 3.6 A fine bamboo stand (a source of valuable timber) in the alley under the SALT-3 model at MBRLC, the Philippines (Tej Partap).

Plate 3.7 Long hedgerows and vegetable farming in the alleys of SALT-1 at MBRLC. One can also see natural terracing (Laquihon).

Plate 3.8 SALT-1 model farm at MBRLC/ARLDF, Mindanao, the Philippines: stabilisation of slopes and green terrace formation are clearly visible to the visitor (Jeff Palmer, MBRLC).

# 4. THE CRITICAL ROLE OF HEDGEROWS

The hedgerow, in a general sense, means a live fence-like structure comprised of tree and shrub species but largely managed in a shrubby form. The hedgerow system of SALT is, however, different in its design and purpose in several ways. The double hedgerow system, as it is known, consists of nitrogen-fixing tree/shrub species planted in two parallel lines, at specified distances and at regular intervals on the contours of sloping land. Although it is a form of agroforestry, the SALT hedgerow system is distinct from general agroforestry practices in the sense that the hedges are managed in a spatial arrangement, along contour lines, to serve both biophysical and socioeconomic functions.

## 4.1 Principles and Functions of Hedgerows

*i. Maintaining Soil Fertility*

The general hypothesis for the soil fertility management role of SALT states that appropriate hedgerow systems under SALT have the potential to control erosion, maintain soil organic matter and physical properties, augment nitrogen fixation, and promote efficient nutrient cycling. Appropriate hedgerow systems here mean systems that are adapted to local environmental conditions and designed and managed to meet the needs and constraints of farmers. In short, such hedgerows will be appropriate for the land and for the farmers.

The rationale for supposing that SALT hedgerows would help maintain soil fertility, is based on the assumption that systems can be designed in which losses from the crop component are balanced by gains from the tree component. In hedgerow intercropping, the hedges provide semi-permeable barriers, while their prunings augment soil cover by returning the nutrients back to the soil. Additionally, the hedgerow system is designed to add nitrogen to the soil by using nitrogen-fixing tree (NFT) species in the hedgerows.

The hedgerow roots form an equivalent of 30 to 40 per cent - sometimes more - of the above-ground biomass (Young 1989). Fine roots are constantly shed and regrowing and form the below-ground equivalent of litter fall. Unlike the above-ground biomass, root residues are rarely removed from the soil and therefore they play a central role in maintaining soil organic matter and physical properties. Nitrogen fixation takes place (with few exceptions) through the root-symbiotic organisms, while the nutrient uptake is wholly through the roots.

Finally, the potential to increase nutrient-use efficiency arises through the capacity of tree roots and associated mycorrhizal systems to take up nutrients from the soil solution.

The most spectacular evidence of nutrient gains through the nitrogen-fixing, tree/shrub intercropping hedgerow systems has been reported from Central and South America, where the nutrient content of leaf litter, from agricultural crops and trees/shrubs combined, was in the order of 150 to 300kg N, 10 to 20kg P, and 100 to 300kg Ca per hectare per year (Young 1989). With fertiliser applica-tion in these systems, the nutrients recycled in litter exceeded the annual fertiliser input; an impressive example of the efficiency of nutrient cycling through hedgerow systems. These results have major implications, both social and economic. For farmers with little or no access to fertilisers, hedgerows of SALT may permit the continuation of crop production with sustained yields, thus ensuring better use of limited land resources.

*ii. Facilitating Efficient Nutrient Uptake and Cycling*

The hedgerows offer opportunities to synchronise the release of nutrients from decaying plant residues with requirements for nutrient uptake by crops. By using hedgerows under SALT, farmers can avail themselves of options for manipulating the timing of nutrient release. This is possible through the choice of hedgerow species with differing rates of litter decay, timing of pruning, and the manner of litter addition to the soil.

Annual crops have the highest nutrient demand during the phase of early growth. In hedgerows under SALT, there is the fortunate coincidence that pruning is necessary in any case to reduce shading before crops are planted. Many widely-used hedgerow species have a half life of 60 days, or less, for their litter decay (Young 1990). These species reach their peak nitrogen release after a few weeks. This corresponds with the timing of the peak requirement of many crops. The purpose of synchronising the release of nutrients from leaf litter with crop requirements is to improve the efficiency of nutrient uptake to make up for the losses from leaching. This, in turn, will contribute to the efficiency of nutrient recycling.

*iii. Facilitating Moisture Conservation*

Very often, in relatively dry hilly areas with longer spells of drought, water availability, at certain periods of the year, is most important for crop production. The benefits of SALT hedgerows in conserving water are well known. Reductions through evaporation in the order of 20 to 30 per cent, have been recorded (Young 1989). It is possible that trees, whether intimately mixed with crops or planted in rows, improve the total water supply by reducing evaporation. There is, however, little evidence to indicate that the hedgerows improve infiltration of water along with reducing runoff.

*iv. Rehabilitation of Degraded Lands*

NFT hedgerows are a good source of organic matter for manure. Their fresh foliage usually contains from 0.5 to 1 per cent of nitrogen. The foliage of vigorous perennial legumes can accumulate 100 to 600kg of nitrogen per hectare. When incorporated into the soil, it improves the fertility, moisture, nutrient retention, and general tilth. At the same time, by improving soil structure, it can also retard erosion; in due course, creating conditions that induce other species to grow well. Thus, such hedgerows act as pioneers, preparing difficult sites for farming or forestry.

With their extensive root system, exploiting deep underground moisture, leguminous trees and shrubs adapt to steeply sloping lands where both grazing and crop production foster erosion. They can often be grown on sites unsuited for food production from conventional crops and, in doing so, they can stabilise eroding soils and reclaim the land for cultivating other crops.

The ability to fix nitrogen and to effectively extract phosphorous and potassium, from otherwise inaccessible soil horizons, allows NFT species to improve degraded lands and make them more suitable for other uses. The wastelands, literally meaning uncultivated lands, which are barren or without vegetation can be made useful through the hedgerow systems established under SALT. The early stage of reclamation of more severely eroded wasteland soils will require that it be put under a well-managed hedgerow system and protected from grazing. Later it can be brought under productive use.

Studies have proved that improvements in soil chemical properties, resulting from natural fallow, can also be achieved through NFT plantation, similar to the influence of hedgerows, in a much shorter time (Mac Dicken 1981).

Such potentials of SALT hedgerows are not so widely exploited as yet, but the same approach is followed in SALT-2, in which degraded land is converted into a productive forage source by closely-planted hedgerows of NFT species. Such a hedgerow supplies cut and carry fodder for stall feeding, and the fertility status of degraded soils improves over a period of time.

*v. Facilitating Natural Terracing*

In an exclusive experiment conducted in the ICRAF field station at Machakos, between 1983 and 1989 (Kiepe and Young 1992), efforts were made to compare the terrace-building capabilities of the hedgerows and other systems. The findings revealed that, in four years' time, hedgerows facilitated terrace building to the extent of 47 per cent of the original slope.

Hedgerow intercropping, with its natural terrace formation and its additional function of maintaining soil fertility through the use of NFTs, has a fraction of the original slope and an ALR (arable land ratio) as good as in bench terraces. The experiment concluded that labour-intensive and expensive construction of terraces are superfluous.

Further, information available on comparative economic analysis of other techniques vis-a-vis SALT (see Chapter 5) also supports the superior performance of hedgerows in terms of their stated role.

## 4.2 Opting for NFTs in the Hedgerows

The basic philosophy behind using hedgerows under SALT is to facilitate soil conservation, restoration, and soil fertility maintenance. This objective is met through the use of NFTs in the hedgerows. The nitrogen contribution of legumes can be vital for maintaining the productivity of sloping lands over long periods, because this benefits other ground vegetation, both crops and non-crops. To acquire nitrogen-fixing capability, legumes form symbiotic associations with nitrogen-fixing organisms, usually nodule-forming soil bacteria of the genus *Rhizobium*, or actinomycete of the genus *Frankia*.

Global experiences concerning the benefits of legumes for improving land fertility testify to their role in the hedgerows. In Australia, for example, the fertility increase effected by legumes has allowed vast areas to be brought under arable cultivation. Nitrogen from legumes is the basis for New Zealand's exceptional pastoral economy. In the United

**Box 4.1: Biophysical Functions of the Hedgerows (Garrity 1989)**

- To break slope length, reduce runoff velocity, and increase infiltration opportunity time
- To reduce the erosivity and transport capacity of surface runoffs
- To cause the deposition of erosion products to trap nutrients and induce terracing
- To restore, build, enhance, and maintain soil fertility through natural additions of nitrogen, by using nitrogen-fixing plants in the hedgerows
- To cause cultivation and planting operations to be carried out on the contour and to stabilise contour cultivated areas on steeper slopes
- The socioeconomic benefits of hedgerow systems are numerous; fruit, fodder, green manure, fuelwood, cash income, or subsistence

**Box 4.2: Selection Criteria for Leguminous Hedgerow Species**

- A nodulating, nitrogen-fixing legume or other species
- Good coppicing ability under heavy pruning (up to 12 times per year or so)
- Ability to grow well in the double hedgerow system
- Potential for producing a minimum of 25 metric tonnes of fresh biomass per hectare, per year
- Potential for prolific seed setting
- Added quality of asexual reproduction
- Resistance to insects and diseases
- Ability to perform well under thick plantation
- Wider adaptability to a variety of soils and climates
- Plants with tap roots and deep growth
- Ability to grow into a tree if left unattended
- A multipurpose tree or shrub

States, legumes contribute about 2.4 million tonnes of nitrogen a year, nearly one-fourth of the amount of manufactured fertiliser nitrogen applied during the same period.

However, most but not all legumes have this capability and species vary in their rates of nitrogen fixation, some are exceptionally good while others are poor nitrogen fixers. Besides, there are several other factors that influence the fixation of nitrogen by a legume. Studies suggest that nodulation is fairly general in the *Mimosoideae* and *Papilionoideae* and that only about 30 per cent of the *Caesalpiniodeae* species bear nodules.

MBRLC/ARLDF has proposed a dozen criteria for selecting promising legume species for SALT hedgerows, as described in Box 7. Although the focus has been on legume species, this does not exclude the option of using other non-legume NFT species.

## 4.3 Limiting Factors of NFT Legumes

Despite their biological potential to fix nitrogen, legumes cannot be assumed to be always fixing large amounts of nitrogen. Legumes with yellow leaves, showing severe nitrogen deficiency, may be seen in hill and mountain areas. The failure of legumes to fix nitrogen may be caused by one or more of the following reasons.

### i. *The Absence of Appropriate Nodulating Bacteria*

Leguminous plants only grow vigorously if they have functioning nodules, and this depends on their roots encountering appropriate *Rhizobium* strains in the soil. There are differences among *Rhizobium* strains too; some cannot infect the particular legume being grown, some invade the root but bring no benefit to the host, and others invade vigorously producing effective nodules that continuously supply nitrogen compounds to the plant.

In nature, the vigorously nodulating strains are usually found in soils in which the particular legume species is native. When a plant is introduced into a different area/region where it has never been grown before, the most effective nitrogen-fixing *Rhizobial* strains used by the introduced plant may be lacking. Thus, when a legume is grown for the first time in a new area, it is crucial to ensure that appropriate *Rhizobia* are present in the soil.

Some legume species accept and use a range of different *Rhizobia* strains, while in other cases a group of different legumes can all use the same *Rhizobium*. In these cases, the plant will grow well in soils of any location that previously supported a crop using a compatible

*Rhizobium* strain. Luckily, this is a common situation, accounting for the widespread success in introducing leguminous plants into new areas/regions.

For several legume species, appropriate strains of *Rhizobium* have been identified. Cultures are available, either commercially or from research institutions. The bacteria can be added directly to the soil, but usually the legume seed is coated with the culture so that, as the root emerges during germination, it is infected immediately.

*ii. Adverse Habitat Conditions for Nitrogen Fixation*

*Leucaena*, one of the promising hedgerow plants, is poorly nodulated at a pH of below 5.5. However, there are some species of *Leucaena* which are tolerant to acidity (National Academy of Sciences 1977). *Desmodium rensonii* is another example of a hedgerow legume which is poorly nodulated in soils with a pH of about five. However, there are legumes like *Mimosa* which bear healthy nodules, even in some of the very acidic soils of the highlands (Rekasam 1993).

It was because of the poor performance of hedgerows under acidic soils that the effectiveness of hedgerows as a superior option was questioned in the highland areas of Northern Thailand (Hoey 1993).

Experimental trials conducted in Northern Thailand underscored the mediocre performance of *Leucaena* hedgerows (Plate 4.1). Consequently, the results rated grass strips and terraces as superior options.

In Northern Thailand, the *Leucaena* hedgerows reduced soil loss when compared to the traditional practice, but this was still above the acceptable limits of soil loss. In this case, firstly, the hedgerows consisted of only *Leuceana* which was sensitive to acidic soils. Secondly, the actual impact of hedgerows is seen only after some years. The above findings, however, indicate that, to achieve better results of soil conservation using the hedgerow system, much depends upon the maintenance of the hedgerows. The performance of poorly maintained hedgerows can be disappointing. The findings reported by Hoey (1993) also indicate the performance limitations of leguminous hedgerow species under acidic soil conditions. This should in fact serve as a lesson that hedgerow plants should be recommended for a location only after verifying their growth performance and capabilities to fix adequate nitrogen in the new environment.

It should also be pointed out that grasses do not fix nitrogen, and the benefits of already known, nitrogen-fixing plant species as hedgerows cannot be undermined.

Hopes may also be raised about the role of hedgerows in helping to reduce the widespread acidity of hill soils; acidity incidentally leads to phosphorous deficiency, which otherwise calls for occasional fertiliser application. As yet, there is little evidence to support such a role of hedgerows (Young 1989), as the hedgerows growing on such soils will draw their nutrients from the same soil. Past reports (Young 1989) on the role of hedgerows in reducing the acidity problems of soils indicate that it may not be wise to expect SALT hedgerows to help solve this problem. The organic matter derived from hedgerow litter, albeit, may exert a buffering effect by helping to check acidification.

Information on nitrogen-fixing trees and shrubs and their nitrogen-fixing capability and substantial augmentation of nitrogen is substantial. But, information on the management and integrated benefits of hedgerows for fruit, fuel, fodder, and crop productivity is still in the development phase.

## 4.4 Promising Hedgerow Species

*i. Diversity and Access*

More than 650 genera and 1,800 species are known to fix nitrogen (Halliday and Nakao 1982), representing about 20 per cent of the total NFT species. Thus, it is neither an exhaustive list for SALT trials under all types of agroecological zone, nor does it include only the best options for SALT. Legume species are found in the temperate zones, humid tropics, cold arid areas, highlands, and lowlands, and they may hold better promise. These remaining species are as yet little used. Today, only a handful of NFT species are recognised as promising hedgerow species, and our knowledge about hedgerow species is also limited to the warm humid tropical and subtropical environments.

There is certainly a need for further work, including identification of indigenous, nitrogen-fixing tree species from different agroclimates, studies of requirements and techniques for *Rhizobial* and *Mycorrhizal* inoculation, and further quantitative studies on the nitrogen-fixation rates by the hedgerow species (Plates 4.2, 4.3, and 4.4).

*ii. Selection Criteria*

Although better biomass yield remains the main criterion for the selection of species, yet, the other one dozen attributes (refer to Box 8) should also be taken into account when considering whether to include or exclude a species as potential hedgerow material. As stated earlier, many species have been culled and many have been added since the beginning of the testing period. To date, over 40 species have been tested in the hedgerows at MBRLC, and among these the sixteen species listed in Table 4.1 are the more promising ones that are currently being taken as probable hedgerow candidates, more specifically for the type of tropical highland environment that exists in the southern Philippines.

**Table 4.1: Promising Hedgerow Species Tested at MBRLC**

| | | | |
|---|---|---|---|
| 1. | *Acacia confusa* | 9. | *Desmodium rensonii* |
| 2. | *Acacia villosa* | 10. | *Erythrina poepiggina* |
| 3. | *Caesalpinia sappan* | 11. | *Flemingia macrophylla* |
| 4. | *Calliandra calothyrsus* | 12. | *Gliricidia sepium* |
| 5. | *Calliandra haematocephalla* | 13. | *Leucaena diversifolia* |
| 6. | *Cassia siamea* | 14. | *Bauhinia purperea* |
| 7. | *Cassia spectabilis* | 15. | *Indigofera tysmane* |
| 8. | *Delonix regia* | 16. | *Calliandra tetragona* |

The "best" species among the tested ones are *Flemingia macrophylla, Desmodium rensonii, Gliricidia sepium*, and *Leucaena diversifolia*. Although they are not the highest yielders of biomass, they meet more of the MBRLC's criteria for a good hedgerow plant than the others. They are heavy nodulators and nitrogen fixers. They grow well in the MBRLC's SALT system. They are generally prolific seed producers and stand up well to heavy pruning. Among these four species, *F. macrophylla* and *D. rensonii* are by far the two most widely used species in environments such as those of the southern Philippines.

Close "seconds" to the above four species are *Calliandra calothyrsus, Bauhinia purperea*, and *Calliandra tetragona*. These species are all high biomass producers but the problem with them is that they may not be prolific seed producers in all environments. To be a good seeder is a must for a hedgerow species, in order to help farmers bring more areas under SALT. In areas that these species can readily seed, they would be excellent choices for SALT hedgerows.

*Cassia spectabilis* and *Cassia siamea* are tremendous biomass producers (Table 4.2). However, they are not seen as the most desirable hedgerow species because they are non-nodulating legumes. Many areas have been observed where the *Cassia* sp. has been growing in conjunction with crops; the crops suffer heavily due to excessive competition.

*Acacia villosa* and *Caesalpinia sappan* show potential during the first few years of growth. However, they experience a tremendous amount of 'die-back' under the heavy pruning in the SALT system, and therefore they do not qualify as potential species. *Erythrina poepiggina* also shows good biomass yield but is excluded due to the undesirable thorn-growing characteristic of the plant.

Lastly, the species *Acacia confusa, Calliandra hematocephalla, Delonix regia,* and *Indigofera tysmane* should also be very promising. However, these species somehow failed to show better performances in terms of biomass yields under the environmental conditions at MBRLC. There is every reason to try and test these species for hedgerows under other agroecological conditions.

A study of the Thai farmers' response to the IBSRAM-supported sloping land management reported that they are finding *Leucaena* and pigeon pea to be favourable in the hedgerow system, with intercropping of fruit trees like mango, jackfruit, and tamarind in every second or third alley. Rice and corn are planted according to the farmer's food needs in every two out of three alleys, or in every alley between fruit trees. Hedgerows are pruned regularly and the prunings used as mulch and organic fertiliser.

**Table 4.2: Biomass Production Evaluation for Contour Hedgerows (1982-92)**

| | Hedgerow Species | Fresh wt T/ha | Dry wt T/ha | Dry matter per cent |
|---|---|---|---|---|
| 1. | *Acacia confusa* | 20.1 | 5.2 | 25% |
| 2. | *Acacia villosa* | 25.7 | 8.2 | 32% |
| 3. | *Caesalpinia sappan* | 26.8 | 7.0 | 26% |
| 4. | *Calliandra calothyrsus* | 44.5 | 14.2 | 32% |
| 5. | *Calliandra haematocephalla* | 22.1 | NA | NA |
| 6. | *Cassia siamea* | 44.1 | 11.5 | 26% |
| 7. | *Cassia spectabilis* | 50.7 | 11.7 | 23% |
| 8. | *Delonix regia* | 18.4 | 4.8 | 26% |
| 9. | *Desmodium rensonii* | 27.2 | 5.7 | 21% |
| 10. | *Erythrina poepiggina* | 30.4 | 5.2 | 17% |
| 11. | *Flemingia macrophylla* | 31.0 | 8.7 | 28% |
| 12. | *Gliricidia sepium* | 28.9 | 6.7 | 23% |
| 13. | *Leucaena diversifolia* | 37.3 | 10.5 | 28% |
| 14. | *Bauhinia purpurea* | 32.3 | 9.1 | 28% |
| 15. | *Indigofera tysmane* * | 23.7 | NA | NA |
| 16. | *Calliandra tetragona* ** | 40.9 | NA | NA |

* First harvest = November 1989; ** First harvest = December 1990 NA = Data not available

### 4.5 Hedgerow Evaluation System

At MBRLC, permanent contour hedgerow tests have been set up to serve as a testing, screening, and seed collection source for potential nitrogen-fixing trees and/or shrubs. An appropriate area has been set aside for this purpose. The selected species are planted in a random block design and each individual species is planted in five replicates. For most trials, the species are planted in a 50cm wide, double hedgerow system and the spacing between hedgerows, centre to centre, is about two metres. Uniform soil and climatic conditions have been ensured for these experiments at the centre.

Originally, 15 species, including some non-legumes, were selected for testing, but the list keeps expanding to include new species and, at times, species have been dropped during the selection process because of poor performance.

*i. Hedgerow Spacing and Trimming Aspects*

While fine tuning the SALT system for better biomass production, manipulating the hedgerow design and management is considered as one possible option. Therefore, experiments have been designed to answer questions such as whether more biomass could be produced with closer spacing in between rows; and whether species could produce as much biomass if they were trimmed closer to the ground, as some farmers prefer.

A triplicated random block design was set up with five different parameters (Table 4.3). Fresh biomass production (kg/plot) has been kept as the sole criterion of the performance of hedgerow structures and designs.

Seven species, *Flemingia macrophylla, Desmodium rensonii, Gliricidia sepium, Gliricidia sepium, Calliandra tetragona, Luecaena diversifolia*, and vetiver grass, are being used as biological tools for this experiment (Table 4.3).

*Flemingia* and *Desmodiu rensonii* used in a cutting height test, were cut at waist height, knee height, and ground level. The triple hedgerow test was set up to examine the following five combinations of hedgerow species: (i) *D. rensonii - C. spectabilis - D. rensonii*; (ii) triple *Flemingia*; (iii) *Flemingia - C. spectabilis - Flemingia*; (iv) triple *D. rensonii*; and (v) *Flemingia* - vetiver - *Flemingia*. In another experiment, the double hedgerow structure was examined for its performance using a mixture of species. The first treatment consisted of one pure row of *D. rensonii* and one of *Flemingia*. The second treatment consisted of mixed plantations of *Flemingia/D. rensonii* in the first and second rows.

The experiments conducted at MBRLC on appropriate height for trimming the hedgerows have ascertained that ground cuttings in which only a six inch stalk is left are detrimental to biomass production. In the case of most species, this stalk length is not enough for the plants to sufficiently recover and coppice. Also, trimming the plants close to the ground increases the chances of 'die back' in the hedgerows. Experiments are in process to look into the impact of trimming at waist and knee heights.

*ii. Biomass Production Assessments*

Among the species tested under the standard double hedgerow system, with 50cm spacing between the two hedgerows, it was found that *Gliricidia*, either by seeds or stakes, yielded more biomass. *F. macrophylla* and *D. rensonii*, the two most widely-used hedgerow species, performed moderately and *C. tetragona* or *L. diversifolia* suffered from the drought conditions that occurred in the southern Philippines, during the experimental years. Similarly,

**Table 4.3: Hedgerow Biomass Production Evaluation Under Different Treatments (MBRLC)**

| | Treatment | Mean (kg) |
|---|---|---|
| Standard Double hedgerows (50cm wide) | | |
| 1. | *F. macrophylla* | 1.13 |
| 2. | *D. rensonii* | 1.44 |
| 3. | *G. sepium* (seeds) | 3.07 |
| 4. | *G. sepium* (cuttings) | 4.14 |
| 5. | *C. tetragona* | 0.77 |
| 6. | *L. diversifolia* | 0.69 |
| 7. | *Vetiver grass* | 1.18 |
| Hedgerow cutting height (50cm wide) | | |
| 8. | *F. macrophylla* - waist (1m) | 0.83 |
| 9. | *F. macrophylla* - knee (0.5m) | 1.30 |
| 10. | *F. macrophylla* - ground | 0.88 |
| 11. | *D. rensonii* - waist (1m) | 1.81 |
| 12. | *D. rensonii* - knee (0.5m) | 1.49 |
| 13. | *D. rensonii* - ground | 1.14 |
| Distance In-between Hedgerows | | |
| | *F. macrophylla* (50cm wide) | 1.35 |
| | *F. macrophylla* (30cm wide) | 0.97 |
| | *D. rensonii* (50cm wide) | 1.83 |
| | *D. rensonii* (30cm wide) | 1.88 |
| Triple Hedgerow (50cm wide) | | |
| 18. | *D. rensonii* = *C. spectabilis* = *D. rensonii* | 1.40 |
| 19. | *F. macrophylla* = *F. macrophylla* = *F. macrophylla* | 1.28 |
| 20. | *F. macrophylla* = *C. spectabilis* = *F. macrophylla* | 1.19 |
| 21. | *D. rensonii* = *D. rensonii* = *D. rensonii* | 1.52 |
| 22. | *F. macrophylla* = *Vetiver grass* = *F. macrophylla* | 1.51 |
| Mixed species (50cm wide) | | |
| 23. | *F. macrophylla* = first row *D. rensonii* = second row | 1.38 |
| 24. | *F. macrophylla* = *D. rensonii* first and second row. | 1.39 |

Source: MBRLC

*Flemingia* and *D. rensonii* were also affected by drought. Vetiver grass, which was placed in the test only as a "check" for other species, showed impressive growth.

*iii. Appropriate Spacing between Hedgerows*

The spacing in between the two lines of a double hedgerow system is another aspect of interest. The trials being held at MBRLC would require more years of data to reach a confirmed conclusion. Although the standard practice at the centre is to keep this spacing at 50cm, more options are under trial. Initial observations reveal that different species may respond differently and to make generalisations will be difficult. For example, from ongoing observations, the growth performance trends reveal that *D. rensonii* performs much better, under a closer spacing of 30cm, than does *F. macrophylla* under the given conditions.

*iv. Desirable Alley Widths*

In a trial designed to monitor the effects of alley width on crop production, five treatments with 6m, 5m, 4m, 3m, and 2m wide alleys were experimented upon. The emerging trend from the past few years' data reveals that the further the spacing of hedgerows, the better is the production. However, when balanced with the per unit production, it can be seen that the individual hill production of maize is much better in a narrow hedgerow spacing. However, firm conclusions can be drawn only after more data are available.

MBRLC is also conducting a weed suppression study vis a vis hedgerow spacing. It has been noticed that there is considerably less weeding under closer hedgerows due to an increase in the mulch per unit area of total production.

*v. Scope for Triple Hedgerow Option*

Field experiments conducted on the triple hedgerow system, 50cm in width, have shown no advantage over the double hedgerow spacing. It has been noticed that the centre row, whatever the species, suffers heavily stunted growth. The only exception is the *Flemingia* - vetiver - *Flemingia* triple hedgerow. In this case, the grass competes so heavily for water and nutrients that the lower hedge of *Flemingia* is severely stunted. In looking at the mixed species in hedgerows, there seems to be little or no difference between the two. However, more years of data are needed before any definite conclusions can be reached (Plate 4.5).

## 4.6 Hedgerow Experiences of ICIMOD and Others

In the ICIMOD-supported pilot SALT project in China, *Leucaena leucocephala* and *Tephrosia candida* in single, double, and triple hedgerow systems were tried. After two years of experimentation, more species have been added to the list, keeping in mind the local agroecological conditions and farming systems' needs (Plate 4.6).

The species added are: *Morus*, i.e., mulberry; *Trema orientalis*; *Casuarina equisetifolia*, *Desmodium yunnanensis*; *Bauhinia purpurea*; *Cajanus cajan*; *Albizia yunnanensis*; *Cassia* spp; *Indigofera* spp; *Dalbergia balansae*; *Alnus* spp (non-legume NFT);-*Elaeagnus lanceolata* and other species (non-legume NFT); *Amorpha fruticosa*; *Campylotropsis polyantha*; *Lespedeza bicolor*; *Coriaria nepalensis* (non-legume NFT); and *Hyppophae* spp (non-legume NFT).

All of these species are native to the area and are considered good candidates for hedgerows. They include species identified to cover a wide range of agroecological conditions from the subtropics to temperate dry conditions. Also, some of these species are nitrogen-fixing, non-legumes.

In the case of SALT trials in China, there is also an exception in the choice of mulberry as a hedgerow plant. It was used after the strong recommendation and insistence of local farmers to use mulberry in one of the two hedgerows. This is partly because the economy of Ningnan county, where the SALT pilot project is set up, depends on silk production.

Several farmers in the county maintain single rows of mulberry hedges at regular intervals in their fields. Thus, the farmers' argument is that they would like to use one leguminous hedgerow for putting the litter back into the soil, but the leaves from the second row, consisting of mulberry, will be used to rear silk insects. This is a fine example of modifying the SALT model according to local needs (Tang Ya et al. 1992).

In the Upper Mahaweli Watershed Management Project (UMWP), Sri Lanka, where SALT has been used on a much wider scale, farmers are also using vetiver just below the second hedgerow as a third line of defence against erosion. The project has recommended a long list of SALT hedgerow tree species, under humid tropic upland conditions (Tables 4.4 and 4.5).

## 4.7 Hedgerows, Agroecological Zones, and Information Needs

The information on management and benefits of hedgerow systems is still not complete. Most available research and data are limited to a small number of tree/shrub hedgerows. In cases where positive benefits are demonstrated, such as the ARLDF model in Mindanao, UMWMP -Sri Lanka, or Ningnan - China, both species and management dependency may restrict the wider applicability of hedgerows to diverse environments and farming systems.

**Table 4.4: Growth Characteristics of Seven Hedgerow Species**

| Tree Species | Height (m) | Root Collar Diameter (cm) | Average Row Yield of Beans Relative to Sole Crops (%) |
|---|---|---|---|
| *Alnus acuminata* | 1.24 (7) | 3.2 (6) | 146 (1) |
| *Casuarina equisetifolia* | 2.40 (3) | 3.8 (5) | 100 (4) |
| *Cordia abyssinica* | 3.62 92) | 9.3 (2) | 46 (6) |
| *Cupressus lusitanica* | 1.61 (6) | 3.2 (6) | 114 (2) |
| *Maesopsis eminii* | 2.09 (5) | 5.3 (3) | 96 (5) |
| *Markhamia lutea* | 2.26 (4) | 3.9 (4) | 107 (3) |
| *Melia azedarch* | 4.36 (1) | 11.1 (1) | 46 (6) |

Source: UMWP 1993

Note: Numbers in brackets are rank order

So far, hedgerow systems under SALT and other related systems have been tested under tropical and relatively warm subtropical conditions, e.g., in the Philippines, Indonesia, Sri Lanka, Thailand, as well as in the uplands of the African continent. There is no information available on suitable hedgerow species for the uplands of a temperate environment. Keeping in mind the diversity of environments and farming systems, as found in the HKH Region for example, much more information on the management and integrated benefits of hedgerows for fruit, fodder, crop productivity, and soil conservation is required.

Since the success of SALT depends to a great extent on the better growth performance of hedgerows and good coppicing potentials, knowledge and information is wanting for a wide range of NFT species that match different agroecological zones and farming systems of mountain areas. Colder climates will certainly restrict faster growth and too

**Table 4.5: Recommended SALT Hedgerow Species for Tropical Highland Areas**

| Species | Elevation (ft) | Drought | N-fixation | Biomass Production | Decomposition rate* | Propagation | Species Seed Treatment | Uses |
|---|---|---|---|---|---|---|---|---|
| *Gliricidia sepium* | up to 5000 | Tolerant | Yes | High | Medium | Seed/Sticks | | EC/GM FW/AF |
| *Erythrina lithosperma* | 2500-6500 | Not tolerant | Yes | Medium | Medium | Sticks | | EC/GM FF |
| *Calliandra calothyrsus* | 1600-5000 | Tolerant | Yes | Medium | Fast | Seed | 6 hr. soaking in hot water | EC/GM FW/AF |
| *Accacia decurrents* | more than 5000 | Tolerant | Yes | High | Slow | Seed | immerse in hot water overnight | EC/GM FW |
| *Flemingia congesta* | up to 6500 | Tolerant | Yes | Medium | Slow | Seed | immerse in hot water overnight | EC/GM AF |
| *Desmodium rensonii* | up to 3000 | Tolerant | Yes | Medium | Medium | Seed | immerse in warm water | EC/GM AF |
| *Cassia spectablis* | up to 5000 | Moderately tolerant | No | High | Medium | Seed | immerse in hot water overnight | EC/GM FW |
| *Tithonia diversifolia* | up to 6500 | Tolerant | No | Low to Medium | Very fast | Sticks | | EC/GM |
| *Vetiveria zizanioides* | up to 6500 | Tolerant | No | Medium | Medium | Shoots | | EC/GM |

Source: UMWP - SALT - Brochure 1993

Note: All species have moderate to good tolerance of acidic soils.

o = Tolerance to drought during establishment
* = Slow rate of decomposition is desirable

FW - Fuelwood
EC - Erosion Control
AF - Animal Fodder
GM - Green Manure

frequent prunings of hedgerows, limiting the benefits of mulching and forage (Plate 4.8). There may also be fewer species available that are more suited to harsher environments in terms of germination and growth (Plate 4.8).

It is strongly suggested that even the identified promising species be tested under local conditions before reliance is placed on them for large-scale planting under SALT hedgerows in a given area. The available information on the potentials and limitations of the SALT hedgerows reveals that it is an emerging system. A large body of grey literature and other anecdotal information suggests its usefulness to the humid tropical and subtropical sloping lands. However, information on the use of hedgerows for temperate sloping lands is still lacking.

Plate 4.1 *Leucaena* is preferred as a hedgerow species because of its fast growth. The plants in the picture, with a Chinese farmer practising SALT, are only a few months' old (Tej Partap).

Plate 4.2 Acidic soils in several upland areas, however, inhibit the growth and performance of many legume hedgerow species; one-year old *Leucaena* plants are seen in the picture (Tej Partap).

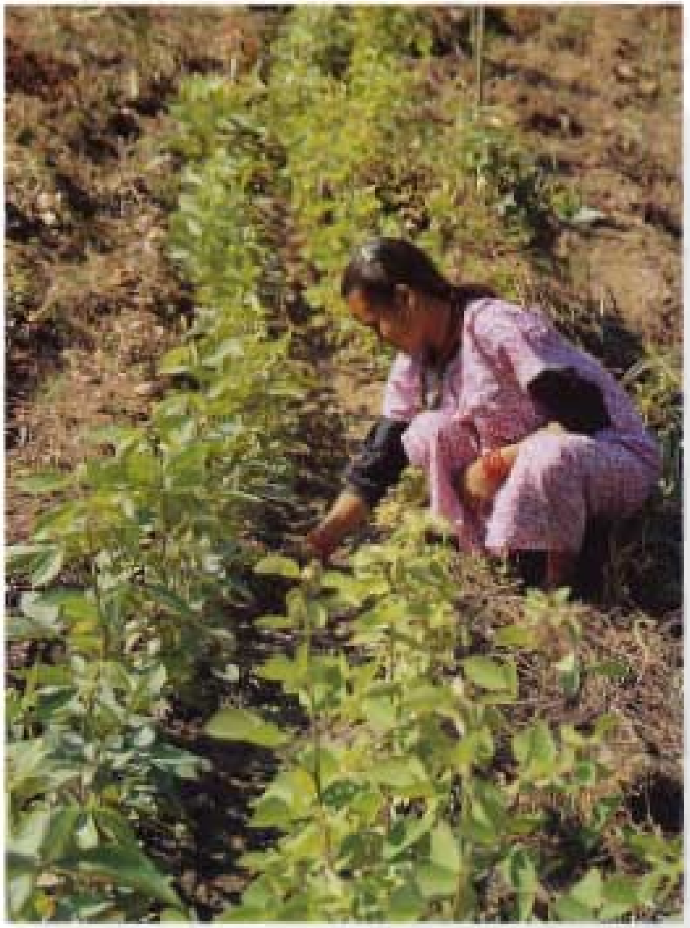


Plate 4.3 Double hedgerows of *Desmodium* and *Flemingia* at the ICIMOD trial plot in Godawari, Kathmandu Valley. These few months' old plants demonstrate their adaptability to the middle mountain areas of the HKH (Tej Partap).

Plate 4.4 Trials on triple hedgerows in Ningnan county, Sichuan, China, set up on a highly degraded site (Tang Ya).

Plate 4.5 Combination of *Leucaena* (legume) and *Alnus* (non-legume NFT), under trial as hedgerow species in Godawari, Kathmandu (Tej Partap).

Plate 4.6 Excellent growth of *Flemingia*, ICIMOD plot of promising hedgerow species in a farmer's field and alleys (HR Watson, MBRLC).

Plate 4.7 Hedgerows can be established either through direct seeding on the contour lines, as shown in the picture, or even through vegetative propagation (B.R. Bhatta).

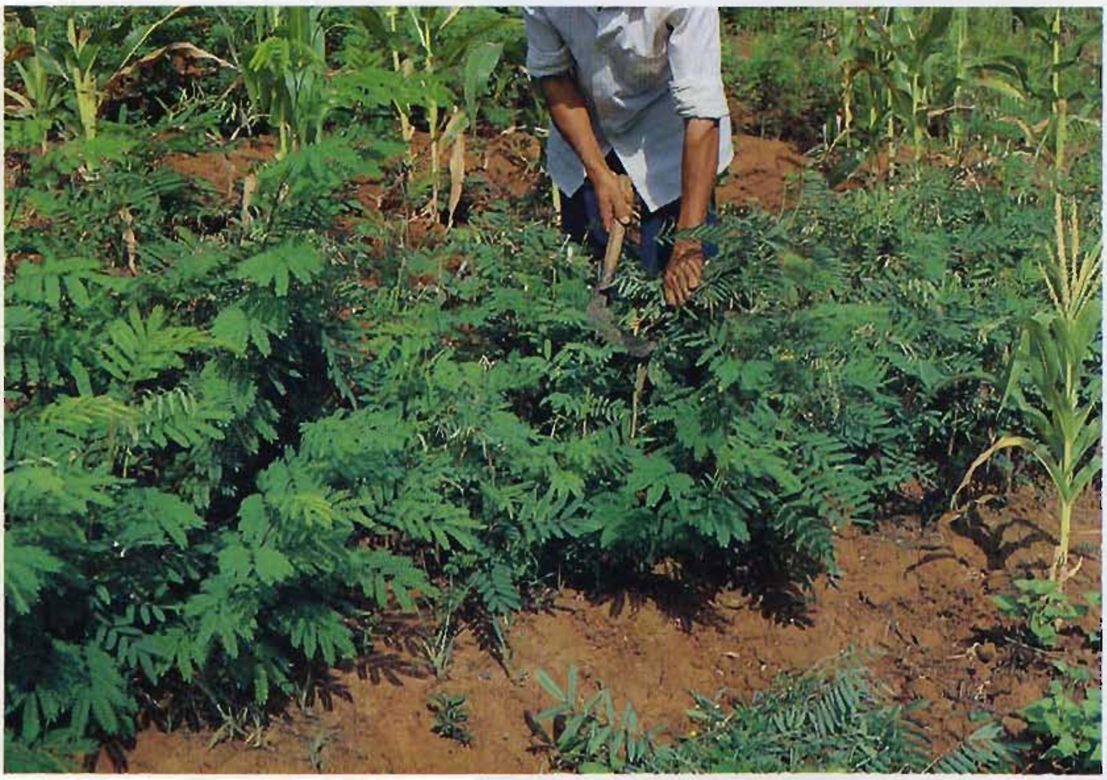


Plate 4.8 Trimming of hedgerows to the right height and at intervals is an important aspect of the whole SALT management operation (Lu Rongsen).

# 5. THE PERFORMANCE EVALUATION OF SALT

From the time SALT was demonstrated as a possible alternative for small farmers so that they could farm their sloping lands on a sustainable basis, the MBRLC was subjected to enquiries about empirical data to support their claims. In response to these demands, the centre, since 1984, has been establishing a permanent long-term programme of SALT trials and testing. Apart from the objectives of improving the system, the multiple experiments were also designed to compare the SALT system with traditional ways of farming on sloping lands. Phase-1 covered a six-year period from November 1984 to November 1990, and phase-2 commenced in 1990. Results/observations collected within the last one decade, and in the form of both empirical data and visual observations, are presented in this chapter. Authors realise that, at times, information may look crude or inadequate, yet our preference is to share it, since there is little published information available on SALT.

The experiments helped assess the performance of SALT in respect of the following two areas:

i. the biophysical appropriateness of the SALT system and
ii. the socioeconomic acceptance of the SALT system.

However,the actual parameters for evaluating the SALT system include:

i. soil erosion control and improvements in soil fertility;
ii. improvements in biomass output and crop productivity; and
iii. the economic analysis of various SALT systems.

**Table 5.1: Land Uses under SALT-farmed and Traditionally-farmed Sloping Lands**

| Land use | Proportion |
|---|---|
| A: Under the SALT-1 System | |
| Alleys under annual crops | 42.9 % |
| Alleys under perennial crops | 29.4 % |
| Area under contour hedgerows | 27.7 % |
| B: Traditionally Farmed Sloping Land, Control | |
| Area under annual crops | 100 % |

Source: MBRLC Experiments

## 5.1 The Biophysical Appropriateness of SALT

### *i. Soil Erosion Control and Slope Stabilisation*

Data covering a period of over six years reveals that the SALT system is very effective in controlling soil erosion (Table 5.2). Over the years, while the soil erosion rate increased from the plots maintaining traditional farming treatments, the erosion from SALT plots declined with each passing year. This could be due to the cumulative impact of crop residues, organic matter accumulation in the soil, increased infiltration rate, and the terracing effect that the hedgerows exert on the SALT system.

The cumulative soil loss from the traditional farming plot over the six-year period was about 1,162MT/ha and from the SALT farm it was only 20MT/ha, which on an annual basis comes to an average of 3.4MT/ha. This meant a reduction in soil erosion of about 58 times (Table 5.2). The rate of soil loss under the SALT system indicates that the values are within the general permissible limits.

**Table 5.2: Soil Loss from SALT-farmed and Traditionally-farmed Sloping Lands**

| Observation intervals (months) | SALT loss (mm) | Control loss (mm) | SALT Cumm. loss (T) | Control Cumm. loss (T) |
|---|---|---|---|---|
| 05 | 0.5 | 4.0 | 6.2 | 53.8 |
| 34 | 0.8 | 20.9 | 10.6 | 278.0 |
| 45 | 1.2 | 46.5 | 15.6 | 618.1 |
| 50 | 1.6 | 58.4 | 21.3 | 776.2 |
| 57 | 1.7 | 71.4 | 22.0 | 950.1 |
| 60 | 1.7 | 77.1 | 23.1 | 1025.4 |
| 68 | 1.6 | 82.8 | 21.4 | 1101.1 |
| 72 | 1.5 | 87.4 | 20.2 | 1162.4 |
| Per year Unit* | 0.25 mm | 14.6 mm | 3.4 T/h | 194.3 T/h |

* Calculated for per unit area and time period

Soil Erosion from Permanent and Annual Cropping. An interesting trend, found while recording data on soil erosion, was the considerably low rate (14 times) of soil erosion in the permanent crop alleys compared to the seasonal crop alleys. The permanent crop alleys in many cases had only slight or no erosion at all, while the bulk of the measured erosion from SALT was from the alleys with annual crops.

The data indicate that permanent crops may be essential in any hillside farming scheme. The permanent alleys can be used as a "belt" to hold precious topsoil on the hillsides. This finding gives credence to the original design of SALT which calls for the plantation of permanent crops on every third strip. The observations also indicate that SALT becomes a better soil erosion control system the longer it is used.

Reports on the soil erosion impact of the SALT system are also available from other Asian countries. A study by Paningbatan and Comia (1990a and b) revealed SALT to be a sustainable option for farming sloping lands. They made SALT tests on 18 per cent slopes and used a modified SALT hedgerow system of one row *Gliricidia sepium* and one row napier grass (*Pennisetum purpureum*). In the alleys (5-6m wide) they cropped maize. The reported soil loss was about 10 T/ha/year.

Two IBSRAM colleagues of Paningbatan reported soil erosion and runoff control under the hedgerow system (SALT) in Indonesia. Their plots were located on 13° slopes, and only a single hedgerow of *Flemingia macrophylla* was used as control. The hedges were spaced about four to six metres apart. The annual average rainfall of the area is about 3,000mm. The rate of soil loss was contained at an average of 12 T/ha/yr in the later years. The analyses of these findings have confirmed that the "mulching" effect of *Flemingia* has contributed substantially towards erosion control from these gentle slopes.

The IBSRAM network team in Thailand (Anecksamphant and Boonchee 1992) used double hedgerows of *Leucaena* and pigeon pea (*Cajanus cajan*) on sloping lands of 29° in the Chiang Mai hills (rainfall 1,450 mm/year) and farmed maize in the alleys. The rate of soil loss from the alleys averaged about 14 T/ha/yr. The Thai-Australia Highland Agriculture and Social Development Project tried several methods for controlling soil erosion in the hilly areas of northern Thailand, and the final analysis of the experts (Hoey 1993), on the comparative efficiency of various methods of erosion control, was shared with outside development agencies after completion of the project in 1993. These findings are presented later in Figure 5.5.

Impact of Trimmings Used as Soil Cover. Trimmings of hedgerows combined with crop residues are intended to provide an effective soil cover against erosion in a SALT system. The general observations made at MBRLC are confirmed by other reports (Lal 1974) showing the positive effect of a good mulch on the soil surface in controlling soil erosion. The study made on a slope of 15° reported heavy erosion from the bare grounds of the test plots, while the mulched plots (6 T/ha of mulch) lost only a fraction of the soil. Further, the loss of rainwater due to runoff was much more (42%) from the bare grounds than from the mulched soil (2.4%).

In a nutshell, the trials revealed that SALT has the capability to control soil erosion from sloping uplands. The combination of double hedgerows, acting as a physical barrier to water runoff, and the rich source of organic mulch make SALT a promising solution for soil conservation on sloping lands. However, current trials are limited in terms of their geographical/agroecological coverage. This demands more research work in different agroecological zones to confirm the potential of SALT as a universal solution for soil conservation and slope stabilisation.

*ii. Improvements in the Biophysical Properties of Soil*

There is evidence of a trend towards increased organic matter, infiltration rate, and nutrient uptake efficiency in the SALT treatment. These conclusions are based on the visual observation of surface organic residue build-up, increased earthworm activity, and a more "crumb-like" soil structure in the SALT treatment opposed to the farmer's treatment. In order to design experiments that farmers can also handle, some "home-made" physical indicators of soil were used to compare the improvements in soil fertility between the two systems. The measured indicators show higher improvements in the soil under the SALT system (Table 5.3).

The greater ground cover, earthworm activity, water infiltration rate, and less surface flow, all combined together, confirm definitive trends

**Table 5.3: Physical Indicators of Change in the Soil Properties of SALT and the Traditionally-farmed Sloping Land**

| Indicator | SALT Testing Plot | Traditionally Farmed Sloping Land |
|---|---|---|
| 1. Ground cover (%) | 95 | 40 |
| 2. Earthworm castings (kg/1 sq.m.) | 23 | 2 |
| 3. Infiltration rate (Times faster) | 7 | 2 |
| 4. Surface runoff per 10 gallons of water spilled (metres) | 1.6 | 6.1 |

Source: Data from MBRLC test plots

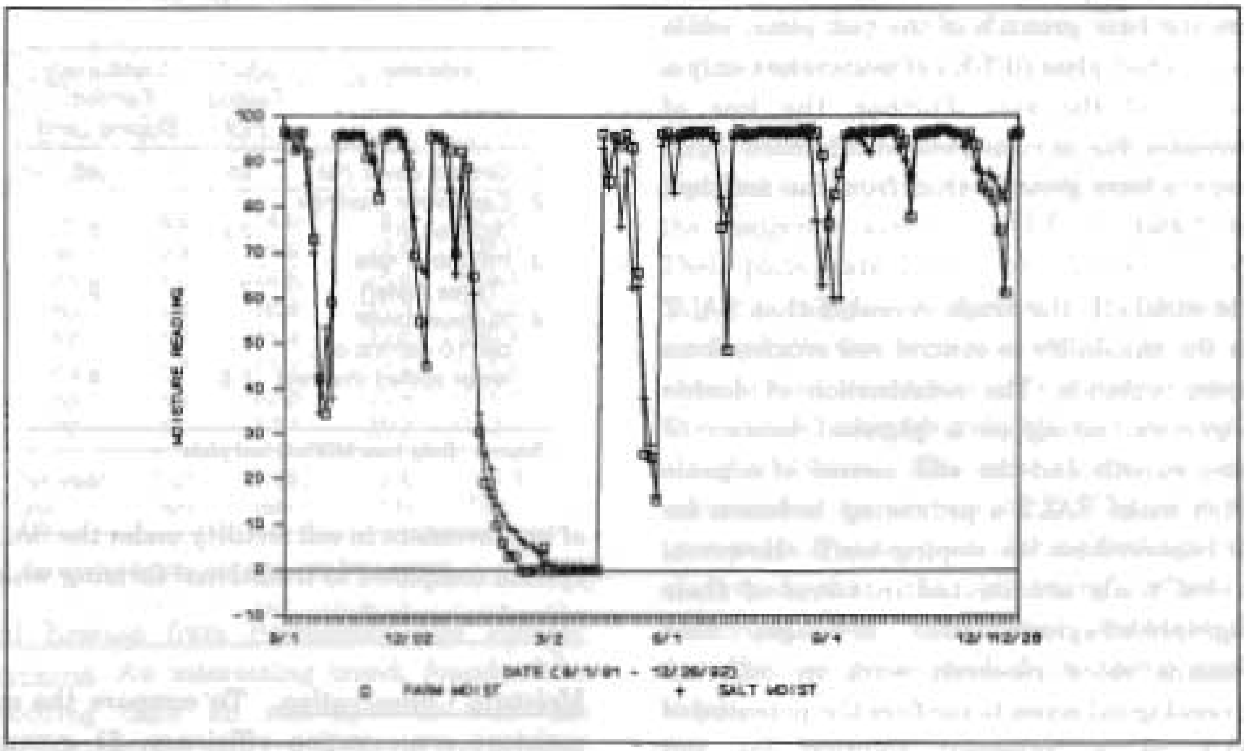
of improvement in soil fertility under the SALT system compared to traditional farming which served as control.

Moisture Conservation. To compare the soil moisture conservation efficiency, 21 gypsum blocks were buried at depths of 6 inches, 12 inches, and 18 inches, both in the traditional farming plot and in the SALT system plot. A 6-12-18 inch station was established in the centre of the traditional farming plot and in each section of the SALT system (seasonal alleys, permanent alleys, and hedgerows). The overall results showed that the moisture patterns in both farming systems looked amazingly similar, especially at the six-inch depth (Figure 5.1). Even when the non-SALT blocks showed signs of decreasing moisture, the soil surface in SALT was still moist due to the heavy mulch build-up.

While comparing the moisture in the SALT system, an interesting observation was made; the hedgerows tended to have slightly more moisture than either the seasonal alley or the perennial alley.

It therefore supports the view that the hedgerows act as "reservoirs" of moisture. The overall impact shows that SALT is more

**Figure 5.1: Bi-weekly Moisture Readings at a Six-inch Depth in a SALT and Traditional Farmer's Farming System**




efficient in soil moisture conservation. This conclusion is made from the fact that even during periods in which the moisture readings indicated "drought" conditions, the crops in the SALT plots were performing well. At the same time, the crops in the traditional farming plot suffered visible drought symptoms such as curling of leaves.

Moreover, if the total moisture per hectare was calculated to include the moisture in the biomass above the ground, the SALT system would have a tremendously higher amount. The biomass in the SALT system (maize, permanent crops, and hedgerow species) contains a large amount of above-ground moisture reserve which is not seen in traditionally-farmed land.

<u>Check on Sediment Flow and Water Runoff.</u> The test was set up to make a sample comparison between the two systems. The stake method showed soil loss from the SALT plot to be 60 times less than in the traditional farmers' system (Table 5.4). The results were confirmed by comparing the actual soil runoff. The data confirmed that hardly anything went into the catchment basin below the SALT farming system, whereas huge volumes of water and soil went into the basin below the traditionally-farmed plot.

*iii. Improvements in Biomass and Crop Fertility*

Comparisons of crop productivity between the two systems, i.e., SALT vs. control, were based on maize crop yields, because maize is one of the major crops grown on the sloping lands in the Philippines and elsewhere in Asia.

The control plot was planted 100 per cent with maize with an average of two harvests per year from 1985 to 1990. The SALT treatment was planted 80 per cent with maize the first cropping year, 60 per cent the second year, and then 43 per cent in succeeding years. These differing percentages are due to the fact that the

**Box 5.1: The State of Traditionally-farmed Sloping Land and SALT-framed Plot**

| Traditionally-farmed Sloping Land (control plot, without any fertiliser inputs) 1984-1993 | SALT-farmed Plot (without any fertiliser inputs) 1984-1993 |
|---|---|
| Ten years of continued farming on the sloping land caused much soil erosion and depletion of nutrients, and the land is now fully degraded. | Ten years of SALT farming on the land provided a perfect system of soil fertility management, sustainable yields, and acceptable levels of net farm income. |
| This non-fertilised sloping farmland was farmed traditionally and the productivity of the land declined steadily, stone boulders started appearing on the land, the land surface became hard, and, during the final years, it became so degraded that further trials on the plot were no longer possible and it has since then been abandoned. | This non-fertilised SALT-farmed land is fairly productive even in its tenth year of cropping. Compared to the state of the control plot, it is about 2.5 times more productive on a per hectare basis and about six times more productive on a per unit basis. |
| In order to rehabilitate this degraded piece of land, SALT has been adopted and results will be known in a few years' time (Plates 5.1 and 5.2). | When compared to a fertilised plot of slope-land farming, the per hectare production may seem lower, but it is actually much higher in unit area productivity (Pages 5.3 and 5.4) |

**Table 5.4: Rainfall, Sediment Load, and Water Runoff from SALT and Traditionally-farmed Plots over a Period of 17 Months (Aug 1991 - Dec 1992)**

| Parameters | SALT Plot | Traditionally-farmed Sloping Land |
|---|---|---|
| Rainfall (mm) | 1820 | 1820 |
| Water runoff (litres) | 164 | 16,000 |
| Topsoil washed (kg) | 0.15 | 1052 |

Source: MBRLC Experiments

permanent crop areas of the SALT plot were used for maize production as long as the permanent crops were small.

The remaining 57 per cent of the SALT farm area generated additional income by way of produce from perennial crops (30% area) and leguminous biomass from hedgerows (27% area), which is not accounted for in the data. Thus the actual gains from the SALT plot are much more than recorded by the data.

The total production records of the SALT farm, including the hedgerow biomass production, have been collected by MBRLC since 1991 and may be available in a few years' time.

By the fifth year, maize production from the cropped area of SALT more than doubled to equal the amount of maize production from a much bigger area of the control plot. To highlight the increased productivity potentials of land under SALT, the values on crop productivity have also been provided in Table 5.5.

**Table 5.5: Maize Yields from SALT Plot and Control Plot (Sloping Land)**

(tonnes/hectare/year)

| | Plot Type | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 |
|---|---|---|---|---|---|---|---|
| i. | Control Plot | 4.7 | 4.3 | 4.2 | 3.1 | 2.6 | 2.1 |
| ii. | SALT Plot | | | | | | |
| a. | Equivalent of one hectare of SALT* | 3.9 | 4.1 | 2.7 | 2.1 | 2.4 | 2.6 |
| b. | Equivalent of one hectare of crop area** (Productivity) | 4.9 | 6.8 | 6.3 | 5.2 | 5.7 | 5.9 |

* The proportion of maize area in the SALT plot varied as follows: 1985 = 85%, 1986 = 60%, and during 1987-90 = 43% of the total land area of SALT. These variations in available maize area, in the initial years, are reflected in the declining values of crop yields over three years.

** Values computed from unit area production to per hectare of maize-cropped area, i.e., parallel to control plot. Results may be considered as indicators of the degree of fertility improvement in the SALT plot.

Source: MBRLC Experiments

### *iv. Production under Low/Moderate Inorganic Inputs*

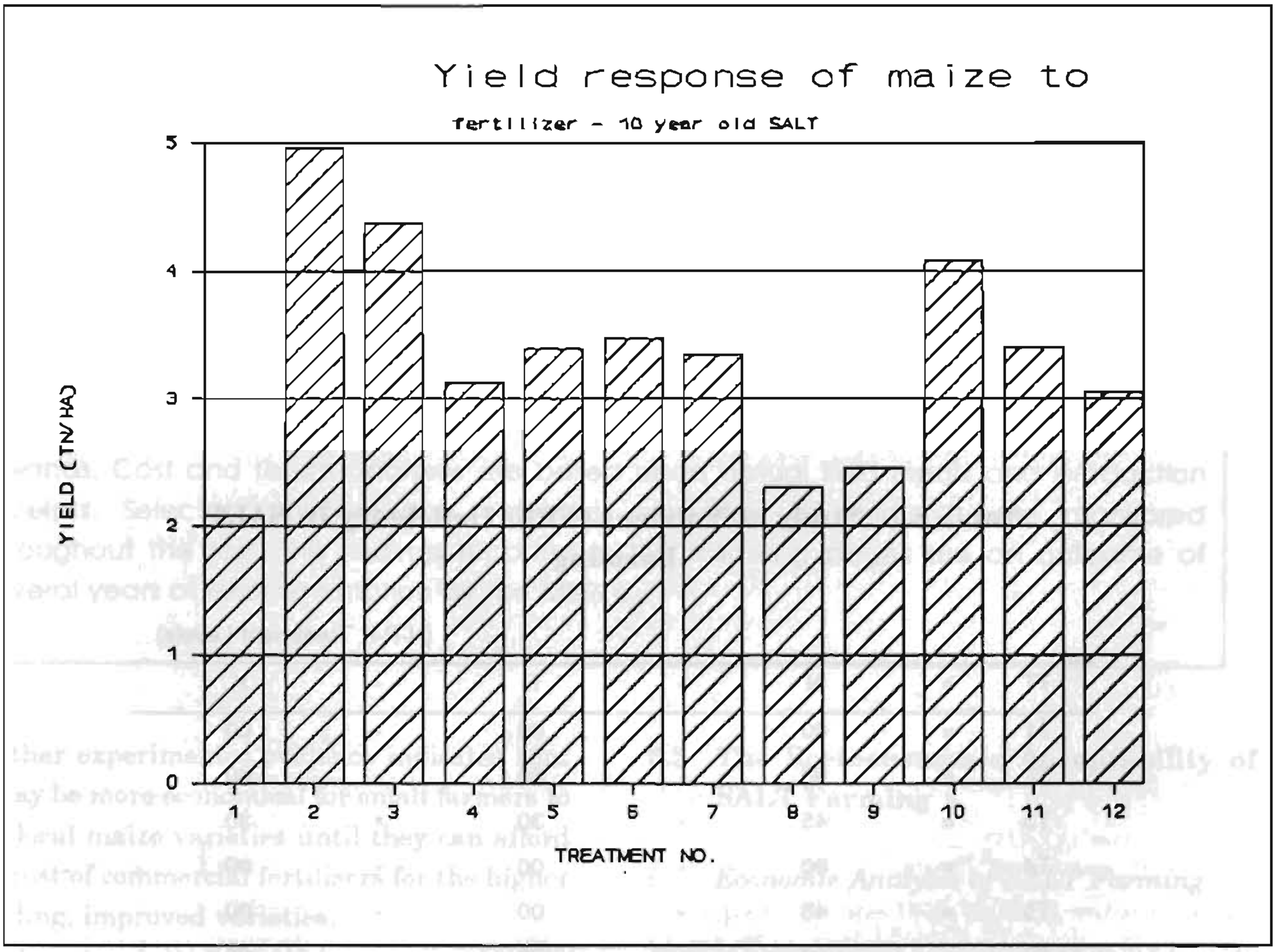
The first comparative performance trials of SALT-farmed and traditionally-farmed sloping lands, without adding any fertiliser inputs, were maintained for ten years (1984 -1993). In 1991, another comparative experiment with similar layouts was set up on another set of plots. These plots are, however, receiving moderate doses of the following chemical fertilisers; N 25kg/h, P 12.5kg/h, and K 12.5kg/h. The comparative performance results compiled for two years are reported under Table 5.6.

### Trials on Nutrient Depletion due to SALT Farming

The nutrient depletion trials were intended to look into the nutrient deficiencies that might have emerged due to the application of SALT. Triplicated random blocks were located on slopes averaging 30° with well-established SALT farming in which the available nutrient levels might have "pulled down" due to heavy cropping over ten years. The various treatments tried during five cropping seasons are given in Table 5.7 and the findings are presented in Figure 5.2.

The problem of adequate phosphorous availability in tropical and subtropical upland agriculture is well known, especially in acidic soils. The data seem to indicate that small additions of phosphorous into the SALT plots may give the most economical crop yield benefits in terms of net return (crop yield increased under phosphorous treatments 2, 3, 6, 7, 10, and 11). However, depending upon the local sources and prices of N, P, and K, the individual farmer's decision, concerning which element will help their production at a cost effective level, has weightage. The best maize yields were recorded under the application of the combinations (T2,T3, T10) of nitrogen and phosphorous (Figure 5.2).

**Figure 5.2: Productivity Changes due to SALT and NPK Inputs**




Another significant observation relates to the increase of maize yield in a typical subsistence farmer's system (grain yield of 1.2 T/ha without fertiliser input) and that of a SALT system, with no external input (fertiliser and mulch from hedgerows), yielding 2.5 T/ha of maize grains. Therefore, a farmer can "sustain" maize yields of 2.5 T/ha with SALT alone. This production level should enable small farmers to purchase moderate amounts of fertilisers, at some point, to further enhance their farm incomes.

### Table 5.6: Comparison of Maize Crop Yields on SALT and Control Plots, with and without Fertiliser Inputs

(Average yields of two crop seasons)

| Crop Year | Plot Type | Maize Yields (T/ha) Fertilised I | II | Maize Yields (T/ha) Non-fertilised I | II |
|---|---|---|---|---|---|
| 1991 | SALT farming | 5.6 | 2.4 | 4.0 | 1.7 |
| 1992 | SALT farming | 7.9 | 3.4 | 5.8 | 2.5 |
| Mean | SALT farming | 6.8 | 2.9 | 4.9 | 2.1 |
| 1991 | Traditional farming | 2.6 | --- | 1.2 | --- |
| 1992 | Traditional farming | 2.0 | --- | 0.4 | --- |
| Mean | Traditional farming | 2.3 | --- | 0.8 | --- |

I: Equivalent of one hectare of maize cropped area (indicator of land productivity)

II: Equivalent of one hectare of SALT area, with only 43% maize cropped area (indicator of production)

Note: The SALT system with moderate fertiliser inputs produced about 30% more corn than the traditionally-farmed sloping land (control), and that too from only 43 per cent of the cropped land (57% less area than control). SALT has definitely increased the productivity of land much more, but some additional inputs of P and K also boost productivity.

Source: MBRLC Experiments

### Table 5.7: Study of Nutrient (NPK) Deficiency in SALT Farming

(N-P-K Treatment Levels)

| TT | = | N | - | P | - | K |
|---|---|---|---|---|---|---|
| T1 | = | 00 | - | 00 | - | 00 |
| T2 | = | 90 | - | 60 | - | 60 |
| T3 | = | 45 | - | 30 | - | 30 |
| T4 | = | 90 | - | 00 | - | 00 |
| T5 | = | 45 | - | 00 | - | 00 |
| T6 | = | 00 | - | 60 | - | 00 |
| T7 | = | 00 | - | 30 | - | 00 |
| T8 | = | 00 | - | 00 | - | 60 |
| T9 | = | 00 | - | 00 | - | 30 |
| T10 | = | 45 | - | 30 | - | 00 |
| T11 | = | 00 | - | 30 | - | 30 |
| T12 | = | 45 | - | 00 | - | 30 |

Source: MBRLC Experiments

**Box 5.4: The Location, Layout, and Management of Comparative Experimental Plots**

The location of the experimental plots is on a fairly uniform sloping hillside. The average slope is about 18°. The climatic and other conditions prevailing in the experimental area are already described in Chapter 3, along with outlines of major experiments. The experimental plots for comparative performance evaluation of SALT vis-a-vis traditional farming ways are set up side by side. Each plot measures 20x40m (0.08ha) for a total of four plots to give a total area of 80x40m or 0.32ha. Since 1984, four replicates of such plots have been covered with two models each of the traditional farming system and of the SALT system. The plots having a traditional farming system are cropped by the 'no-till' method. It is basically a "slash and burn" method without the burning. In rotational cropping, on an average, two crops of maize and one crop of *mung* beans were farmed each year.

The SALT plots were planted with leguminous double contour hedgerows every four to five metres. The original hedgerows of *Leucaena leucocephala* were replaced by *Flemingia macrophylla*, because of *Heteropsylla cubana* infestation. Every third cropping strip or "alley" was put under permanent crops (bananas, robusta coffee, citrus, and arabica coffee). The annual or seasonal alleys were farmed in the same method used by local farmers with the exception that seasonal crops were planted on the contour because of the hedgerows.

The proportional land area under each SALT replication is shown in Table 5.1. Crop productivity concentrated on maize production, since it is one of the staple crops of the uplands. Cost and return analyses are based upon actual field inputs and production receipts. Selected physical and chemical properties of the soil were monitored throughout the test. The findings reported in the following pages are an outcome of several years of experimentation by the MBRLC.

Further experimental evidence indicates that it may be more economical for small farmers to use local maize varieties until they can afford the cost of commercial fertilisers for the higher yielding, improved varieties.

A trial conducted of the local varieties to compare them with a few selected hybrids on the same low-fertility inputs revealed that, under low input conditions, in which fertility depends only on hedgerow inputs, local varieties are usually more profitable.

## 5.2 The Socioeconomic Acceptability of SALT Farming

*i. Economic Analysis of SALT Farming*

As reported elsewhere, the SALT system is comprised of four different models representing small family farms. These models differ in terms of farming components, e.g., SALT-1 is basically a hedgerow system designed to control soil erosion and maintain soil fertility and this makes an impact on crop productivity; SALT-2 incorporates forage crop production and livestock rearing in addition to SALT-1 activities, resulting in additional output/gains from livestock; SALT-3 becomes more diversified because the component of a small private forest is included in it, so as to earn cash income from selling timber, along with gains from crops and livestock; SALT-4 is designed to include horticulture as a major component of farming. Going by the components of these different SALT farming systems, definitive variations would be expected in the cost return analysis. Apart from results of studies made at MBRLC, related information gathered from other sources will also be included in the discussion.

*ii. The Cost Return Analysis of SALT-1*

For the first two years, the net income from SALT farming is less than the net income from the traditionally-farmed sloping lands (Figure 5.3). In the following years, income from the latter decreases steadily, while the net income from SALT farming starts increasing. The ratio of the net income from the SALT system increases each year and, in the sixth year, it more than doubles that from the farmers' traditional system. The contribution from perennial crops to income from SALT increases every year for several years until the perennial crops contribute a major portion of net income. The gross income, total expense, and net income from SALT farming recorded for 12 years (1980-1992) are presented in Table 5.8.

The average annual income of hill farmers in the MBRLC's vicinity was about 4,000 *pesos* (US$ 200) during this period, with most farmers farming more than one hectare of land. At this rate of income, potentially a farmer can triple his farm income by adopting the SALT system.

Experiments conducted by the Asialand Network Cooperators, on sloping land management in the Philippines, gave better corn yields in the SALT alleys than under farmers' practices, after high inputs of NPK and with no fertiliser application. On a site in northern Thailand, where the Asialand Cooperators cultivated corn in the alleys, very good yields (compared to control) were obtained continuously for four years without any external inputs. In the fourth year, the cooperators tried to increase the yield by using fertiliser, the results were not encouraging. In Thailand, in general, plant growth under alley cropping was better than in the farmers' practice. Terrace formation was observed under the alley cropping technique in subsequent years. In Vietnam, the effect of intercropping and of alley cropping on the growth of coffee, using a mixture of *Tephrosia* and *Crotalaria* as hedgerows, was very encouraging.

*iii. Labour Requirements for SALT-1*

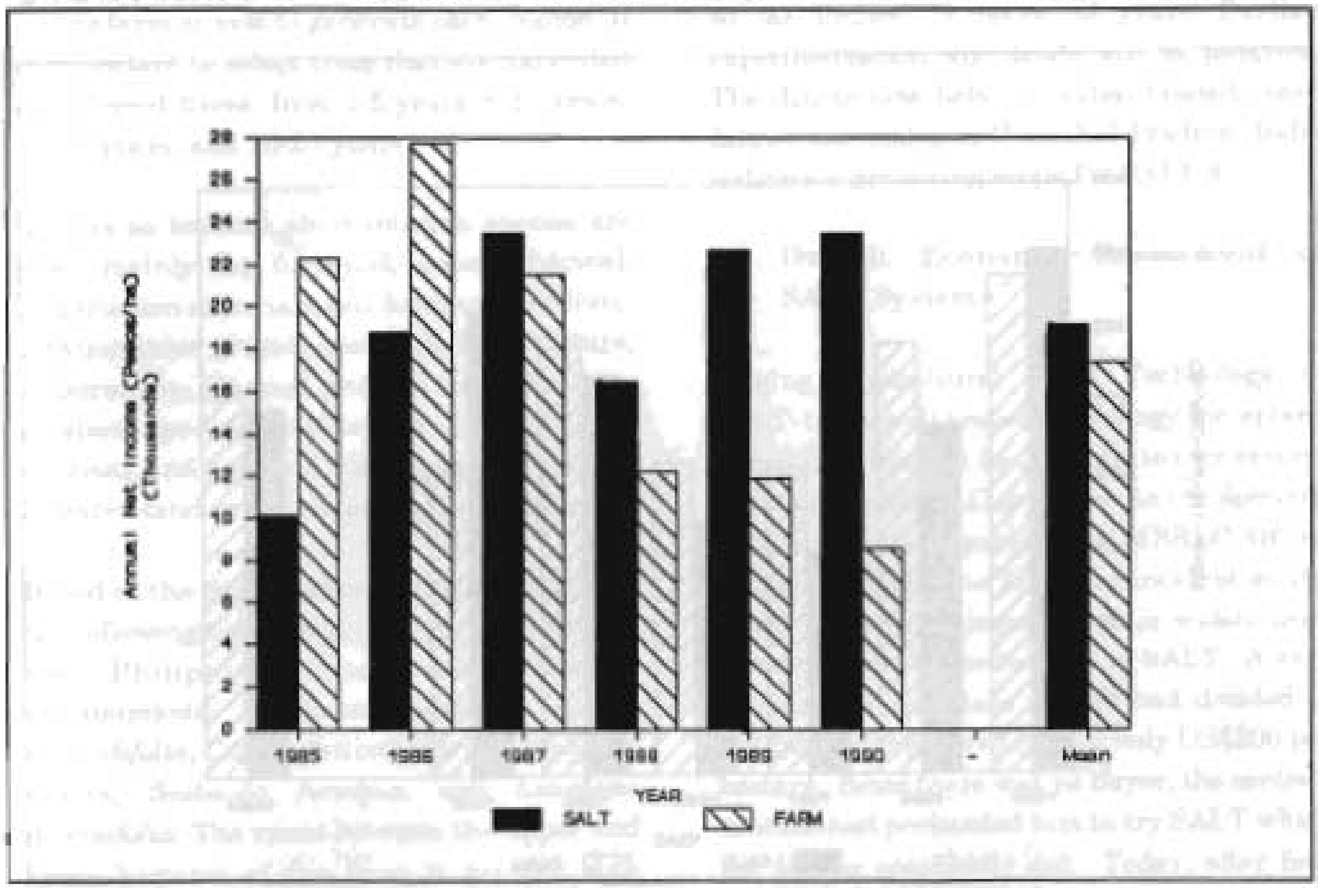
It had previously been thought that SALT farming would be more labourious due to the maintenance of hedgerows. More labour is used in the first year for planting hedgerows and permanent crops, but in successive years the need for labour is reduced (Figure 5.4). This is because, in SALT-1, there is less area under annual crops (43%), and perennial crops are less labour intensive.

The maintenance of hedgerows in the successive years, however, requires the same amount of labour for regular trimming. The largest share of labour is required for weeding of annual crops. The labour needs also increase at the time of production from perennial crops (citrus in this case). In comparison, the annual labour input for SALT is actually slightly lower than that of the traditionally-farmed sloping land.

*iv. The Cost Return Analysis of SALT-2*

Simple Agrilivestock Technology, or SALT-2, is a form of agrosilvipastoral system since it

**Figure 5.3: Comparison of Net Incomes from SALT and Non-SALT Farming**




Source: MBRLC Experiments

**Table 5.8: Cost Return Analysis of the One-hectare SALT Farm (MBRLC) (Data of 12 years [1980 to 1992] in US$)**

| Year | Gross Income | Total Expenses | Net Income |
|---|---|---|---|
| 1980 | 285 | 56 | 229 ** |
| 1981 | 154 | 29 | 125 ** |
| 1982 | 450 | 92 | 358 ** |
| 1983 | 302 | 62 | 240 *** |
| 1984 | 715 | 87 | 628 **** |
| 1985 | 780 | 93 | 687 **** |
| 1986 | 665 | 85 | 580 * |
| 1987 | 863 | 153 | 710 * |
| 1988 | 864 | 138 | 728 * |
| 1989 | 940 | 140 | 800 **** |
| 1990 | 865 | 98 | 767 **** |

Note: Since actual data was recorded in *pesos*, the exchange rate conversion made was @ 20 *pesos* = 1 US $.

1. Costs of material inputs accounted for but labour costs excluded because farmers use family labour.

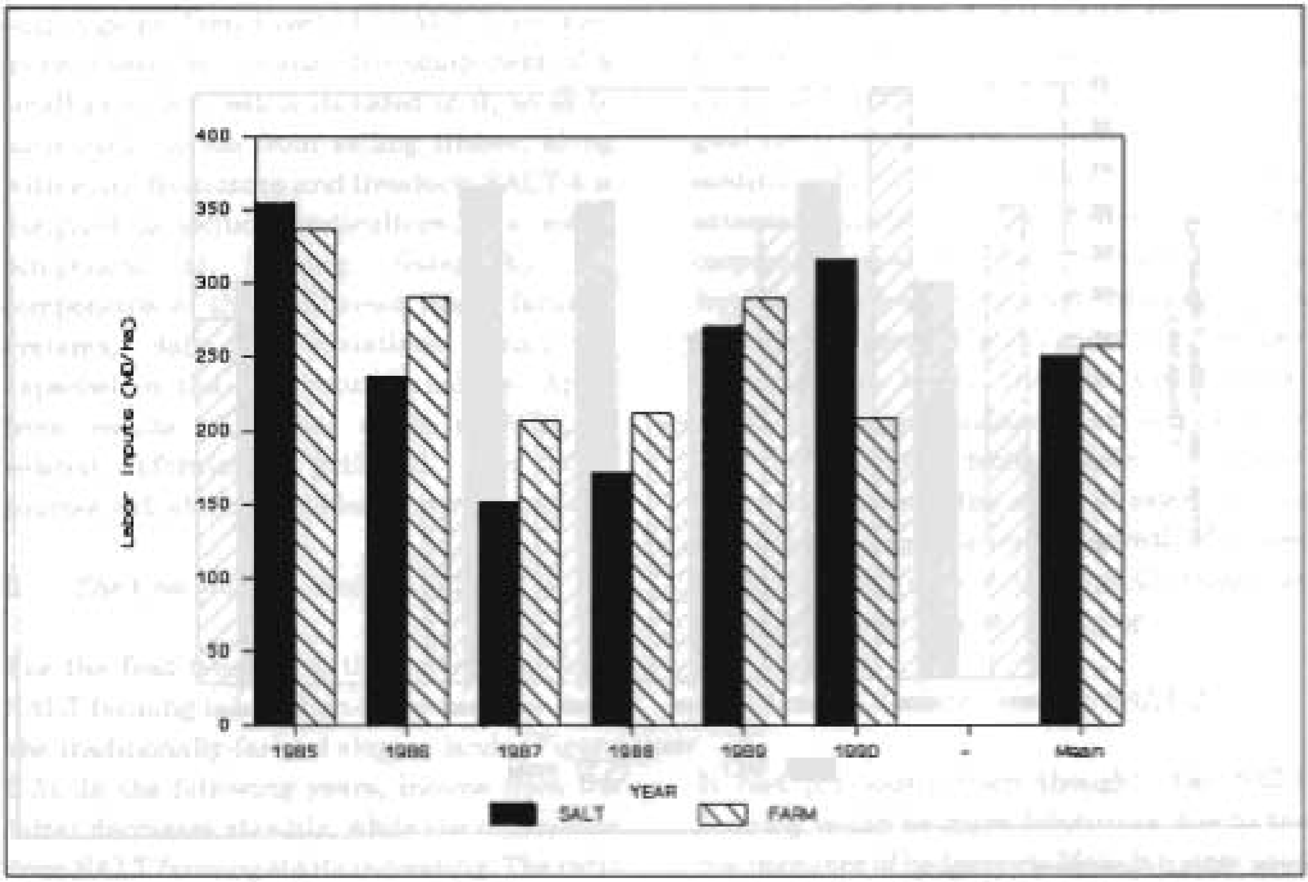
** Permanent crops had not reached production stage.

*** Droughts occurred in Mindanao.

**** Permanent crops started producing.

* Psyllid infestation of *Leucaena* and no biomass, *Leucaena* hedgerows replaced by *Flemingia macrophylla*.

**Figure 5.4: Comparison of Labour Requirements between SALT and Non-SALT Farming**




Source: MBRLC Experiments

integrates agricultural crops, forage production, and livestock as components of farming. Fuelwood production is a by-product from SALT-2. As reported earlier, under SALT-2, 40 per cent of the farmland is devoted to agricultural crops, 40 per cent to raising forage crops, and the remaining 20 per cent to forestry. The SALT-2 performance evaluation at MBRLC is based on the trials and testing on its one and a half hectare farm allocated for this system.

Our data show that SALT-2 can generate a monthly cash net profit of about US$ 100 from a one and a half hectare farm. The return on investment (ROI) achieved by MBRLC is around 33 per cent, projecting a cost-benefit ratio of 1.3 (Table 5.9).

Additionally, half a hectare of forage plot of SALT-2 supports 12 female goats and a male goat, which together produce an average of 4,700 litres of milk annually. With this size of SALT-2 farm,farmers can also get about 16 tonnes of goat manure annually, plus the biomass from the contour hedgerows for protecting and ameliorating the soils on the farmland and to enhance productivity and sustainability.

*v. The Cost Return Analysis of SALT-3*

In SALT-3, the system is designed to produce food, fruits, forage, fertiliser, and fuelwood to meet the subsistence and cash needs of the farmer.

On a one-hectare farm, the higher portion is placed under a productive afforestation scheme. Farmers are encouraged to plant a variety of useful tree species having good market value for timber. Timber may be used on the farm or sold to generate cash income. It is important to select trees that are harvested at different times: from 1-5 years, 6-10 years, 11-15 years, and 16-20 years.

This is so because short-rotation species are used mainly for fuelwood, poles, charcoal, construction materials, and furniture. Medium-rotation trees provide materials for furniture, construction, charcoal, and leaf meal. The long-rotation species provide saw logs, lumber, charcoal, and fuelwood. Each species is planted in pure stand in a strip along the contour.

Based on the trial experimentation at MBRLC, the following tree species are found useful for the Philippines and other similar environments: *Samanea saman*, *Acacia auriculifolia*, *Calliandra calothyrsus*, *Sesbania sesban*, *Sesbania formosa*, and *Leucaena diversifolia*. The space between the upper and lower hectares of the farm is planted with bamboo (*Bambusa* spp).

The cost-benefit data for SALT-3 in Table 5.10 is for five years only (1987-91). Since it is a short period over which to assess the benefits from the tree crops, which span up to 20 years, the benefits recorded here are only from marginal non-timber products and should not be taken as actual indicators of total benefits.

*vi. Economic Issues of SALT-4*

Small Agrofruit Livelihood Technology or SALT-4 has been introduced in recent years at the centre. Its general objectives, as stated earlier in Chapter 3, are to produce food, increase income, and conserve the soil on sloping lands. Sixty per cent of the upper portion of the whole farm can be allocated to horticulture. Fruit tree mixtures can be designed in such a way as to contain short-term, medium-term and long-term fruit tree categories to ensure sustained benefits over a long period. Data on returns from SALT-4 are so far limited in terms of years. Further experimentation and trials are in progress. The discussions held on orchard-based small farmer economies in Himachal Pradesh, India indicate a promising scope for SALT-4.

## 5.3 Overall Economic Assessment of SALT Systems

Sloping Agricultural Land Technology or SALT-1 is a well tested technology for upland farming systems. It has been tested for several years at the MBRLC as well as in the farmers' fields under the supervision of MBRLC. Of the numerous cases, the following incident at the centre's extension impact area is widely used to best illustrate the benefits of SALT. A very discouraged mountain farmer had decided to sell his unproductive farm for only US$200 per hectare. Since there was no buyer, the centre's extensionist persuaded him to try SALT which the farmer sceptically did. Today, after four years of "SALT-ing" it, this farmer is no longer willing to sell that same piece of land even for US$ 2,000, i.e., ten times the earlier value.

SALT-1 is no doubt a simple, low-cost farming system which focusses on 1) controlling soil erosion, 2) maintaining soil fertility, and 3) providing food and sufficient income for the farm family that uses it. Under low-input conditions, SALT performs as an optimum production system focussing on long-term sustainability. Without "outside" additions, relatively stable yields, although low according to modern production standards, can be obtained and maintained with miscellaneous inputs from SALT hedgerows alone. The system can also be made highly productive by using moderate inputs.

The other benefit of SALT-1 is that it can be scale neutral in terms of size of landholding. Although experimental evaluations are based on one hectare or half hectare units, the very

## Table 5.9: The Cost Return Analysis of SALT-2, 1987-1991

Per ha in US$

(@ 20P = 1 US$)

| Particulars | 1987 | 1988 | 1989 | 1990 | 1991 | Total |
|---|---|---|---|---|---|---|
| **I. Returns** | | | | | | |
| 1. Crop produce (annual) | - | 142 | 503 | 128 | 180 | 945 |
| 2. Crop produce (fruits) | - | - | - | 3 | 34 | 37 |
| 3. Goat breeders | 403 | 495 | 1032 | 1140 | 668 | 2739 |
| 4. Goat meat | 12 | 24 | - | - | - | 36 |
| 5. Goat milk | 1645 | 2863 | 2186 | 3930 | 3521 | 11568 |
| **A. Total cash** | 2060 | 3524 | 3722 | 5201 | 4403 | 15325 |
| 6. Replacers | 125 | 125 | 125 | 125 | 125 | 625 |
| 7. Added value to the livestock | 650 | 950 | 950 | 950 | 950 | 4450 |
| 8. Manure | 820 | 820 | 820 | 820 | 820 | 3280 |
| **B. Total non-cash** | 1595 | 1895 | 1895 | 1895 | 1895 | 4345 |
| C. Total returns | 3655 | 5419 | 5617 | 7096 | 6298 | 19670 |
| **II. Costs** | | | | | | |
| 1. Seeds and other inputs | - | 27 | 38 | 46 | 255 | 366 |
| 2. Feed and other miscellaneous expenses | 1535 | 1843 | 2465 | 2216 | 2404 | 10463 |
| 3. Labour (eq.) | 1264 | 1497 | 1732 | 1720 | 1850 | 8065 |
| 4. Mortality of animals, depreciation | 313 | 344 | 344 | 344 | 344 | 1689 |
| **D. Total cash cost** | 1535 | 1870 | 2503 | 2262 | 2659 | 10829 |
| **E. Total non-cash cost** | 1577 | 1841 | 2076 | 2064 | 2194 | 9752 |
| **F. Total costs** | 3112 | 3741 | 4579 | 4326 | 4853 | 20581 |
| o Net profit (C-F) | 543 | 1678 | 1038 | 2770 | 1445 | 7474 |
| o Net cash profit (A-D) | 525 | 1654 | 1219 | 2941 | 1744 | 8074 |
| o Return on investment (%) | 17.3 | 59.6 | 22.7 | 64.2 | 29.4 | 38.6 |
| o Cost-benefit ratio | 1.1 | 1.6 | 1.2 | 1.6 | 1.3 | 1.3 |

Source: MBRLC Trial Experiments

**Table 5.10: Cost Return Analysis of SALT-3, 1987-1991**
(Per ha in US$)

(20P = US$ 1)

| Particulars | 1987 | 1988 | 1989 | 1990 | 1991 | Total |
|---|---|---|---|---|---|---|
| I. **Returns** | | | | | | |
| 1. Agricultural produce (cash) | 227 | 394 | 440 | 1018 | 1092 | 3171 |
| 2. Forest produce (cash) | - | 38 | 88 | 143 | 268 | 537 |
| A. **Total cash** | 277 | 432 | 528 | 1161 | 1360 | 3758 |
| B. **Tree plantations (non-cash)** | 406 | 813 | 1141 | 1417 | 1642 | 5419 |
| C. **Total returns** | 683 | 1245 | 1769 | 2578 | 3002 | 9277 |
| II. **Costs** | | | | | | |
| 1. Site preparation | 50 | - | - | - | - | 50 |
| 2. Hedgerow seeds and forestry plantations | 130 | 5 | 4 | 4 | 3 | 146 |
| 3. Crop seeds | 85 | 7 | 6 | 7 | 58** | 163 |
| 4. Fertilisers, pesticides, etc | - | 320 | 295 | 274 | 275 | 1164 |
| D. **Total cash cost** | 304 | 371 | 353 | 326 | 368 | 1722 |
| E. **Non-cash labour** | 416 | 845 | 977 | 1030 | 1135 | 4403 |
| F. **Total costs** | 720 | 1216 | 1330 | 1356 | 1503 | 6125 |
| o Net cash profit (C-F) | -37 | 29 | 439 | 1222 | 1499 | 3152 |
| o Net cash profit (A-D) | -27 | 61 | 175 | 836 | 992 | 2037 |
| o Return on investment (%) | 4.8 | 2.3 | 24.5 | 90.4 | 95.6 | 43.5 |
| o Cost-benefit ratio c/b | 0.9 | 1.0 | 1.3 | 1.9 | 2.0 | 1.4 |

Source: MBRLC Trial Experiments

nature of the hedgerow system is such that it can be applied to any size of landholding with varying degrees of slope. This is exactly how the SALT-related systems, called hedgerow systems, are being applied outside the Philippines by various agencies.

In view of the smaller landholdings of hill farmers, and these too fragmented into several parcels, as is the case in several parts of the HKH, SALT-1 will have to be considered in the scale neutral form. In such areas of sedentary agriculture, SALT-1 is useful for managing soil conservation on existing, sloping farmland parcels of varying sizes.

There is, however, another aspect of hill farming, i.e., shifting cultivation, in which an adequately sized, single piece of farmland, usually larger than one or two hectares, has been the norm. In shifting cultivation areas, the size of the farmland is determined by the amount of available family labour. Initially, SALT was developed keeping in mind the problems of shifting cultivators, and so one of its goals was to determine the optimum landholding size for a normal family of four to six members. From this angle, the MBRLC findings relating to the normal size of a family farm are very useful for several upland areas affected by shifting cultivation. They could serve as a yardstick for the settlement of shifting cultivators in various upland areas.

Judging from the types of land use and the diverse benefits befitting upland farmers' needs, one would agree that SALT-2 is the most useful kind of system for a farm family. It can have wider applications in areas where shifting cultivation is prevalent as well as in areas of sedentary upland agriculture, depending greatly on livestock for its sustainability but facing a fodder crisis, e.g., the middle hills of Nepal.

Within the HKH Region, one finds that sloping agricultural lands are degrading. Evidence of farmers having to abandon these lands is quoted in Chapter 2. Uncultivated land, commonly called wasteland, or common property land, which is generally converted into agricultural land in times of land pressure (and that is indeed happening in several countries), is also a victim of land degradation. Thus, it can neither be converted into productive farmland nor is it supplying adequate amounts of fodder biomass, which was the intended role of these lands. Experiments have shown that SALT-1 and 2 combined have the potential to contain degradation, restore the fertility of cultivated farmlands, and regenerate the supportlands.

SALT-3 has value for farmers but has limitations in terms of wider application, because of the land tenureship laws in several countries. Also the landholding size of farmers from most upland areas is rarely two hectares. Certainly, not more than 10 per cent of upland farmers in the Asian highlands would own that much land. However, in shifting cultivation areas, where farmers can use as much land as they can farm, this is not a problem. Cultivating trees involves land ownership, a wholly institutional issue which is beyond the scope of this topic.

SALT-4 has the fruit and permanent cash crop component, which is considered to be a better farming system for the uplands from both the ecological and economic points of view. As shown by ICIMOD studies, horticulture is one of the prime comparative advantages of the hill and mountain areas. Consequently, the scales of fruit farming also vary a great deal from one area or agroecological zone to another. Although the percentage allocation of farmland recommended by MBRLC for SALT-4 seems to have a good rationale, the fruit species will differ from one agroecological zone to another and so will the farming system. In evaluating SALT systems, consideration should also be given to some of the factors detailed in Annex 2.

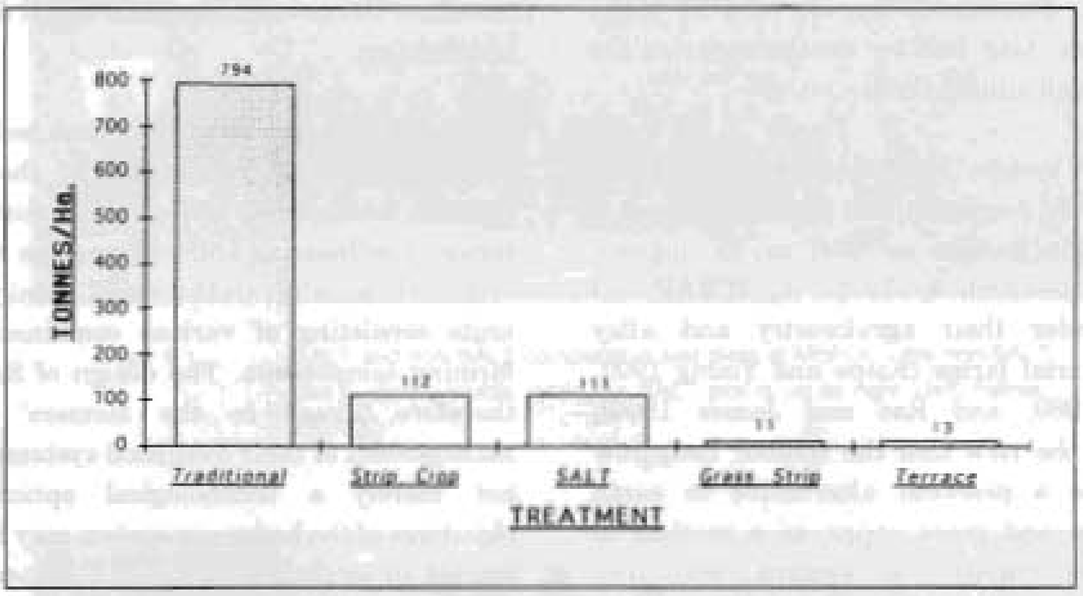
## 5.4 Comparative Experiences of Related Technologies

Picking up the discussion further from Chapter 2, where various available regenerative technologies were described, a comparison of the performance rating of SALT is made with many of them in this section. Consequently, some repetition of facts has been intentionally made.

The multiple option (biological and mechanical) based soil conservation programme, launched under the Thai-Australia Highland Agriculture and Social Development Project in the northern areas of Thailand from 1985-93, reported that the terracing and grass strip technology could be used effectively to reduce the soil loss rates (2 T/ha/yr) to sustainable levels (Figure 5.5, Hoey 1993). After evaluating the trials for controlling soil loss, increasing crop yields, and the economics involved, the project observed that the best option for the area might be the contour grass strip technology, rather than the hedgerows of SALT. Incidently, the performance of SALT hedgerows was second to the above two approaches under the given acidic soil conditions in northern Thailand.

This is an important observation, indicating the limitations of SALT and its hedgerow system in certain environments.

**Figure 5.5: Comparative Soil Loss for Different Cultivation Practices**




This also shows that no one system can be sufficient in itself and cannot be universally applicable for achieving sustainable levels of soil loss and soil fertility maintenance. The fact that poor establishment and growth on acid soils can limit the performance of SALT hedgerows points to the need for diversifying the choice of hedgerow species and selecting those with optimum growth and yield, but adapted to the local environment.

However, crop yields still declined with time under the grass strip method, indicating that soil erosion control and actual conservation of the soil resources are different activities, as the latter involves maintaining fertility which cannot be achieved by a uni-dimensional approach like the grass strip method. Findings also highlight the fact that a system can have none or acceptable soil loss and still be

**Box 5.2: Perceived Limitations of SALT**

- It represents a radical change from present practices
- SALT hedgerows occupy significant cropping areas (27%)
- Hedgerows need maintenance and protection from grazing
- Competition may cause reduction in crop yields
- Hedgerows can act as hosts to pests, diseases, and birds
- Continuing research on the above aspects is revealing facts that hold many assumptions made irrelevant

unsustainable in terms of maintaining crop yields. This is also a slowly emerging trend that one finds in terraced farming.

Yet another, much publicised, bioengineering approach to soil erosion control is the use of vetiver grass, which is both a technically sound and an economically practical basis for a hedgerow/contour cultivation system (Smyle and Magrath 1990).

However, dependence on any one of these approaches may not be the best option for sloping agricultural fields.

The SALT system, however, is designed with a rare in-built mechanism to function both as a soil erosion barrier as well as to improve fertility. Research conducted by ICRAF and IITA, under their agroforestry and alley cropping trial farms (Kiepe and Young 1992, Young 1989, and Rao and James 1990), supports the view that the contour hedgerow system is a practical alternative to earth structures and grass strips as a method of controlling runoff and erosion, with the additional benefit of soil fertility. The natural terrace formation and the additional function of maintaining soil fertility are comparable to grass strips and bench terraces.

The above information strengthens the argument that, although there are several biological options related to SALT, in terms of its function to control soil erosion, the universal application of many such technologies seems unlikely. One may also notice that agencies like ICRAF, IITA, IBSRAM, and others have focussed R & D efforts on the hedgerow system and not on the SALT system.

This is because the hedgerow technology, as such, is scale neutral, but the SALT system is based on the assumptions of a small farmer's landholding.

It should be emphasised here that hedgerows are one principal component of the SALT system, which goes a few steps further in terms of delineating and testing more realistic and economically viable small family farm units consisting of various combinations of farming components. The design of SALT is, therefore, closer to the farmers' overall management of their livelihood systems and is not merely a technological option. The objectives of the hedgerow system may be more limited in scope than the SALT system. Still more limited are the objectives fulfilled by other options. From the point of view of sustaining the productive potential of the hill agricultural system, the SALT and hedgerow systems should be perceived as certainly superior to other options in terms of application, i.e., relatively wider but not universal.

Plate 5.1 SALT and non-SALT comparative test plots at MBRLC - the non-SALT plot is clearly visible, while the SALT plot is on its right (Jeff Palmer, MBRLC).

Plate 5.2 The state of the non-SALT plot after ten years - much of the soil has been washed away and several stone boulders have appeared on the field (HR Watson, MBRLC).

Plate 5.3 Terraced alleys and hedgerows of the comparative SALT trial plots after ten years, at MBRLC (H.R. Watson, MBRLC).

Plate 5.4 The fertility of the stabilised and terraced alleys has enhanced considerably and good crop growth and yields were recorded without external fertiliser inputs (H.R. Watson, MBRLC).

# 6. REPLICATION OF SALT: BENEFITS, PRECONDITIONS, AND PROGRESS

## 6.1 Reasons for Advocating the Replication of SALT

Why should upland farmers be encouraged to adopt SALT to manage their sloping farmlands? What are those comparative benefits, both direct and indirect, that SALT can bring specifically to the farmers and to the farming system as a whole? What potential does this technological option hold for agencies working on various aspects of sustainable development and promoting ecologically and economically sound farming approaches? For a discussion on the potential multiple roles of SALT, these general queries are here reframed under the following headings:

i. SALT and productive farm management;
ii. SALT and its suitability in various agroecological ecozones;
iii. SALT and farm size: relevance to small farmers;
iv. SALT and the scope for cash crop farming;
v. SALT and the food security/nutrition of farm families;
vi. SALT and other related technologies;
vii. SALT and its contributions to biodiversity management; and
viii. SALT and gender considerations.

Many of these topics may have been discussed in previous chapters under different contexts. However, at the cost of some repetition, these are included here, so as to frame a clear picture of the total benefits from SALT.

*i. SALT and Productive Farm Management*

When SALT was being conceived as a technological option, the goal was to develop an alternative system that could combine erosion control efforts with fertility management. As described in Chapter 5, it is now confirmed that the bioengineering approach applied under the SALT system is comparable to mechanical erosion control methods. The most common mechanical option employed traditionally by farmers, and also followed by several development projects, is the terracing of sloping land.

We are not arguing against the terracing system, which has been in use for centuries in most countries of HKH the Region, and which is one of the better known traditional systems for farming sloping lands (more details in Chapter 1). The main point in favour of SALT is that this bioengineering approach, besides stabilising sloping lands, also offers the additional benefit of maintaining the soil fertility of farmlands in two ways; (i) by way of nitrogen-fixation as a direct input into the soil and (ii) through biomass from the hedgerows. The nutrients from the biomass flow back into the soil, either directly as mulch or as compost, after using it as fodder for the livestock.

Some queries are raised about the economics of the SALT system versus the terracing system. Initially, the cost of terracing is of course higher than that of establishing SALT. But it is argued that afterwards the hedgerows may require regular maintenance, taking more time on the part of farmers. This may be true, proper management of hedgerows needs labour and other inputs to some extent, but keeping the hedgerows in good shape implies maximum production of biomass, usable both as mulch and fodder. This tilts the overall economic benefits in favour of SALT. Numerous reports from most HKH countries highlight rising fodder and fuelwood scarcity and the increasing amount of time being spent by the farmers to meet these subsistence needs. Thus, the extra time and inputs spent on the maintenance of hedgerows, seen against this backdrop, appear to be a better alternative.

What are the implications of SALT in a situation where landholdings are large and family labour is in short supply? SALT, by design, favours intensive farming and regular care of the farmland. Therefore, a judgement not favouring the application of SALT farming under such farmer options may be inappropriate, because by adopting all systems of SALT, i.e., SALT-1, 2, 3, 4, the farmer can make an effective division of his land into a labour-demanding alley cropping area (43%) and a less labour-demanding SALT-2. If one were to make further adjustments, then the area under SALT-3, which is least labour demanding, can be increased substantially. SALT-4 is an alternative option which helps spread the labour-input pressure of the family. It demands labour either at a period when it is freely available, or for the purpose of cash crop harvests bringing immediate economic gains, for which farmers will not mind hiring labour by paying cash.

Complaints about SALT being labour intensive, in cases in which farmers plant and maintain hedgerows over a large area only as a soil conservation measure and do not adopt the whole system, seem inappropriate. This in a way is the alley farming approach and not, in a strict sense, the concept of SALT. There are several instances of non-adoption of the alley farming/hedgerow system on this account. Therefore, the designers of SALT have incorporated the farm size as an essential component wherever larger farmlands come into question. Thinking from another angle, a farm family will maintain a larger crop cultivation area because of poor productivity and greater food demands of the family, as is the case with several shifting cultivation families. If the same demands were to be met with lesser land, by increasing productivity, then the farmer would opt for less labour-demanding, land-use options.

*ii. SALT and Its Suitability in Various Agroecological Zones*

Sloping farmlands are distributed over a wide range of agroclimates, fromthe tropical to the temperate. Restricting our discussion to Asia in general and the HKH in particular, one finds that sloping land farming is spread from the tropical environment to the cold temperate, high mountain areas. The whole of the HKH, for example, can be divided into the broad agroecological zones and farming systems described below.

The suitability of SALT to these agroecological zones and their implications for farming have been further elaborated upon.

**(a) The eastern Himalayan region, with low hills and a warm subtropical climate, is dominated by slash and burn farming (shifting cultivation). The north-east Indian Himalayas, parts of Bhutan, Bangladesh, Myanmar, and the Hengduan Mountains of China fall into this category.**

SALT has a proven value as an alternative to the shifting cultivation system. This is because the SALT system has been conceived and designed keeping in mind the farming conditions of shifting cultivators. The SALT system provides for the development of a compact small family farm on a given piece of sloping land, where cropping, livestock, horticulture, and forestry can be incorporated at the farmers' will as SALT-1, SALT-2, SALT-3, and SALT-4. Since there is no permanent land tenureship for shifting cultivators, one would be talking about resettling these roaming families using SALT as an approach. Incidentally, resettlement efforts for shifting cultivators are underway in all the HKH countries and the governments are trying out several approaches, including permanent land tenureship, compact farming, general agroforestry, and the facilitation of terracing of sloping lands. Therefore, in this agroecological zone, SALT as perfected by MBRLC, holds the potential of a good alternative farming approach. Almost all of the promising hedgerow species identified by MBRLC should adapt well in most parts of this agroecological zone.

(b) **In the low and mid-hills of the central and western Himalayas, characterised by warm subtropical climates and mixed farming systems, crops and livestock are equally important. In both terraced and sloping land farming, small landholdings and high population density are the norm in this agroecological zone. The low and mid-hills of Nepal, Bhutan, central and western India, parts of Pakistan, and the Hengduan Mountains of China fall into this category.**

While considering the suitability of SALT to the agroecological zones and farming systems indicated under item (b) above, we are reminded of the inherent features of these farming systems which become both constraints and opportunities for the application of SALT farming. Small landholdings divided into several parcels constitute one such major constraint. This is contrary to the design of creating a compact SALT farm with all of its components located around the house. Although it is true that the real impact of SALT can be felt by establishing a compact farmland, components of the SALT system are equally relevant to these permanent, scattered sloping parcels of land. To begin with, SALT-1, i.e., the hedgerow technology, can be applied on any number of sloping parcels of land, because it is scale neutral. We realise that it may be partly due to this reason that SALT-1 is also known as "alley farming", and it aims to control soil erosion and maintain the fertility of agricultural lands using bioengineering methods, without the size of the landholding being a condition.

One will find that of the SALT-1 hedgerow system is extremely relevant to permanent sloping lands faced with the problems of soil erosion and fertility decline. It does not need reiteration that these are two issues dominating low and mid-hill agriculture in most parts of the HKH Region. There exists a system of maintaining private grasslands (known as "*ghasnis*" by the low and middle hill farmers of India and Nepal [see also Box 7.3]) in order to ensure adequate fodder supply for maintaining the livestock. Should there be need to improve these grassland systems, wherever these lands are faced with degradation, the second alternative of SALT-2 seems most appropriate. Not only will it improve the productivity of these grasslands, but one can foresee a variety of nutritive fodder supplies flowing from these lands. The farmer can use both options, grass and hedgerow combinations or only hedgerows, as fodder.

The likelihood of the acceptance of SALT-2 in this agroecological zone is increasing with increased pressure on grazing lands and subsequent degradation. The problematic limiting factor here would be the combination of livestock. Farmers want to have buffaloes, cows, and bullocks as their main livestock force and goats and sheep as a secondary option. SALT-2 has the provision mainly for goats for milk and sheep for meat.

It is, however, understood that the identification of promising hedgerow species out of the long list of native legumes and other NFTs has to precede the application of SALT in this agroecological zone. Crop combinations, suited to local farming conditions, should be favoured.

There may, however, be a small percentage of farmers willing to try SALT-3, not because of its significance but because it is dependent on the availability of additional land.

Excluding the hedgerows, SALT-4 already exists in some form. Farmers have been reaping the benefits of horticulture in several parts of the HKH and its relevance is seen in two ways. One is to make use of the hedgerow system under pure perennial plantation crops, e.g., tea, coffee, oranges, and a host of other horticultural crops. As an example, Sri Lanka has successfully demonstrated the value of SALT hedgerows in tea plantations. Two is the usual mixed farming of perennial plantation crops. Allotment of alternate alleys for annual crops and permanent crops, designed under SALT-4, will have to be flexible because much would depend upon the size of land, local practice, and the degree of domination of the horticultural crops.

**(c) The cool temperate agroecological zone is comprised of high hills and mountains. The subsistence slope-land farming is undergoing transformation towards horticulture and cash crops, with added comparative advantages. Livestock is an integral component of the farming systems. Parts of Nepal, India, Pakistan, and some areas in the eastern parts of China fall into this category.**

Since the benefits of SALT have been tested in tropical and subtropical conditions, it remains to be seen how far the technology can succeed in colder environments. In terms of slope-land farming, it may be a potential zone and one can consider the relevance of SALT-1. The major biological constraint, however, will be the growth performance of hedgerows. The general norm of monthly trimming of hedgerows and using the biomass as mulch, without composting, may have to be reconsidered. Similarly, because of the limited growth period, the benefits of slope stabilisation and natural terracing on sloping lands may also take a long time.

SALT-2 seems to hold little promise for farming systems in this agroecological zone on two counts. One, the environmental conditions do not provide for the year-round growth of plants and the hedgerow plants will not be able to provide fodder during most of the winter. For this to happen, a lot of research work to identify appropriate species is needed. Two, the farm families maintain large numbers of livestock, mainly sheep, goats, and cattle, as part of a mixed farming system. Although the practice cannot be called agropastoral farming, the contributions from livestock to their livelihood are much more than those from crops. Also, keeping large numbers of livestock is justified by the fact that plenty of pasturelands, meadows, and forests are available. SALT-2, therefore, may not be applicable here unless major changes take place.

Similarly, SALT-3, may not be as significant to the farming communities of this zone in terms of the growth of hedgerows and due to the availability of ample forest resources. Horticulture, be it with fruit crops, vegetables, or floriculture, is emerging as a farming enterprise with a lot of comparative advantages in this zone. Combining hedgerow systems with the existing cash crop farming is ecologically and economically desirable. The thrust towards low-external input systems, having a good production performance and the increasing value of organic farming are points favouring SALT-4 in a modified way.

This is also the agroecological zone where the shade from hedgerows will be considered to be a major limiting factor; it is considered to be a constraint to the availability of light and adequate heat rather than as a conserver of soil moisture.

(d) **The cold temperate high mountain environments are both wet and dry. They cover the famous trans-Himalayan cold and dry zone, spread over several countries of the HKH, comprising parts of Afghanistan, Pakistan, Ladakh and Lahul Spiti in India, and a major part of the Tibetan Autonomous Region of China.**

The cold and wet temperate high mountain areas are generally dominated by agropastoral farming systems. Farming in the cold and dry zone areas of the trans-Himalayas is marked by scanty rainfall. It is basically a rainshadow area, and agriculture depends upon irrigation. Soil erosion due to heavy rains is not a problem in this zone. Further, the land has to be terraced for irrigation. The growing period is too short and there are few species of shrubs and trees. Here, only one crop season is available for farming the usual subsistence mountain crops. Apart from *Hyppophae* (Seabuckthorn), little is known about any legumes and NFTs that can be selected for hedgerows from this zone. Thus, going by the existing ground realities of a harsh environment, the existing farming practices, and the limitations of SALT to perform under such environments, the application of SALT in the cold and dry zone seems both undesirable and unfeasible.

### iii. *SALT and Farm Size: Relevance to Small Farmers*

The SALT technology was designed basically to suit small farmers and therefore the goal was to create a compact, 0.5 to 1 hectare sustainable family farm to provide adequate food and meet the cash income needs of the family. The efficiency of the system to meet these needs adequately was shown by its performance evaluation in Chapter 5.

However, the points of discussion here are that SALT hedgerows cover over 27 per cent of cropland, thus reducing the actual cropping area (refer to Table 5.1). When it is seen in the context of figures relating to the landholding sizes of upland farmers in the HKH Region, the validity of the constraint is further strengthened. The initial investment and the regular maintenance demanded by SALT may be beyond the reach of small farmers. Also, in situations in which farmland is divided into several smaller parcels, the scope for the application of SALT further declines.

Despite all these difficulties, there are inherent features that favour small farmers. It does not really matter how large or small the land parcel is, if hedgerows are to be established. Similarly, the number of parcels and the consolidation of farmlands are also not mandatory, although these could constitute an added feature. The most important precondition is that the farmer should have a long enough area sloping land to make at least few hedgerows on one parcel. The alley width varies from two to five metres, based on the slope degree, thus, sometimes, even a single contour hedgerow may be desirable on a particular land parcel. The length of the hedgerow is not an issue at all. Hedgerows do occupy farmland and there have been instances, quoted under a separate section in this chapter, in which farmers have refused to adopt SALT on this count. However, this has always been in the mind of the promoters of the technology. The findings presented in Chapter 5, in this respect, confirm that the overall production from the plot, with even 43 per cent of land allocated to foodgrains, equals the production from traditionally-farmed sloping land (the productivity doubles by the fifth year). Income from another 30 per cent of the land is a bonus to the farmer under this system.

**Box 6.1: SALT is a Regenerative Technology for Marginal Lands**

Unlike the green revolution technology, SALT is basically designed to upgrade the marginal upland resource base - the asset of the marginal people, to enable it to produce optimally on a sustainable basis. It is conceived and designed to encourage low-external input and optimum yields from sloping lands. For these reasons, SALT qualifies as a better regenerative, agricultural, technological option for small hill farmers in some warmer agroecological zones.

- ICIMOD's rationale for encouraging the replication of SALT

Experiments at MBRLC, and even by IBSRAM cooperators for sloping land management, confirm the fact that SALT is the best option for low-external input agriculture. Crop yields, with the use of only the mulch available from hedgerows, have been reported to be more than satisfactory. MBRLC experi-ments also confirm that the small farmers' option for local crop varieties is most appropriate for SALT, since these perform better under no-external input conditions. However, SALT farming has also proved to be satisfactory with the use of moderate to heavy inputs. In short, the findings confirm that it is an option that stays ahead in terms of better yields under all input conditions (from no external NPK input to heavy NPK) when compared to traditional farming on sloping lands.

### *iv. SALT and the Scope for Cash Crop Farming*

As a part of the transformation process for mountain agriculture, cash crop farming on small landholdings is emerging as a viable alternative option to foodgrains. Hill farmers of the low, mid-hill agroecological zone and those practising slash and burn farming in the subtropical uplands within the HKH Region, in particular, and the uplands, in general, are under great pressure to transform their subsistence farming to cash cropping with comparative advantage. In more progressive pockets of the mountain areas having access to markets, farmers have found ways to cultivate vegetables on sloping lands by managing small-scale irrigation methods. In other progressive areas, fruit orchards have been successfully established on sloping lands. For vegetable, floriculture, and other annual cash crop farming, farmers with sloping lands are at a disadvantage.

For farmers wanting to upgrade their sloping land resources to reap a better harvest of cash crops, even with a little financial input, SALT holds great promise. Take the simple case of the increasing demand for organically-produced vegetables and the appreciable sustainable production performance of a ten-year SALT experiment at MBRLC without any inorganic inputs (refer to Chapter 5). However, for cash crop farming, if SALT is promoted with a package of other regenerative agricultural technologies, such as low-cost water harvesting systems and the popular plastic film technology from China (ICIMOD studies identified these as promising technologies for hill farmers), the productivity may rise to levels at which avoiding inorganic fertiliser inputs will only make a small degree of difference.

On the other hand, low to moderate fertiliser inputs are also well received by a SALT system, showing maximum yields. Moreover, using SALT will help maintain the physical and chemical properties of the soils; otherwise a general complaint of the hill farmers against using inorganic fertilisers.

### v. *SALT and the Food Security / Nutrition of Farm Families*

The obvious questions that arise under the prevailing conditions of increasing food insecurity among hill/mountain farmers are, who owns the sloping farmlands and what contributions can this technology make to provide relief? Additionally, does the technology hold promise for improving the nutritional supplies of farm families?

The main causes behind increasing food insecurity among hill communities are smaller landholdings with low-fertility status, resulting in poor yields. Diverse food crops, including vegetables and fruits necessary for good nutrition cannot be grown by these farmers either for want of sufficient land or, more often, because these crops cannot be grown on such poor soils.

SALT is a simple approach to improving the fertility of such poor degraded soils, and this is expressed in terms of improved production of food crops. Let us make a simple calculation, if the grain production from 43 per cent of a SALT farm equals the production from 57 per cent of a larger area of traditionally-farmed sloping land, it leaves a lot of scope for doubling food production; not only of grains but also of diversified items that should help enhance the nutritional status of the farm family. This calculation, based on MBRLC experimentation, has received a lot of credibility after several farm families reported cases in which they could manage their food requirements from their farmlands three to five years after adopting SALT.

Further, there are some noteworthy achievements in this respect. There were cases of sloping farmlands, in the Philippines, Thailand, Sri Lanka, and other countries, in which the degradation had reached levels at which it was no longer possible to produce meaningful harvests. MBRLC, and other institutions promoting the hedgerow technology, encountered numerous examples in which use of the SALT approach had not only restored the fertility of the lands but in which it had also improved several fold. Today, farm families tilling these lands look beyond food security and nutritional needs, since these needs are being met comfortably through adopting SALT farming.

The application of the technology, however, has its own limitations in terms of yield improvements, food security, and nutritional supplies. The results will also depend to a great extent on the way the SALT system is maintained by the farmers. One farmer may be able to achieve the goal while the other may fail, simply because of management faults and lack of investment.

### vi. *SALT and Other Related Technologies*

A general overview of related technologies was made earlier in Chapter 1. Here, the issue is opened up again to analyse the comparative advantages of SALT vis a vis other technologies. The main biologically-oriented options being promoted globally, basically for soil erosion control, are hedgerow system-based alley farming (of which SALT is considered to be one type), planting vetiver grass hedgerows, and the contour grass strip method.

Alley farming is a broad term used for cropping with contour hedgerows. Most of the research into alley farming has been carried out in Africa where the focus has been on trying to find combinations of hedgerow species and on experimenting with yield performance. The SALT system (a norms-based alley farming type) has established the principle of a double hedgerow system of NFTs, which cannot be flexible. Alley farming is a general practice in which contour hedgerows could be of any plant, including grasses, and may contain any number of hedgerows. It is left to the farmers to decide what is good for them. This is an important deviation which marks differences in performance, giving more often than not plus points to SALT. Vetiver grass hedgerows and contour grass strips have been acknowledged for their excellent performances in terms of soil erosion control in several countries. The fact remains nevertheless that they perform only the function of slope stabilisation, whereas SALT is designed for multiple functions. There have been cases in the highlands of Thailand, and in some other areas, in which the establishment of SALT failed and farmers preferred vetiver grass or contour grass strips for simplicity in management and effectiveness in soil erosion control. Acid soils in the hills constitute, for example, one case in which grasses would perform better than hedgerows.

*vii. SALT and Its Contributions to Biodiversity Management*

At a time when global efforts are focussed on the conservation and management of biodiversity, it goes without saying that most of our indigenous crops and crop varieties have been pushed by the HYV culture to the brink of extinction (it is even more true in the case of hill/mountain crops and their varieties). The world has seen fewer hopes on the technological front that favour the retention of the local varieties by the farmers. Against this backdrop, trials made with local and HYV crops in SALT farming, in which the former performed better (refer to item 5.2. iv), makes a good case as an opportunity to manage and conserve the threatened crop genetic resources through SALT farming. Unlike most other technological options, SALT is one which is not developed under the assumption of maximising yields through using HYV. In contrast, it supports the rehabilitation of most marginal lands to give optimum yields from the crop varieties that grow favourably under such marginal conditions. Because of this, wider adoption of SALT can even add to *in situ* conservation and management efforts aimed at indigenous crops and their varieties.

**Box 6.2: A Promising Addition to the Pool of Potential Options**

SALT is one of the promising options for sloping land farming but not the only option. It is the best option for certain environments and farming systems but may show poor performance under another set of ecological conditions in which other related biological technologies may hold promise. Therefore, the intention behind developing and promoting SALT has always been to make a meaningful contribution towards building a pool of potential options to give farmers a wider choice of better alternatives to farm their sloping lands.

- The way the Mountain Farming Systems' Programme of ICIMOD looks at the SALT system

*viii. SALT and Gender Considerations*

Numerous studies carried out on gender issues highlight the plight of the women folk belonging to small upland farm families. They contribute more than their share to managing a living under poor livelihood conditions. Women contribute the lion's share of the labour required to maintain the fertility of degrading sloping lands. They are the ones walking long distances to collect leaf litter to make compost, in order to ensure yields from marginal sloping lands. Carrying compost to the field is again carried out largely by women folk. This drudgery is one of the many outcomes of poor management of sloping farmlands. When grain production from the farmland falls short by many months to feed the family, a chain of activities demanding extra work starts.

Against this background, opting for SALT farming brings one major relief to women folk, by eliminating the need for litter collection to make compost. This somewhat eases the drudgery on women. Increased yields from the farmland, ensuring food security to the family, brings a lot of relief to women folk. Productive land can offer them opportunities for a diversified cropping system, bringing hopes of food for all seasons. Crop residues and increased weed biomass from productive land reduces the need for fodder from outside the farmland substantially. Further, enhanced income from the farmland, by way of cash crop farming, not only relieves the pressure of hard work on the women folk but may add to their financial status and may even lead to their participation in the decision-making process.

## 6.2 Farmer-level Concerns for the Adoption of SALT

A checklist of potential constraints - technical, economic, financial, legal, and political - which may impede or sometimes totally block efforts to promote the SALT programme - should be prepared in the process of determining the preconditions for adoption. In the following pages the issues involved in the adoption or replication of the technology are discussed at two levels, one, at the farm level and the two at the areal/regional level. The processes involved in the introduction and promotion of the technology in an area/country/region are further elaborated upon separately in the following chapter, illustrating steps for the introduction of SALT in the Hindu Kush-Himalayan Region.

Identifying a receptive physical environment for introducing a technology in a given area is one step, but how best the concerns of the farmer are taken care of in the process of its application is the second key step in the direction of successful replication. Enough examples are known of neglect and failure to meet the latter challenge, which accounts for the non-adoption of innovations by farmers Experience shows that gaps remain in between the three stages viz., _____ learning and training at the source _____ implementing the knowledge and information on the ground in a new place _____ and actual adoption by farmers.

The former gaps refer to the appropriate mechanisms of technology transfer from one region to another, including correct understanding of the preconditions for replication in new environments. The problem of non-adoption by farmers emerges purely because of the local concerns of the farmers.

First, let us define what should be regarded as successful adoption, because the adoption of a technology is sometimes inappropriate.

In many instances the technology is perceived as promising by development programmes, and farmers are lured or forced to implement it through credit programmes. SALT hedgerow plantations may be carrried out on the farmers' fields by the project staff somewhere, farmers being paid for their labour inputs and plant material supplies. Many of these no longer exist as cases of successful adoption. Instead they are only quoted as examples of successful implementation efforts. Under such examples one may list the SALT projects covering

1,600ha in 21 villages in Laos, 300ha of 3,000 beneficiaries in South Cotabata, and 400 farmers adopting SALT in Cebu (Fujisaka 1992 and Fujisaka and Cenas 1993).

The widespread successful adoption of SALT, noted by some projects in South-east Asia, took place because the farmers in these areas were concerned about soil erosion as a major cause behind the steadily declining yields of their staples. Contour hedgerows turned out to be the option for them, controlling both soil erosion and declining soil fertility. The project staff, adopting a participatory approach, learned from farmers to adapt a basket of hedgerow components suitable to local and personal circumstances and encouraged this. Extension in these cases was conducted using farmer-to-farmer techniques, with the full backing of a fully capable sponsoring organisation dedicated to the cause of promoting SALT. This, however, is the second and the true face of adoption.

*i. A Study of the Key Adoption Determinants of SALT*

Despite many the benefits from the SALT technology, there would still be many farmers unwilling to adopt SALT to farm their sloping lands, for one reason or the other. Identifying the key factors for adoption may help prioritise the areas for support and efficient utilisation of resources. A study carried out MBRLC (Laquihon 1988) revealed seven major key determinants and 13 minor determinants of SALT adoption by upland farmers (see Boxes 6.3 and 6.4).

The study further observed that technology adoption is largely contingent on the physical, biological, and sociocultural determinants that are present both inside and outside the farmer's farms. In the case of SALT, the key determinants were 72 per cent sociocultural, 14 per cent biological, and 14 per cent physical.

**Box 6.3: The Major Determinants of SALT According to Ranking**

- Extension, training, and exposure to SALT
- Anticipated benefits from the technology
- Availability of seeds of the right hedgerow species
- Capability of the sponsoring organisations
- Dedication and sincerity of concerned organisations
- Limits to sources of outside farm income
- Suitability of agroclimatic conditions
- Access to markets

On the other hand, the minor adoption determinants were 46 per cent sociocultural, 31 per cent physical, and 23 per cent biological.

**Box 6.4: Minor Determinants of SALT According to Ranking**

- Land ownership
- Government policies and laws
- Labour availability
- Pattern of rainfall
- Dominant farm weeds
- Direction of sunlight
- Livestock type and number in the village/area
- Local leadership and organisational capabilities
- Religious beliefs
- Credit availability
- Irrigation facility
- Available alternatives, e.g., terracing
- Dominant farm pests and diseases

Among farmers with secure tenure, the initial investment of labour, difficulty in obtaining hedgerow planting materials, and the technical training and back-up required, were among the serious constraints to introducing the SALT system.

Experience shows that incorrect identification of the adoption domain for SALT has proved disastrous in many instances. Therefore, a careful examination of the issue involved should precede the actual application of SALT on the ground. Before commencing efforts to introduce SALT in a locale, baseline information should be compiled as part of the prerequisites. The basic baseline data requirements are outlined in Box 6.5.

**Box 6.5: Baseline Data Requirements for Effective Planning of a SALT Programme for a Village/Locality/Area**

- Available land resources of importance in the context of the SALT programme, i.e., sloping degraded lands and the felt need for management
- Nature of user communities dependent on the sloping lands
- Attitudes of the local populace towards the desirability of managing their sloping lands, livestock, and forests
- Precise understanding of factors constraining these resources
- Technical information on production levels associated with mixes of agricultural crops, livestock, forestry, and horticulture
- Probable evolution of the supply and demand situation in the context of planned surpluses after introducing SALT
- Consumptive and non-consumptive benefits that the local communities derive from the lands in question
- Existing management efforts designed to maintain these land resources, be they private, local, indigenous, external, government-sponsored, or NGO assisted
- Terms and conditions of access to and exploitation of the degraded sloping lands, as influenced by formal laws

The three types of preliminary information required as baseline data include data/information on the availability of suitable sloping farmlands/degraded lands, ownership/land use, and the traditional management systems of these vulnerable lands. Analysis of this data/information facilitates correct extension and efficient application of the technology. Ignoring the significance of baseline information for replicating SALT may lead to difficulties in successful adoption later, if not in implementation.

*ii. Learning from Experience*

Some useful personal experiences and other secondary information are being added to augment the information concerning the preconditions for the application/adoption of SALT by farmers.

i. Target farmers should be made aware of the problems addressed by SALT, and such problems must be the key issues faced by these farmers. For example, in some countries of the HKH Region, one can refer to the realisation among farmers about the increasing unsustainability of shifting cultivation due to declining fertility and falling crop yields. Soil erosion from sloping lands and the associated problems of emerging degraded lands also are well understood by local communities. However, the degree of problems varies and so does the response of farmers to SALT. Farmers in most parts of the mountainous areas of the HKH recognise the marginal productivity of their sloping agricultural fields only too well and try to manage it through various means, both traditional and modern.

ii. General awareness about the technology is equally important for its successful adoption by farming communities. Thus, an extension programme for the dissemination of information to farmers is essential. Innovative methods may be used as extension tools.

**Box 6.6: Salient Features of the Extension System for SALT**

- The extension system should be designed to encourage local people to experiment with SALT, using both indigenous knowledge as well as outside expertise
- To achieve wide and in-depth coverage of target populations, an extension approach involving farmer-to-farmer exchange of the technology will have more chance of success
- On-farm extension activities should be tied to the regional experimental centres maintaining a prototype for the area
- The SALT extension system should be designed to provide a continuous flow of feedback to the SALT experimental centres about the local problems, successes, and failures, so as to keep improving the system according to local needs

Currently, the MBRLC's Extension Programme employs the so-called "impact area" strategy. An extension worker is assigned for each impact area, specifically a village, and concentrates his efforts on making a SALT "impact." For instance, one impact area had 300 SALT farmer-cooperators in just three years. The extensionist divides the area into sub-areas and resides in each sub-area for a few months to work with as many SALT cooperators as he can. This extension approach was found to be more productive than the shot-gun method used earlier, because the extensionist has a specific site to develop within a specific time period.

**Box 6.7: The SALT Training Approach**

The mentors of the technology strongly recommend a training and extension approach which follows the principle of:

"what is heard is forgotten; what is seen is remembered; and what is practised is known."

Even today, MBRLC follows this approach, without discriminating among the levels of visitors who come to the centre to learn about SALT.

Need for Line Agencies. SALT may become a reality in those areas in which it promises net profits and does not overtax the local resource base or organisational capabilities of the local/village institutions. However, for wider application of the technology, efforts are also needed to motivate and build the capabilities of a line agency within the government machinery. This is one way of bringing SALT into the planned development fold as a component of soil conservation/watershed management/fertility management/rehabilitation of degraded lands.

As far as possible, efforts can be made to graft SALT research and extension on to the existing communications' systems that have been established by forestry, agriculture, or livestock agencies, or by any integrated development project. The existing extension workers can be given supplemental training. But, given the current and probable future conditions, neither agricultural, nor livestock services, nor the forestry departments can hope to muster enough manpower and expertise to work individually for promoting SALT.

Experience in this field has shown that either NGOs, or integrated projects, or the people themselves have proved to be the most appropriate agencies, so far.

iii. There have been instances when the introduction of SALT in a given area, otherwise thought appropriate for tackling prevalent problems, did not succeed. The reason in each case was that farmers were already managing the problem successfully through alternative traditional measures with which they were more comfortable. The lesson learned from this was that the introduction and application of SALT need not be advocated in areas where problems are already well managed. Further, the SALT system may be adopted by this category of farmer only if it proves better than or equal to the alternative approaches in terms of solving the problem.

iv. Several factors (physical, biological, and social), existing in a particular location, have in the past in combination determined the success and failure of our efforts to introduce SALT. Several times, adverse site effects attracted bad publicity from the local populace because they considered those adverse site effects to be locally inherent conditions which should not be challenged but rather accommodated.

Therefore, the caution is that the application of SALT on the ground, in any location, should be preceded by a careful examination of all dimensions of the local influencing factors. As notable examples of adverse site effects one can include highly degraded land and non-availability of water, aspect, site prone to excessive grazing, social connotations of some communities, etc.

v. MBRLC and the cooperating institutions in other countries have faced situations in which a cool response from farmers to trying SALT on their farmlands was because of the costs involved in arranging seeds and seedlings of hedgerows, the choice of crops and other plants, labour requirements, and the breeds of animals recommended for setting up the SALT-2 system. Therefore, advance planning of these general requirements is recommended.

vi. On-farm experimentation with SALT is an essential element. Although some form of controlled research in the experimental stations may be required, it is equally important to conduct SALT trials on the farmers' fields to make sure that research results are applicable in reality. The conditions for SALT trials on farms may differ from those on experimental stations in several ways. Farmers with a good understanding of their own production environment, requirements, and priorities, can make valuable contributions to the design of SALT models on their farms. In a way, SALT field experiments with the farmers' type and the prototype trials are two parallel activities - each essential and mutually supportive.

vii. Farmers will not maintain hedgerows for soil erosion control if the soils in a given area are less erodible and fertile (Fujisaka 1992). Also, rainfall of more than 5,000mm per year means that soil erosion control measures are not needed simply because of the rapid regrowth of vegetation, which makes cropping impossible any way.

viii. In one place, contour hedgerows made little sense to farmers because these were placed on gently sloping lands (Fujisaka 1992). In another place, farmers remained unimpressed because of the project personnel's negligence while using the A-frame and other instruments to determine correct contour lines. This carelessness resulted in crooked hedgerows and terraces did not form. Similarly, if agencies recommend inappropriate species for hedgerows, damage will ensue.

ix. There is always a possibility that animals from neighbouring farms will destroy the hedgerows (Fujisaka 1992). This indicates the desirability of favouring a community-based approach for SALT in which all or most of the farmers in an area are encouraged to adopt SALT simultaneously.

x. When farmers did not put back the hedgerow prunings for mulching, the result was that many of them had to abandon their farms because of soil nutrient depletion and poor yields. Some of these farmers switched to high-value crops and the use of inorganic fertilisers on their contoured fields after soil fertility declined (Fujisaka and Cenas 1993). Unfortunately, the recycling of biomass was adopted only when farmers did not have other lands available, the labour costs were relatively low, the prices of inorganic fertiliser were very high, or the required fertilisers were not available.

### 6.3 Progress in the Wider Application of SALT

Evaluating the progress in the global replication of SALT would not be complete without including the efforts of other institutions/agencies working in Asia, Africa, and the Pacific, promoting hedgerow-based technologies under various names. In this section, in addition to SALT, we will also give an overview of the IBSRAM programmes on sloping land management, viz, Asialand, Africaland, Pacificland; the Alley Farming Programme of Africa; and the research activities of ICRAF on hedgerows.

*i. MBRLC/ARLDF Initiatives*

To benefit from the innovative approach for sustainable farming on sloping lands, over the past few years, every year, hundreds of people, including farmers, from environmental and agricultural research and development-related agencies, both national and international, have been visiting (about 1,500 per year) or receiving training on SALT at MBRLC. So far, more than 3,000 international visitors, representing miscellaneous organisations and/or agencies, from over 47 countries, have acquired first-hand information or undergone a short training course on SALT.

In addition, SALT training materials have been translated into the Indonesian, Thai, Vietnamese, Indian, and French languages by the respective international users themselves.

The staff members of ARLDF have assisted in establishing SALT pilot projects in several of these countries. Currently, collaborative SALT promotion programmes are underway in Thailand, Indonesia, Malaysia, India, and Vietnam. Small training centres for SALT are being established in India and Vietnam. Joint efforts between ARLDF and ICIMOD are underway to introduce SALT into the HKH Region (details in Chapter 7).

In Sri Lanka, the SALT technologies have been picked up and implemented quickly, mainly by the Sri Lankan State Plantations' Corporation, the Upper Mahaweli Watershed Management Project, and various other NGOs. The success of SALT in Sri Lanka has been noted on two counts; one, the rehabilitation of degraded sloping farmlands and, two, control of soil erosion from tea plantations.

In northern Thailand, the Hill Tribe Development Foundation (NGO) and several other projects, e.g., the GTZ and Thai-Australia Highland Agriculture are making extensive use of the SALT/alley cropping/hedgerow system. In Vietnam, SALT has been adopted and promoted by the universities. Their approach to implementation is relatively slow, but the research and testing before actual extension are good.

Further, countries have tended to adapt the SALT system to their own physical and socioeconomic environment, e.g., the experiments with indigenous species in hedgerows. There is one interesting example in which a hedgerow species, *Tephrosia candida*, was not performing well in the southern Philippines, so it was listed as a secondary choice at MBRLC, but the same species proved to be the most promising hedgerow in north Vietnam. Similarly, cropping patterns have been varied to meet local needs. These adaptations are seen as good and necessary for the wider application of SALT.

*ii. IBSRAM Programme on Sloping Land Management*

IBSRAM has started three region-specific programmes, viz., **Asialand**, **Africaland**, and **Pacificland**, for the research and management of soils, including soils on sloping lands. The goal of **Asialand** is, for example, to introduce improved and appropriate technologies for the management of sloping lands through its network. During the past few years, the network cooperators in China, Indonesia, Malaysia, the Philippines, Thailand, and Vietnam focussed attention on the introduction and validation of different technologies. The positive effects on crop growth, soil loss control, and terrace formation are now becoming known.

The network project in China, using the alley farming technique, has performed impressively in reducing soil loss. Efforts are now being made to spread the technology to the neighbouring farmers in Luodian county. Using *Amorpha traticosa* as the hedgerow plant, the cooperators in the network have chalked out a five-year plan of action to spread the hedgerow technique to cover about 3,000ha.

In Indonesia, the Asialand network is trying alley farming using king grass as a barrier instead of the usual hedgerow species. The grass is cut regularly and used as feed for stall-fed goats (SALT-2 approach). Soil properties on treated sites are showing improvements in terms of reduced compactness, which otherwise is a major problem in the area, and now more farmers are adopting the technology.

Similarly, substantial progress has been achieved in the testing and demonstration of various alley farming combinations in the Philippines, Vietnam, and Thailand. Efforts are being made to convince farmers to adopt the technology.

During the past few years, IBSRAM has thus built up a strong network of research and demonstration on sloping land management. It is not only confined to Asia but also includes Africa and the Pacific regions. It may be important to repeat here that the options being tried by IBSRAM are many, but the hedgerow system (SALT is known by this name in the network) is the key option.

*iii. Progress in Alley Farming in Africa*

There is a lot of technical understanding of the alley farming system in Africa, as a result of the immense research attention it has received over the years. This research was spear-headed by IITA, ILCA, and ICRAF and spread by national research institutions, aided by the two networks - AFNETAN and the Agroforestry Research Network of Africa.

**The Alley Farming Network for Tropical African Nations (AFNETAN)** is working in eight African countries, with more than 15 projects on alley farming research, management, training, and extension activities. From the programme activities of AFNETAN, it appears that its focus so far has been on station trials, and it has not dealt adequately with the concerns of farmer adoption. However, AFNETAN's, 'train the trainer scheme' has made a very wide impact with reference to human resource development in alley farming.

During the Second International Conference on Alley Farming in 1992, organised by the AFNETAN, it emerged that, in Africa, alley farming is largely a research issue with only a few development activities being carried out, whereas in Asia there is less research (reference to SALT - MBRLC) and yet the system is being promoted vigorously by a number of development and non-government agencies (MBRLC/ARLDF, World Neighbours, Hill Organised Foundation - Thailand, and ICIMOD and its national cooperating agencies in the HKH Region). There was a lot more to show on the farmer involvement and adoptability issues in the Asian context than in the African context.

*iv. Initiatives of IIRR*

The International Institute for Rural Reconstruction (IIRR) at Silang Cavite, the Philippines, is yet another organisation that has been focussing on the generation and dissemination of information on appropriate techniques for sloping land management (IIRR 1992 and Capastrino 1990).

Plate 6.1 The Uplands in Myanmar: the subtropical upland agroecological zone, characterised by the dominance of shifting cultivation and sloping land farming. It is very suitable for SALT farming (Tej Partap).

Plate 6.2 The subtropical mid-hill zone, characterised by terraced farming on steep slopes. It is also a suitable agroecological zone for SALT farming. (Tej Partap).

Plate 6.3 The wet temperate mountain agroecological zone, marked by a colder climate, forests, and sloping or terraced fields. Establishing SALT in this zone may need prior R & D efforts because of the climatic peculiarities (Tej Partap).

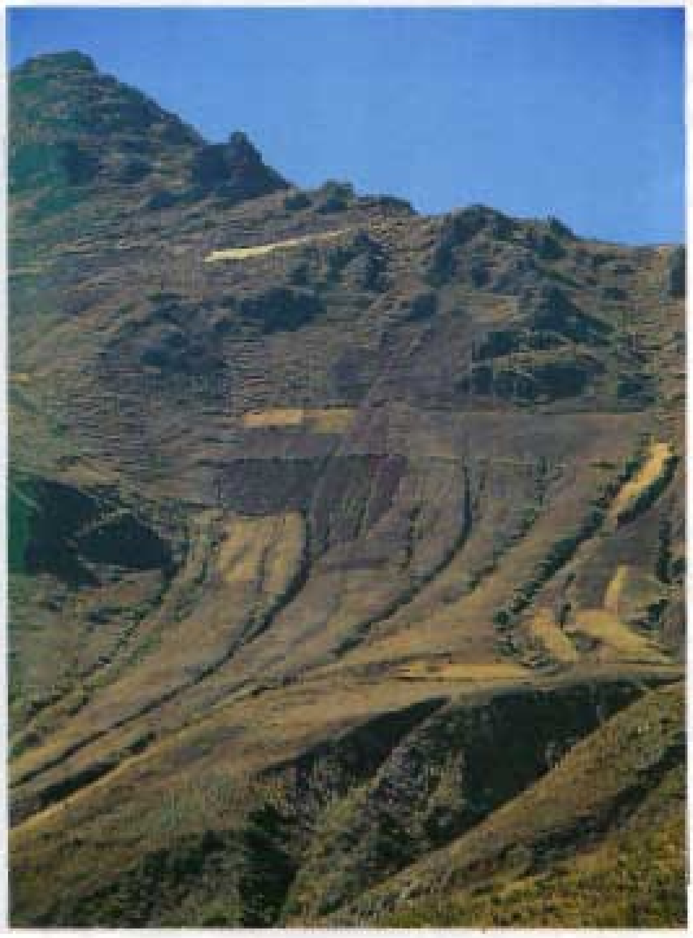


Plate 6.4 The cold and dry high mountain agroecological zone, characterised by a cold climate, little rain, and one crop season, and where the establishment of SALT could be difficult (Tej Partap).

Plate 6.5 Hands-on experience in the training relating to SALT. Jeff Palmer, the Training Director of MBRLC/ARLDF, giving training to the ICIMOD-sponsored team from the HKH countries (Tej Partap).


Plate 6.6 The Extension mechanism of SALT adopted by MBRLC is explained by this Board of SALT Farming Cooperatives (MBRLC).

Plate 6.7 The MBRLC extension worker training farmers: the extension agencies for SALT should have well-trained manpower who are prepared to work with the farmers on their farmlands (MBRLC).

Plate 6.8 The participatory extension approach adopted in Ningnan county, China, for promoting SALT has proved very successful (Tang Ya).

# 7. SCOPE AND INITIATIVES FOR REPLICATING SALT IN THE HKH

## 7.1 Scope for SALT in the HKH

In several areas of the HKH Region, a receptive environment for the introduction of SALT exists. The problems being faced by the farmers in the HKH Region, to which SALT can offer some solutions, include soil erosion, land degradation, declining crop productivity, declining grazing land resources, and shortage of fuelwood. Besides the points already made about the significance of SALT to upland areas in the preceding chapters, the issues are reframed here, under the categories listed below, to focus on the scope for solving the principal land-based problems that have emerged in different agroecological zones of the HKH Region.

i. Transformation of Swidden Farming
ii. Rehabilitation of Degraded Sloping Farmlands
iii. Regeneration of Degraded Pastures and /or Grasslands
iv. Low-external Input Agriculture (LEIA)

*i. Transformation of Swidden Farming*

The unsustainability of swidden farming, for several reasons, has emerged as a common problem in the following areas of the HKH countries: the Chittagong Hill Tracts of Bangladesh, the southern parts of Bhutan, the south-eastern parts of the Chinese Himalayas, the north-eastern Indian Himalayas, and the hilly regions of Myanmar. Over the past few years, the national and provincial governments of these countries have been trying several approaches to transforming swidden farming into sedentary agriculture. The steps undertaken include permanent land tenureship under "*jhoomia* upland settlement projects" (Bangladesh); support for terracing sloping lands (India and Bhutan) so as to encourage the shifting cultivators to settle permanently, and alternative forms of farming systems emphasising the plantation of crops like rubber and other fruit trees on fixed locations. Efforts have also been directed towards maximising yields through external inputs. However, there seems to be a lot of scope for a SALT-type, local resource-based, low external input-oriented, integrated technological option for swidden farmers in this agroecological zone.

SALT can supplement the policy initiatives on the settlement of shifting cultivators with two distinct advantages. First, the initiative for transforming swidden farming into sedentary agriculture needs such integrated technological options and adoption by farmers may be comparatively easier, since the farmers are in the process of changing their system anyway. Second, the requirement of the SALT system for compact farmland is actually implemented under settlement schemes. In addition, the no tillage/ploughing practice, prevalent among swidden farmers, and the types of animal also match with the SALT system. For the planners, SALT offers scope for integrating the efforts expended on environment, forestry, and agriculture to promote a farming system that is biomass-oriented, regenerative, and which inherently requires people's participation in order to bring about sustainability.

*ii. Rehabilitation of Degraded Farmlands*

After decades of experience with the green revolution, it is recognised now that the approach has failed to serve its purpose on the marginal land resources which dominate most of the upland farms (sloping lands). To add to this, it is now recognised that crop yields on these lands are either stagnating or falling (refer to Chapter 1). The increasing population has put pressure on farming intensity, resulting in further degradation of these marginal hilly farmlands at a much faster rate. Since the problem is well recognised throughout the HKH Region, the regional countries are trying several solutions, combining policy approaches with technological options and institutional initiatives.

Since SALT is designed to upgrade marginal sloping lands in order to enable them to give optimum sustainable yields, the above scenario may be taken as a favourable environment for the application of the SALT system. This is one of the few bioengineering approaches known today for restoring degraded farmlands. The technology is comparatively simple and does not require much investment. The simple design of SALT means that farmer to farmer extension of the technology is possible.

*iii. Regeneration of Degraded Pastures and /or Grasslands*

Because of ever-shrinking landholdings and falling cropland production, hill farmers in most parts of the HKH Region are increasingly using livestock as an alternative means of livelihood. This has increased the pressure on grazing lands to the extent that, during the past one decade, the problem of biological degradation of these non-agricultural lands has assumed serious proportions. The consequences are felt in the form of insufficient fodder, poor health of the cattle, and increasing difficulties in maintaining livestock herds. The various alternatives being promoted are planting fodder trees on farmlands, promoting community forestry management for the cut and carry fodder approach, and even cultivating fodder in the winter. However, appropriate technological measures for restoring regenerative capacities of these lands are required.

In parts of the low and mid hills (Nepal and India), many farmers maintain their own grasslands (*ghasnis*). With the shrinking and degrading community grazing lands, improvement of these private grasslands has been identified as a possible alternative. The objective is to increase their carrying capacity and the availability of fodder for more months of the year.

The MBRLC staff had the same objective in mind while designing and testing SALT-2. The SALT-2 model provides for highly regenerative forage gardens supplying nutritive fodder. To save on fodder, the model also gives preference to smaller animals for milk (goats), meat (sheep), and cash income. Therefore, SALT-2 can be seen as one possible technological option for enhancing the productivity and carrying capacity of traditionally-managed private grasslands and pastures in the tropical and subtropical upland environments of the HKH countries.

*iv. Low External Input Agriculture (LEIA)*

An increasing number of development agencies and policy-making institutions are becoming convinced that capital-intensive, green revolution techniques are simply not feasible alternatives for the poor farmers who live in ecologically, geographically, and developmentally less favourable upland production conditions. In these relatively diverse, complex, risk-prone areas, far away from the markets, external inputs are either too expensive or simply not available. To optimise productivity, farmers must depend on local resources, ecological processes, recycling, and site-specific genetic materials.

External inputs cannot be excluded, but should be used strategically so as to complement internal inputs, or deal with emergencies. Social factors must also be taken into consideration, using indigenous knowledge and institutions to foster self-reliance and stronger local economies. These, in fact, are some of the basic ideas behind low-external input agriculture.

The technology needed to make low-external input agriculture sustainable can be derived from various sources, such as ecological farming, regenerative agriculture, permaculture, and natural farming. But the process of perfecting the approaches is still in its infancy and the need for appropriate technologies, suitable to different environments/ecological conditions, does exist.

Tested for its regenerative capacities and sustainable production potential under low-external input conditions, SALT farming on sloping lands has confirmed its capabilities as one of those few known, promising options. Trials and tests conducted for over a decade have proved that, with little/no external inputs, it is possible for poor small farmers to obtain sustainable optimum yields by upgrading the fertility of their farmlands using the resources maintained on the farmland itself (see Chapter 5). This is the fourth consideration advocating the application of the technology wherever feasible in the HKH Region.

## 7.2 ICIMOD Initiatives and Outcomes

Realising the significance of SALT for sloping farmlands, ICIMOD launched a multi-pronged programme of action in 1991. The objective is to facilitate the replication of the technology in the needy areas of the Hindu Kush-Himalayan Region. The initiatives include the categories discussed below.

### i. *Facilitating Information Dissemination*

SALT has been incorporated as an important component of ICIMOD's programme on Replicable Successful Experiences' under its Mountain Farming Systems' Programme. To create awareness about SALT among the various research, development, and extension agencies of the HKH countries, ICIMOD organised a training programme for a multi-national group of field officers and scientists at the ARLDF in 1992. While making observation on the possible replication of SALT systems in the HKH Region, this team of experts recommended a number of needed modifications in the models, the suitability of hedgerow species, and agroecological zone-based research and management needs. Currently, more activities directed to applied research, awareness training, and dissemination of knowledge and information about SALT are being carried out in the HKH countries.

Under a new programme on the rehabilitation of degraded lands, additional efforts have been carried out in Nepal, Bangladesh, Pakistan, and the Indian Himalayas through training, field research, testing, and demonstration, in order to disseminate information on SALT.

**Box 7.1: ICIMOD's SALT Programme Activities**

- Facilitating information dissemination about SALT through sponsoring study tours and training and undertaking applied research to analyse the preconditions for replication
- Developing suitable communication materials, publications, videos, slide sets, and pamphlets for wider use
- Facilitating development of prototypes for different agroecological zones of the HKH Region
- Strengthening the institutional capabilities of national, regional, and local institutions for the successful replication of SALT in the Hindu Kush-Himalayan Region

### ii. *Developing Suitable Communication Materials*

Production of audio-visual materials (video film, slide sets), highlighting the relevance of

SALT to sloping land farming in the HKH, and written literature ( including this publication) are part of the overall initiatives on building communication materials. Next in the list of planned programme activities are the generation of training material for trainers, establishing a regional network of institutions/agencies involved in SALT application/extension activities, and strengthening of linkages and cooperation with international institutions like ARLDF/MBRLC, IBSRAM, ICRAF, and the Alley Farming Network for Tropical African Nations (AFNETAN).

*iii. Facilitating the Development of Prototypes for Different Agroecological Zones*

The Need for Prototypes. SALT is not a purely farmer-based technology needing no inputs from formal research institutions. There is much scope for research in various aspects. In the context of varying agroclimates and farming systems, within the HKH Region, diagnosis and design studies by both researchers and extension workers of local institutions/agencies are necessary to suggest suitably modified SALT models for local farming communities. In this respect, the prototype SALT trials become exploratory test-cum-demonstration models with locally desirable combinations of components and management features. In SALT trials, the choice of species, their arrangement in hedgerows, and the management practices of the whole SALT system are likely to be site-specific.

Also, extension workers and farmers may further validate various aspects through on-farm trials. To have wider application value, a prototype trial must be made flexible enough to incorporate modifications desired by the farmers or those emerging through new information from design studies.

**Box 7.2: Why Establish Prototype SALT Models in the HKH?**

SALT is an innovative model of an integrated, diversified farming system for sloping lands; it is an innovation with built-in, long-term applied testing and even tinkering mechanism. It calls for the establishment of prototype models of this new approach to be set up for every agroecological zone and farming system, thus serving as facilities for continuous trials, testing, and demonstration of SALT to suit local conditions and needs.

- ICIMOD's SALT programme rationale and strategy

ICIMOD-initiated SALT Prototypes.

**SALT in Ningnan**. In 1991, a prototype pilot trial-cum-demonstration plot of SALT was set up jointly by ICIMOD, the Ningnan county government, Chengdu Institute of Biology, and the Institute of Geography, CAS, in Ningnan county in the Hengduan Mountains of the Sichuan province of China. Although the initiative is only half-way through, some useful observations are available as lessons. The performance of the model during these past years has been able to convince farmers in the area to adopt SALT farming. Encouraged by the successful impact of SALT in soil erosion control and in enhancing soil fertility, the local county government has made plans to undertake SALT farming on a micro-watershed basis. The pilot SALT programme initiated by ICIMOD has since been taken over by the county government.

A few lessons pertain to the arrangement of adequate hedgerow seeds until the local farmers develop their own facility. In addition, farmers prefer a combination of hedgerow species, i.e., both legumes for fertility enhancement and non-legumes of local farming significance. In the case of Ningnan farmers, they strongly advocated the plantation of mulberry in one of the two hedgerows in a contour line. This is because the cash economy here is dependent on silk production. Farmers also wanted relatively wider strips for ploughing purposes. The density of plants in the hedgerows has to be high to make a good impact. Poor density permits considerable soil erosion.

**SALT at the ICIMOD site in Nepal.** Prototype SALT models are being developed by ICIMOD at its HQ complex site in Godawari near Kathmandu, Nepal. The necessity for creating an MBRLC-type facility within the HKH Region, which can serve the testing and demonstration-cum-training purpose, is felt. Validation of management aspects and choosing hedgerow species for the HKH Region are some key features of this prototype. Established in 1993, ICIMOD staff members are working to accomplish the setting up of SALT-1,2,3, and 4 models by the end of 1994. The Centre may be able to share the results after about two to three years.

**SALT in the Chittagong Hill Tracts of Bangladesh.** A prototype was established in 1992 in the Chittagong hills of Bangladesh to serve as a model to the small swidden farmers who are looking for alternatives to swidden farming. Future plans include promoting the implementation of SALT in villages established under upland settlement schemes, using the participatory approach.

**Rehabilitation of Degraded Lands.** SALT as a technological option for rehabilitating degraded lands is being tested through a series of pilot trials set up throughout the HKH in different ecological settings, namely, the Kumaon Himalayas in India, the mid-hills in Nepal, the North-west Frontier Province in Pakistan, and the Yunnan Province in China. A few years from now, these trials are expected to generate enough data to enable interested institutions to design better bioengineering methods for the rehabilitation of degraded lands in this region, in general, and in the uplands, in particular.

**Box 7.3: SALT Initiatives in Himachal Pradesh, India**

The Regional Centre of the National Afforestation and Eco-development Board (NAEB), located in Solan, Himachal Pradesh, has identified suitable areas for application of SALT in the State. NAEB has also come up with designs of SALT prototypes accommodating local agro-ecological imperatives and needs of the farming community of this Indian Himalayan State. Areas with the following land uses have been recommended for priority action for the application of SALT.

- Sloping agricultural land, including fruit orchards, in low and middle mountain zones with subtropical climate;
- Sloping degraded wastelands/ grazing lands, in low and mid-hill zone;
- Sloping grasslands (*ghasnis*) in the low and mid hills, (*ghasnis* are both privately owned as well as community lands) in the low and mid-hill zone;
- Natural forests class-3, used by farming communities as supportland for grazing, fuelwood, and other uses in low and mid-hill zone;

A long list of hedgerow plant species and crop combinations have also been proposed in these designs.

**Future Programmes.** As stated elsewhere, ICIMOD activities on the replication of SALT in the HKH were started as part of the programme on Sustainable Mountain

Agriculture, funded by the Asian Development Bank. Encouraged by the promises SALT holds for the HKH, the ADB is now funding an exclusive project on the promotion of SALT in the HKH countries. The main emphasis of this project will be on the development of prototype SALT models for testing and demonstration in all possible agroecological zones of the HKH Region.

These efforts will be further supplemented by developing the capabilities of national institutions under another programme (described below).

*iv. Strengthening National Institutions*

Perceived Needs. Institutional considerations for the replication of SALT demand an understanding of the problems involved in the design and implementation of the programme in the HKH Region. It is necessary to focus on creating/building institutional capabilities with reference to information generation about various aspects of technological adaptation to a variety of agroecological zones and agroecosystems. In addition, there are issues related to the participation of farmers. Nevertheless, building strong institutional mechanisms for exchange of information at various levels is also important.

It is understood from the earlier discussion that the participation of local people should not be limited to simply the execution of ready-made formula designs of prototypes. The HKH is too complex to admit formula solutions of the SALT system. Those who till the land and herd the animals have to be made full partners in any realistic effort to adopt SALT. Implicit here is the need for extension agencies capable of promoting SALT systems in their respective locale in each country/area of the HKH. A popular SALT programme would assume an extensive and spontaneous participation from the people.

**Activities**

These institutional aspects have attracted the attention of ICIMOD for redressal, in order to make the replication of SALT in the HKH successful. A human resource development scheme for SALT is planned for the HKH countries under the Mountain Farming Systems' programme on 'Institutional Strengthening for Sustainable Mountain Agriculture'. Funded by the Government of the Netherlands this activity will include development of training materials, train the trainers' programmes, and a series of farmers' and extension workers' training activities. Farmer to farmer exchange visits and study tours to areas where SALT farming has been successfully carried out are also planned under these activities.

Plate 7.1 A multi-national team of professionals from the HKH countries undergoing SALT training sponsored by ICIMOD at MBRLC, the Philippines, in 1992 (MBRLC).

Plate 7.2 ICIMOD initiatives in establishing a SALT prototype for the mid-hill areas, Godawari, Kathmandu, Nepal (B.R. Bhatta).

Plate 7.3 ICIMOD-supported SALT pilot testing-cum-demonstration site in Ningnan county, Sichuan, China (Wei T. Chang).

Plate 7.4 Ningnan county, SALT pilot project site after one year of establishment (Tej Partap).

Plate 7.5 SALT hedgerow pilot testing-cum-demonstration site in Kabhre, the mid-hills of Nepal; ICIMOD project on the rehabilitation of degraded lands (Lu Rongsen).

Plate 7.6 ICIMOD-supported SALT pilot testing-cum-demonstration project in the Chittagong Hill Tracts, Bangladesh, was started in 1992 (D.K. Khisha, SALT Coordinator, CHTDB).


Plate 7.7 Sustainable hillside farming initiatives of the Myanmar Agricultural Services in the upland areas of Myanmar (Tej Partap).

Plate 7.8 The upland areas of Myanmar - improved crop yields and biomass production as a result of the promotion of various regenerative sloping land management techniques (Tej Partap).

# 8. SUMMARY AND CONCLUSIONS

## 8.1 The State of Sloping Land Resources

The HKH has two major types of agro-ecosystems, i.e., (i) sedentary agriculture, in which farmers have land rights over their landholdings, including terraced or sloping farmlands which are generally fragmented into several land pieces; and (ii) swidden agriculture, in which farmers do not have land rights over any particular land but by practice/convention they exercise their right to cultivate/farm a particular area. While the size of landholdings of sedentary farmers has shrunk over the decades, shifting cultivators, on the other hand, are faced with shorter fallow periods.

The problems of sloping farmlands include poor land management, increasingly intensive farming, and reduced fallow periods, leading to soil erosion and degradation. The indicators of degradation are decline or stagnation of biomass production and crop yields. This, in turn, has increased the demand pressure on adjoining supportlands of several types, i.e., forests and grazing lands. The result is that the regeneration and carrying capacity of these supportlands have also reduced although the degree varies among areas and countries.

In a nutshell, the natural resource base in far too many of the hill and mountain areas is being seriously degraded, leading to ecological and economic poverty. It need not be elaborated upon that there will be an increase in the instances of food insecurity, poor incomes, and dependence on external resources/supplies in the uplands unless alternatives are found to avert the situation.

While blaming conventional development approaches for these outcomes (Jodha and Shrestha 1993), there is increasing realisation that mountain perspective-oriented approaches need to be based on enhancing the regeneration capacities of the local resource base, diversification, and harnessing of 'niche', with in-built mechanisms of sufficient production and protection of the local resource base.

## 8.2 Search for Sustainable Land Use Options

Alternative options for sustainable use of sloping land resources call for new initiatives that will introduce regenerative technologies based on local resources and demand fewer external inputs, in order to bring about agricultural development and environmental management. The process should start with examination of the available technological tools. To name a few, the list will include SALT, alley farming in general, other agroforestry approaches, vetiver grass, and grass strips. To what extent each technological option can contribute to achieve the goal depends on specific situations and the existence of external factors - such as the capacity of farmers to adopt it and the capacity of development, research, and policy institutions to adapt to new realities.

Since the scientific understanding of regenerative and sustainable agricultural options for the mountains and hills (uplands) is still in its infancy, any initiatives focussing on the search for potential options in this area would be most welcome.

In this respect, biological conservation measures for sloping land management have demonstrated good potential. SALT, a form of agroforestry, is one such biological, regenerative technological option, designed for managing soil erosion and the fertility of sloping lands. SALT has the potential to supply a number of farm inputs from within the farm boundaries while facilitating the upgradation of the marginal land resource with least external input.

The limited experiences with SALT confirm its role as an effective option for soil conservation and fertility management. It is effective at reducing erosion, soil loss, and surface runoff, besides enhancing soil fertility. Trials have revealed that biological terracing formed behind the hedgerows can be more stable than terracing and it produces better yields.

In the coming decade, the increasing problem of swidden farming, degradation of sloping farmlands because of intensified agriculture, and the increasing thrust on local resource-based sustainable farming will increase the need for alternative farming practices, and this is where the SALT system will find a great deal of favour as one of the better options.

## 8.3 Wider Application of SALT

*i. Technological Elements*

Double hedgerows in SALT are planted along the contour lines. The essential features of these hedgerow plants are efficient nitrogen fixation, good coppicing behaviour, and the multiple use-value of the biomass produced. So far, most research on hedgerow species has focussed on biomass production, which also indicates their adaptation range to hill/mountain soils.

SALT-1 is similar to alley farming; in both cases the hedgerow is the key element. However, the principal norms laid down for SALT make a distinction between the hedgerows established under SALT, i.e., these have to be double hedgerows, necessarily using nitrogen-fixing plant species. The SALT-1 type can be scale-neutral, which means that it can be applied on any size of landholding.

The simple agrilivestock land technology, or SALT-2, has increased in significance in parts of the HKH Region, especially in the subtropical mid-hill areas where the degradation of supportlands, which feed the livestock, and the need for livestock are almost equally intense. Several farmers in the area maintain a piece of land of their own as grassland. It produces dry fodder and is also used as a grazing area for a limited period. These are areas that can be identified as appropriate for the application of SALT-2. The type of livestock recommended under SALT-2 and those kept by the farmers in the HKH differ, e.g., Nepalese farmers prefer cattle. Thus farmers may have to make some alterations and adaptations. Goat farming, however, is nowadays becoming popular with the small farmer, especially as there is a shortage of fodder in these areas. Therefore, in such areas, those farmers who have already adopted goat farming as part of their overall farming system may be encouraged to adopt SALT-2 first. Another element concerning SALT-2 relates to access to land. Several small farmers may not have land to set up their own SALT-2 farm. Under such circumstances, groups of villagers can set up fodder plots of SALT-2 on the common land, and mechanisms may be worked out for the management and sharing of the produce by offering necessary support to and revitalising the local institutions. The successful community forestry and user group experiences seen in Nepal, confirm that such an arrangement can work out well, owing to the common threat for survival.

Promoting the SALT-3 component as part of the overall SALT system may receive a mixed response, although there are areas where conditions exist for promoting SALT-3. Farmers have a marginal piece of land available either in the upper section of their land or along the edges somewhere. There is also an acute shortage of timber, compounded by very high prices and non-availability. But there are also areas, in countries of the HKH, where farmers may have land but where the law discourages timber harvesting on any land, whether private or government. This may require discussions with the policy-planning and decision-making bodies.

SALT-4 already exists in various forms in several parts of the HKH, except for the fact that hedgerows are not laid out properly, although live fencing and bunding is a part of the traditional farming practice. Horticulture is a recognised activity in the hills and has a lot of comparative advantages. However, the existing system may differ from the actual SALT model and it should, in fact, be considered as a regional modification. The fruit orchards and tea/coffee plantation crops in several areas of the HKH countries offer most encouraging conditions for adopting SALT. Farmers are earning good incomes, but the increasing problem of soil erosion is felt. Orchard owners might be willing and also have the means to use SALT in their orchards on sloping lands. In Sri Lanka, for example, SALT has been widely adopted in the tea gardens because of its positive impact on soil conservation and on the growth of tea plantations. There are vast tea plantation areas in the NE Indian Himalayas, Nepal, China, and some in Bangladesh where SALT can play a role.

*ii. Some Limitations*

As of today, a very limited number of species has been listed as promising hedgerow plants. Further, most of them are good for tropical and subtropical climates only. This is because SALT and other hedgerow systems, whether in Asia or Africa, have been experimented on/or tested in warm and humid climates.

**Box 8.1: MBRLC Statement on SALT**

It is not claimed that SALT is a perfect farming system. There is not and never will be one system for all farmers. SALT is not a miracle system, nor a panacea. To establish a one-hectare plot of SALT requires much hard work and discipline. It took many years to deplete the soil nutrients and lose the topsoil; no system can bring depleted and eroded soil back into production in a few short years. The price of soil loss is poverty, but trials with SALT have restored land to a reasonable level of productivity.

Rev Harold Watson, Director, MBRLC/ARLDF

As efforts are made to expand SALT to higher altitudes with colder climatic conditions and shorter growth periods, new indigenous species, better adapted to such climates, will have to be screened and tested. Unless the right hedgerow species are identified for colder mountain environments, the utility of SALT will remain limited to tropical environments. Giving due consideration to the needs of the local farming communities, while selecting hedgerow species for an area, is equally important.

Another element that is highlighted in relation to the chemical nature of upland soils is the acidic nature of soils, which makes it difficult for several fast-growing species to be established on these soils. Thus, species that are climatically suitable may find problems in performance because of acidic soils.

*iii. Preconditions*

Whatever has been learned so far, it might be right to say that the hedgerow technology is still an emerging system that remains to be sufficiently characterised for different agroecological zones, soil types, and farming systems. It is a priority area for research and experimentation efforts, before plans are made to expand SALT to different locations in the uplands. Efforts may be switched over to farmers' fields in any area, only after identifying the right combinations of hedgerow species. The success in spreading SALT to diverse upland conditions will largely be determined by the success in identifying promising hedgerow species for these environments.

The application on the ground has to precede with the correct understanding of the concerns of local farmers. There is a long list of reasons for farmers' indifference to the adoption of this technology, and these need to be properly addressed. Compiling the following three types of information as baseline data may be necessary for correct decision-making about the introduction and implementation of SALT in an area; the availability of suitable farmland or degraded land, ownership of the land, and the way it is used. In addition, information about popular interest in managing these sloping farmlands in a better way will indicate areas where success may be achieved in the implementation of SALT systems.

One of the prime considerations in the application of SALT in the HKH Region is whether it is possible to apply it on fragmented parcels of land. The casual answer may be yes, if the fields have long enough slopes, but, answers to this issue have to be found through further on-farm testing and suitable modifications.

*iv. Institutional Issues*

Participation by the local people in SALT projects cannot be limited to the simple execution of generalised strategies. Mountain areas, and farming practices therein, are too complex to admit any formula solutions of the SALT system. Those who till the land and herd the animals must become full partners in any realistic effort to create viable SALT programmes under varying farming conditions.

Implicit here is the need for extension agencies that are capable of promoting SALT systems in their respective locales. SALT may become a reality in those areas in which it promises net profits and does not overtax the local resource base or the organisational capabilities of the local/village institutions. However, for wider application of the technology, efforts will also be needed to motivate and build the capabilities of a line agency within the government machinery. This is one way of bringing SALT into the planned development fold as a component of soil conservation efforts, or watershed management.

The technology should be encouraged in areas/countries that reflect the need and willingness for managing sloping and degraded lands, where there is popular demand for information about SALT methods, and where political opportunities in light of the other programmes already functioning in the given jurisdictions exist.

*v. Role of International Institutions*

There is a lot of scope for international institutions, such as ICIMOD, IBSRAM, ICRAF, and the international donor agencies, to join hands to facilitate wider application of SALT and associated regenerative technological options that promote soil conservation and fertility management. These technologies require a lot of testing and modifications at the local level. This means that the need for learning through sharing experiences is imperative in this case. As steps are taken to set up prototypes for different agroecological zones of the HKH, in addition to what is learned from the MBRLC, knowledge and information generated by the IBSRAM network on sloping land management and even by AFNETAN in Africa on alley farming, will be very useful. Similarly, making use of research outputs of ICRAF, not only in the search for suitable hedgerow species for different agroclimates but also for several other aspects of alley farming, will be beneficial. Fortunately, scientists at ICRAF are already engaged in research on hedgerow technology (as they call it) and efforts are needed to create mechanisms for sharing this information for wider use.

In this whole thrust for replicating SALT on a wider scale, the role of the mother institution, MBRLC/ARLDF, is crucial. There will be greater demands from the MBRLC to maintain the original demonstration model of SALT, as a perfect management piece for offering training facilities both at the centre and on-sites to farmers. The long-term experiments, set up by the centre, will continue feeding new knowledge and insights for updating the SALT system from time to time.

*vi. The Complementary Approach*

As the replication of SALT progresses in different agroecological zones of mountain areas, several limitations will also be experienced. Even with the present limited experience, the preference of some farming systems in some uplands has gone to some other sister approaches based on biological conservation, e.g., plantation of contour grass strips and vetiver grass. Upland farming will benefit if all these options are viewed as complementary to each other, as it may indeed prove to be, rather than promoting each option as a competitor or replacement of the other.

## Annex-1

# TEN BASIC STEPS FOR SETTING UP THE SALT SYSTEM

The basic steps for setting up any of the SALT systems are the same, but SALT-2, 3, and 4, have some additional activities that are indicated in each of the 10 steps.

**STEP-1: Making an A-Frame**

The A-frame is a simple device for laying out contour lines across the slope. It is made by nailing together three wooden poles in the shape of the capital letter A, with a base of about 90cm. A carpenter's level is then mounted on the crossbar.

As a cheaper alternative, one can use wooden or bamboo poles of around 1.5 inches in diameter. Two of these poles should be 2.1m long and the third one 1.2m long. The two longer poles are nailed or tied at one end, about 10cm from the end. These will form the legs of the A-frame. Notches are made at the points of contact so that the poles do not slip.

The legs are spread and braced with the shorter pole to make the Figure-"A". The crossbar is tied or nailed, about 10 cm from each end, to the centre of the legs. The crossbar supports the legs of the frame and serves as a guide in checking ground level positions.

One end of the string is tied to the point where the two legs of the A-frame are joined. The other end of the string is tied to a rock or any other heavy object. A point to be noted here is that the rock should be heavy enough to stay still against the wind and, second, the rock should hang about 20cm below the crossbar.

Calibration of the A-frame is done on level ground. While holding the A-frame in an upright position, three spots are marked, two on the ground where the legs of the A-frame touch it and one on the crossbar where the weighted string passes it. Then the A-frame is turned around so as to reverse the placement of the legs on the earlier spots and the marking on the crossbar repeated. If the two marks on the crossbar coincide, this is the central point. If, however, the marks on the crossbar differ, another mark is made at the mid-point between the two.

The calibration accuracy of the A-frame is verified by moving one leg of the frame around until the string passes the level point on the crossbar. That spot on the ground is marked and the placement of the A-frame legs changed again. For correct calibration, the string should pass through the same marked central point.

**STEP-2: Locating Contour Lines**

Contour lines are lines across a hill slope at the same elevation or height and are used in the establishment of SALT hedgerows. Understanding the concept of contour lines is important because effective erosion control through SALT depends much upon the correct establishment of contour lines and, if incorrectly designed, it could, in fact, aggravate soil erosion or be of little use.

The reason behind establishing contour lines is to maintain equal vertical distance between hedgerow lines. For effective erosion control, experience has shown (IIRR 1990, 1992) that the vertical distance between contour lines should be maintained between 0.75m (slope gradient below 15%) and 1m (slope gradient above 15%). The horizontal distance between the two contour lines does, however, vary with the degree of steepness. For example, as the contour lines travel across a hillside, they will be at a closer distance on the steeper parts of the hill and vice versa.

For marking contours, it is desirable to study the land first and to visualise where the contour lines will run and what the area will look like when terraced, particularly the height and width of the terraces. Other helpful tips include always looking behind at the line of stakes and assessing whether the lines are running parallel; getting a feel of the main direction of the slope because the contour lines will have to run perpendicular to this direction; and not following the exact contour lines from peg to peg but looking ahead and smoothing out the line by taking a line of "BEST FIT" between the stakes. Following the peg to peg method may in all probability create a zigzag line.

Before marking the contour lines, it is desirable to clear vegetation and other obstructions from the strip of land through which the contour lines are likely to pass. Contouring should be started from the highest point going downwards.

In the application of SALT-2, i.e., the agri-livestock system, contour lines are marked over the land selected for forage production in such a way so as to form one metre wide raised beds. Two furrows, both a half metre wide, are made on each contour line and NFT hedgerow forage plants thickly planted on them.

The contour lines are marked commonly by using the A-frame. A stake is driven at a point on the area boundary and one leg of the A-frame placed just beside and above it. Then the other leg is swung around until the mid-point of the crossbar, or the carpenter's level, shows that both legs are touching the ground on the same level. Then a stake is driven beside the A-frame's rear leg.

To mark the whole contour line, the A-frame is moved around by placing one of its legs on the last spot marked on the ground and then finding the contour and marking it with the stake. The process is repeated until one reaches the other end of the field. An important point is to keep rotating the A-frame, so that the person operating the A-frame faces its A and B sides on every alternative contour marking process.

The same process of contour marking is repeated until one reaches the bottom of the hill.

Contouring work is generally started in the middle of the sloping field, downwards to the bottom of the field, and then from the middle upwards to the top. This helps to minimise cumulative errors. This is a matter of farmers' preference and no hard and fast rules exist.

The vertical spacing of 1m to 1.5m between contour lines is measured using various methods. Farmers have been using shoulder height and arms, in most cases. A more secure method is to measure the vertical distance of contour lines by looking over a "T-stick" (Fig. 3.1) of appropriate height, back at the previous contour line.

The actual distance between the contour lines, however, varies with the slope of the hill. The practice so far has been to limit the distance of the contour lines to two to five metres, even if the distance arrived at by using the standard techniques differs from this. This could happen very often on gentle or steep slopes. The logic behind this is that, if the contour hedgerows are too far apart, the benefits of mulching and nitrogen fixation may not be evenly distributed throughout the contour strip.

Although marking contours with the A-frame is a slow process, this is the only method that does not require any purchased inputs and is thus within the reach of farmers. It has been found to be consistently accurate on very steep and heterogeneous slopes also.

Several other alternative methods are also known and used for marking contour lines (Collet and Boyd 1977). Among them, the hose-level is the most accurate low-cost method and is preferred for making contour lines on gentle slopes (Kiepe 1992).

It is possible with the hose-level to measure to a precision level of better than 0.1 per cent. Another advantage is that the two positions can be marked at any distance from each other up to the maximum length of the hose.

### STEP-3: Preparation and Establishment of Contour Lines

The simplest soil erosion control structure is a contour hedgerow, usually of nitrogen-fixing trees/shrubs. This living wall of plants slows down the passage of rainwater and traps soil to slowly form natural terraces. The contour lines are prepared by cultivating or ploughing one and a half to one metre-wide strips along the contour lines. The stakes/pegs serve as guides during the preparation of the contour lines for planting.

### STEP-4: Planting Nitrogen-fixing Plants and Trees/Shrubs

For establishing a double hedgerow of plants, two furrows, one to a half metre apart, are dug. Plantation is carried out on these furrows by either sowing seeds of appropriate species or by planting cuttings of some species instead of seeds. When seeds are planted, the usual practice followed is to sow two to three seeds per hill at a distance of one-fourth of an inch between the hills. The seeds of some species need to be soaked for varying time periods before sowing, and the depth at which the seeds should be planted also varies depending on the species.

The farmland marked for planting forage crops should be established six to eight months before goats or other livestock are brought in. Hedgerow species that are palatable, high in protein, fast coppicing, and high-yielding forage crops are recommended for planting. A suggested composition of forage crops is 50 per cent *Desmodium rensonii*, 25 per cent *Flemingia congesta*, 20 per cent *Gliricidia sepium*, and 5 per cent grasses like napier. The hedgerows can be pruned regularly between half to one metre above the ground for animal forage. The missing hills of the hedgerows maintained for forage should be located and replanted regularly. Weeds can also be planted according to need.

When fully grown, the hedgerows bank the soil and serve as sources of fertiliser. The ability of nitrogen-fixing tree/shrub species to grow on poor soils and in areas with long dry spells makes them good plants for restoring forest cover on watershed slopes and on other lands that have been denuded of trees. Through natural leaf drop, they enrich and fertilise the soil. In addition, they compete vigorously with the coarse grasses that are common on degraded lands that have been deforested or depleted by excessive cultivation.

Ipil-ipil (*Leucaena leucocephala*) is the best example of nitrogen-fixing trees for hedgerows on a SALT farm. Other plant species tried successfully are - *Flemingia congesta*, *Acacia villosa*, *Gliricidia sepium*, *Leucaena diversifolia*, and *Desmodium* spp. such as *D.gyroides*, *D. distortum*, and *D. discolor*.

To maintain diversity, it is always recommended that different species be planted in the two adjoining hedgerows. Using a combination of species in the hedgerows is desirable in order to minimise the risks of attacks from pests. Where time is of no importance, the trees can be left to grow until they are four to five metres high which, by then, should form a shade that will kill the grasses and eliminate the need for cutting them.

**STEP-5: Cultivating Alternate Strips**

The land space between the thick rows of nitrogen-fixing trees/shrubs, where the crops are planted, is called a strip or "alley". The system of alley cropping is an attempt to integrate traditional forest management practices and natural nutrient cycling processes into a more intensive, productive, and sustainable farming system. Fast-growing legumes are planted in hedgerows along the alleys. Contour farming is similar to alley cropping but is practised on sloping lands and is designed to reduce soil erosion and water runoff.

If it is necessary to cultivate the land before the nitrogen-fixing hedgerow plants are fully grown, then it is recommended that crops should be planted on alternate strips of 2, 4, 6, 8, and so on. In alternate strip cultivation, the uncultivated strips would collect the soil that erodes from the higher cultivated strips. Once the hedgerows are fully grown, every strip can be cultivated.

**STEP-6: Planting Permanent Crops**

Perennial horticultural crops may be planted at the same time that the hedgerows are planted. These species of permanent crops vary according to the agroecological zone and farming system in question. For example, at MBRLC in the Philippines, coffee, cacao, banana,and citrus have been grown successfully. In areas that are not cultivated, the spots for planting can be cleared. Under SALT, planting permanent crops on every third strip is recommended. Tall crops are planted at the bottom of the hill, while the short ones are planted at the top to avoid shading.

To avoid further soil disturbances, 3/4 of the agricultural area in SALT-2 is placed under long-term perennial crops and 1/4 under short-term annual crops.

As permanent plants of forestry tree species under the SALT-3 system, MBRLC has experimented with the following tree species - *Samanea saman*, *Acacia auriculiformis*, *Pterocarpus indicus*, *Sesbania sesban*, *S. formosa*, *Calliandra calothyrsus*, and *Leucaena diversifolia*. All species are planted in pure stands.

Agroclimatically, wherever possible, bamboos are recommended for planting in the space between the upper and lower sections of the farm. The trees can be harvested between 5-10 or 11-15 or 16-20 years of age, depending on the species and the needs. Short-term trees yield poles and fuelwood, medium-term trees provide materials for furniture, construction, and leaf meal, and long-term species provide valuable quality timber in the form of saw logs.

Farmers may also want to raise sheep, poultry, or geese in this small forest. Ring weeding is carried out and other efforts are also made to improve the tree stands.

In the SALT-4 model developed at MBRLC, food crops occupy 20 per cent of the total farm size and are planted on the lower portion of the farm, while fruit trees are planted on the upper portion of the farm. The fruit trees occupy about 60 per cent of the whole farm area.

This is, however, quite flexible and, over the years, several interesting modifications have been made in the SALT-4 system. For example, whole farmlands of the farmers are planted with plantation crops or fruit crops and double hedgerows are developed in between on the contours to allow natural formation of terracing and to maintain fertility. Several instances have been recorded in which farmers made modifications according to their convenience. Some liked to plant the entire area with fruit trees and planted crops in between, while others proportioned their land according to their landholding and access to markets for selling fruits.

### STEP-7: Planting the Short-term Crops

Short-term and medium-term, income-generating crops are planted between strips of permanent crops as a source of food and cash income, while waiting for the permanent crops to bear fruit.

While in SALT-2, food and cash crops are grown on the upper half portion of the farm so that the soil loosened due to cultivation is caught at the lower half portion by the forage crops. In the SALT-3 model, annual food or cash crops may be grown for some years in between the trees.

### STEP-8: Trimming the Hedgerows

One year after planting, the hedgerows are coppiced at a height of 1 to 1.5m (40cm recommended by IIRR 1992) from the ground, every 30 to 45 days. The cut leaves and twigs are piled at the base of the crops to serve as organic fertilisers for the crops. In this way, the need for more inorganic fertilisers is reduced to a minimal level. There is, however, a word of caution that the time period for coppicing, i.e., 30 to 45 days, has been found suitable for the warmer tropical conditions prevailing in the Philippines. This may not be the same under all agroclimatic conditions, for the growth rate of hedgerows would differ and this is what determines the periods of trimming in a particular location. For example, under cold climatic conditions, trimming may be appropriate only once or twice a year but it could be around three times a year in wet temperate Himalayan environments and more frequent in the mid-hills.

### STEP-9: Management of the SALT System

The annual crops are always rotated to maintain productivity, fertility, and good soil formation. A good way of doing this is to plant grains, tubers, and other crops in strips where legumes were planted previously and vice versa. Other crop management practices can be followed as per requirement.

In SALT-2, it is recommended that the goat house should be constructed in the middle of the farm, between the boundary of the forage garden and the agricultural area, in order to save time and labour in hauling manure out to the farm and carrying forage to the goats.

A floor space of 20 to 25 sq.ft. per goat is recommended. For convenient removal of manure, the floor is raised about four feet above the ground, with floor slots nailed about 1/2 inch apart. Essential divisions and fixtures in the goat house are the kids' separation pen, milking stanchion, milkroom, storeroom, feeding trough, grass rack, and water and salt trough.

Goats, or other animals of choice, should be brought in only after six to eight months, when the forage garden is well established. The recommended breeds for best results in captive feeding are the purebred, the crossbred, or the upgrades of Nubian, Alpine, and La Mancha. In case these breeds are not available, one may start with any other biggest, available goat. A good stocking pattern is one buck and 12 does per 1/2 hectare of a well-developed agro-forestry/forage farm.

Dairy goats need concentrates (high energy feeds) aside from the forage (high fibre feed). Goats should be given forage composed of at least 10 per cent of their body weight along with plenty of water and some salt.

Farmers will have products for marketing, i.e., (i) milk which will have to be sold daily; (ii) the kids of the goats which can be marketed after 10 to 12 months when they weigh between 35 to 55kg.

SALT-3 requires the following additional processes - setting up an agroforestry nursery, managing the seedlings, finding contour lines on the upper half portion of the farm, and establishing the tree components. In SALT-3, developing 1/2 hectare of the tree plantation area on the upper portion of the farm is recommended. The tree crops are compartmentalised. To meet the three-fold objective of soil rehabilitation, firewood production, and growing timber, the land use is maximised by following the strategy of creating small wood lots of high density.

The products from this farmer forest can be harvested at appropriate times, processed, and then marketed. In the forestry component, forage from prunings and fuelwood and roundwoods from thinnings can be obtained right from the second year onwards.

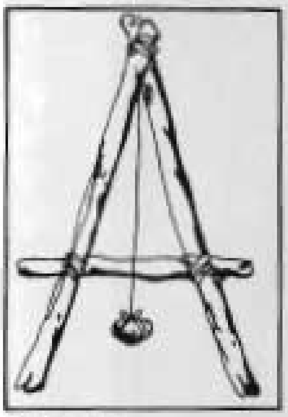
SALT-4 requires the following additional steps: setting up a nursery area on the farm, locating and preparing the contour lines for planting hedgerows in the orchard, and planting food crops on the lower portion of the farm.

**STEP-10: Building Green Terraces**

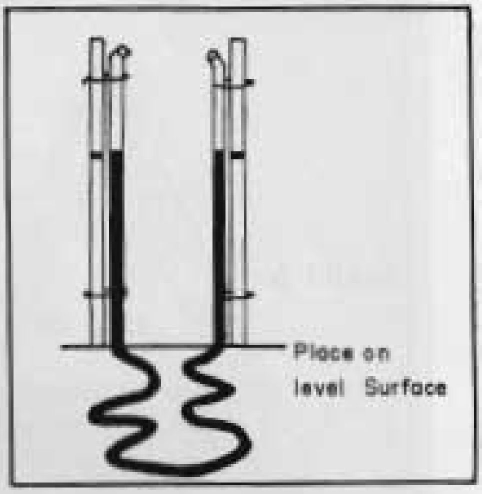
Apart from ensuring better crop production, the intended role of SALT is to contain soil erosion. This is done by the double hedgerows of nitrogen-fixing plants. As the farmers go on farming, year after year, they keep gathering and piling up straw, stalks, twigs, branches, leaves, rocks, and stones in the space between the two hedgerows.

As the years go by, soil, mud, and other materials piled up at the base of the hedgerows facilitate the building of permanent, naturally green terraces which are stronger and more viable than mechanically built terraces.

Among the cultural practices that farmers need to follow in SALT-farming are weeding, pruning of hedgerows (at 30-45 days' intervals), planting hedgerow strips, and controlling pests and diseases. In addition, to facilitate natural terrace building, it is desirable to keep on adding stones and branches at the centre of the hedgerows.

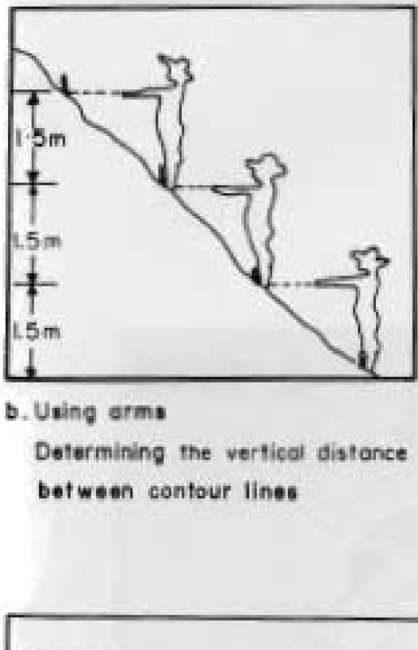


A – Frame

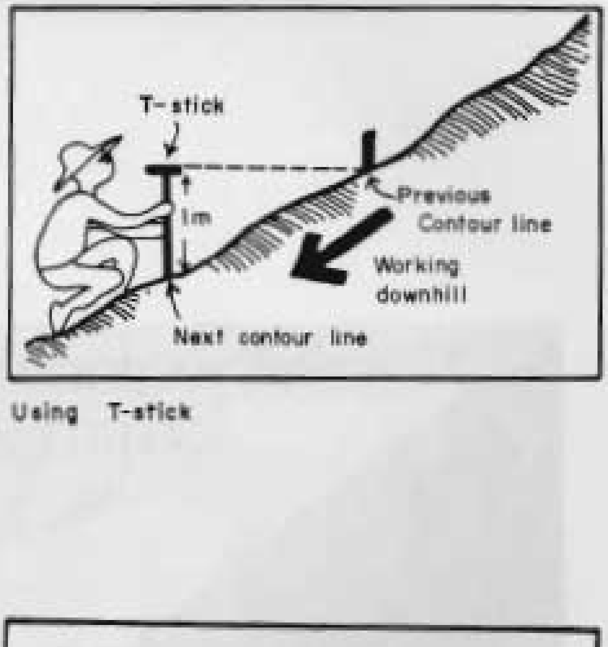



Water level

a. Determining contour lines

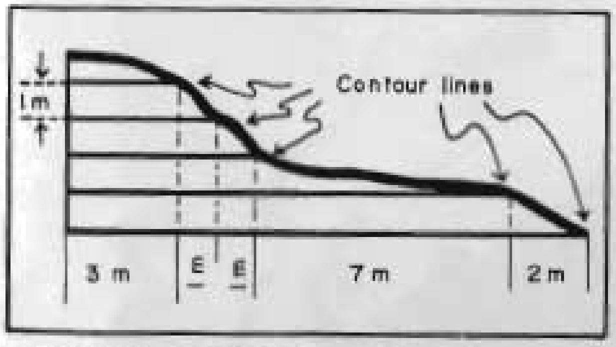



b. Using arms

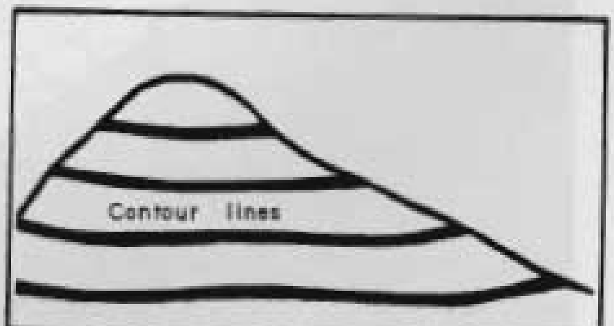



Using T-stick

Determining the vertical distance between contour lines

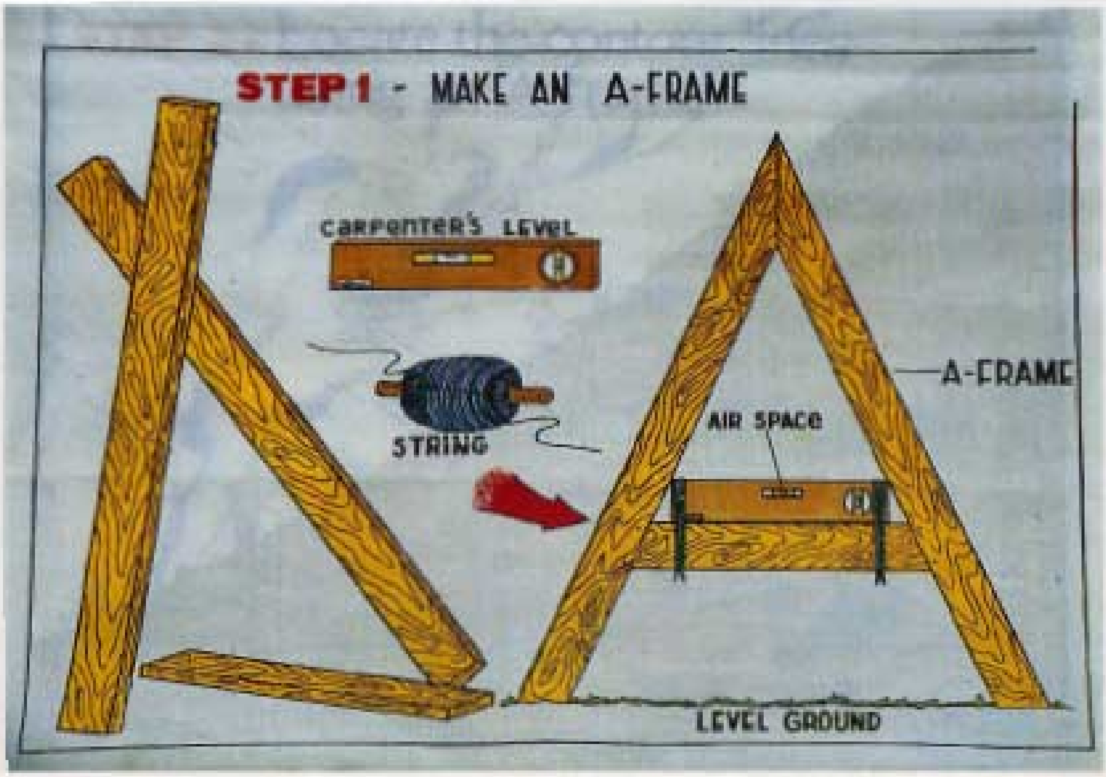


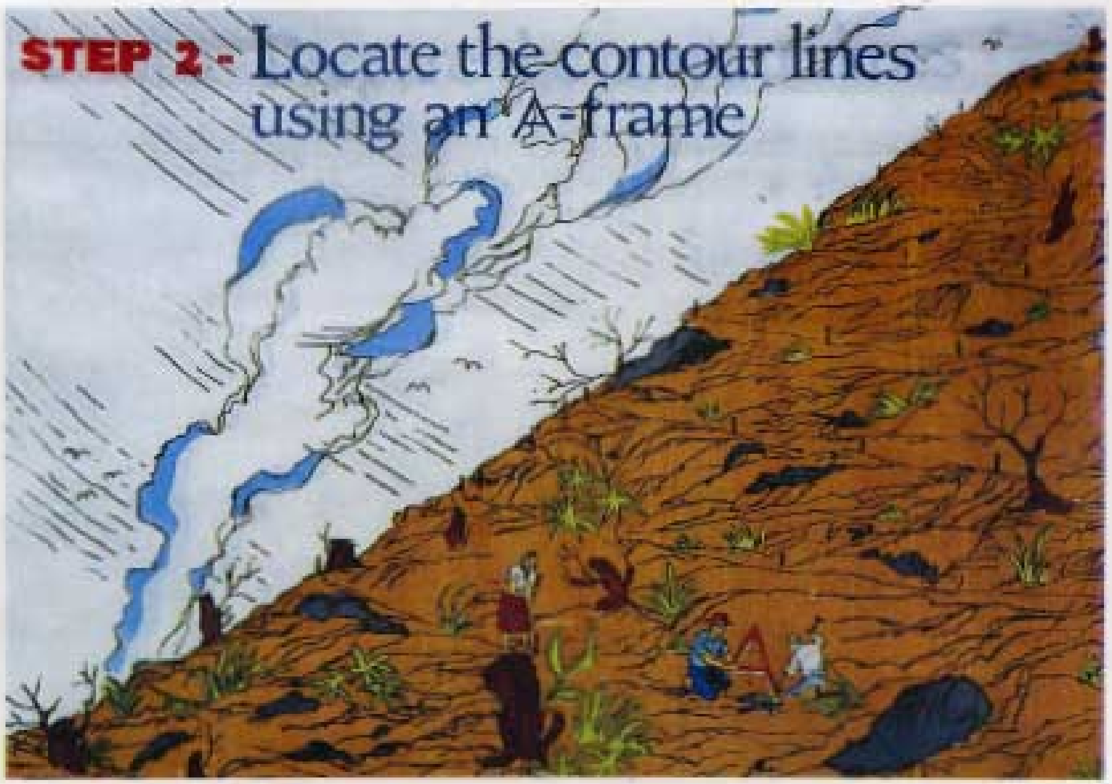

c. Variations in horizontal distance with different slopes.



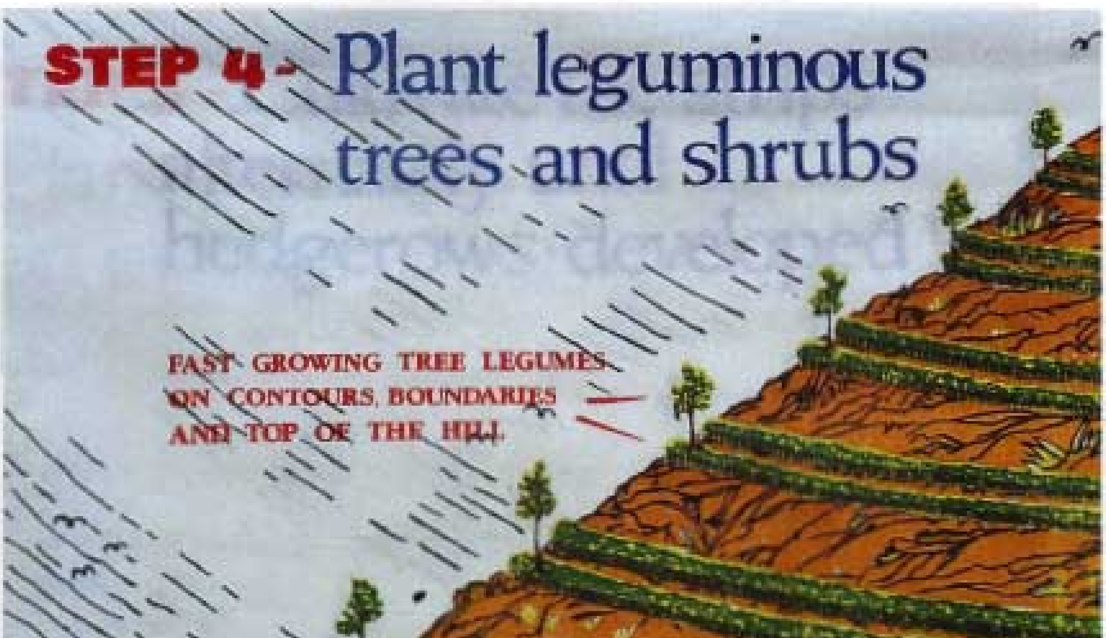

d. Contour lines

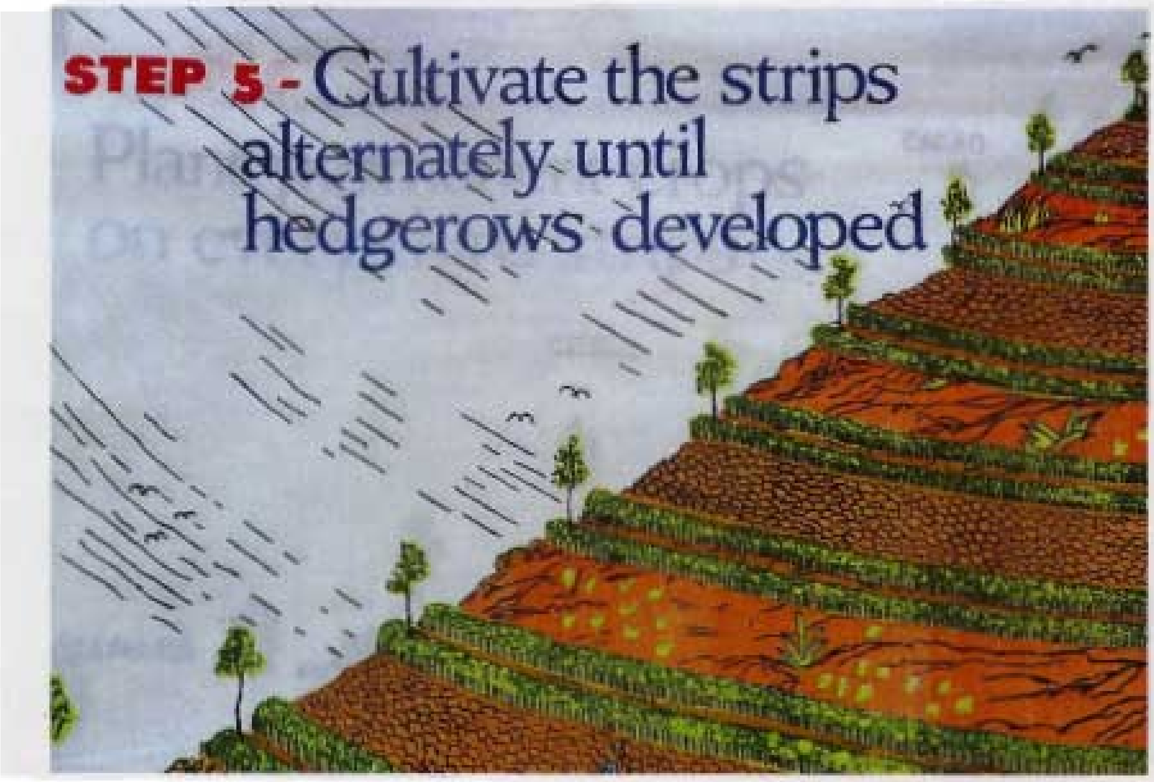
Graphic illustration of ways of marking contour lines.


STEP 1 - MAKE AN A-FRAME
CARPENTER'S LEVEL
STRING
A-FRAME
AIR SPACE
LEVEL GROUND

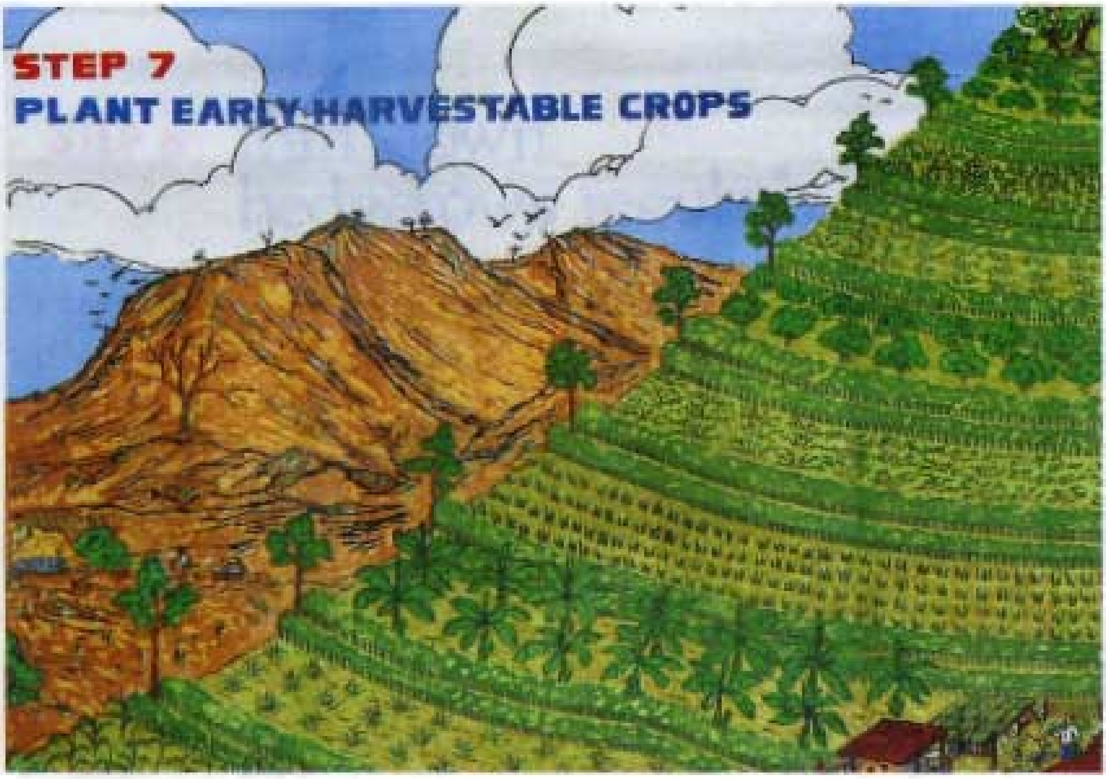

STEP 2 - Locate the contour lines using an A-frame

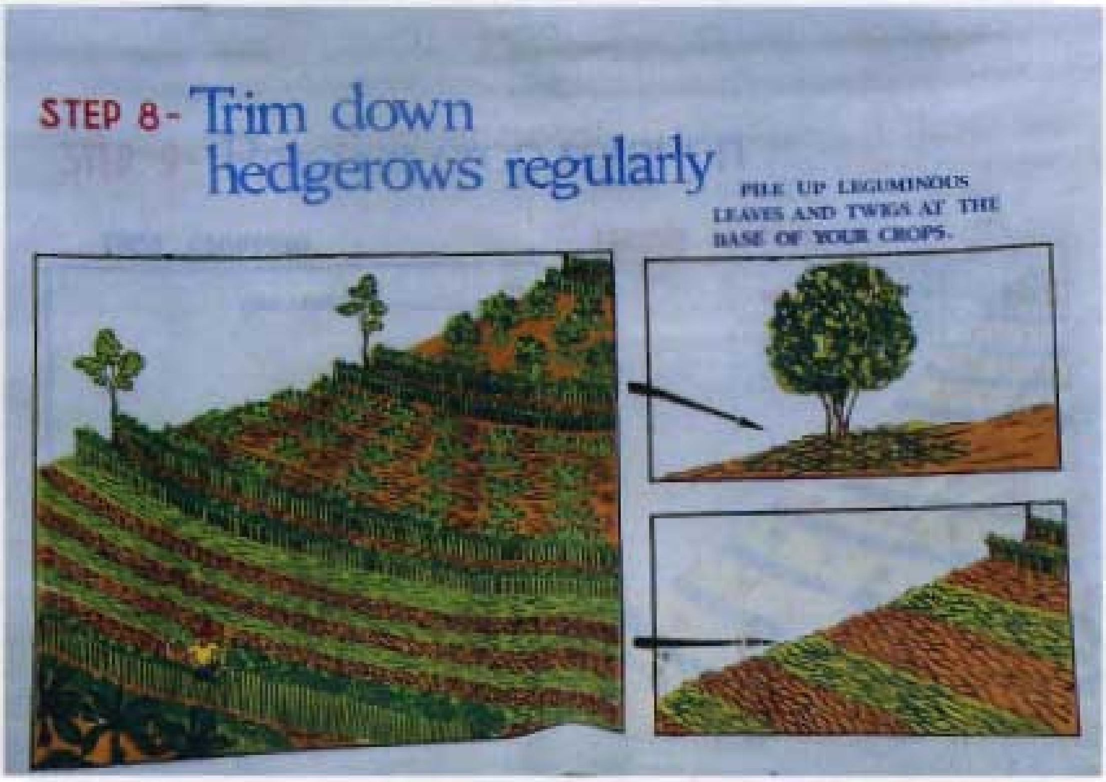

STEP 3 - Prepare the contour lines

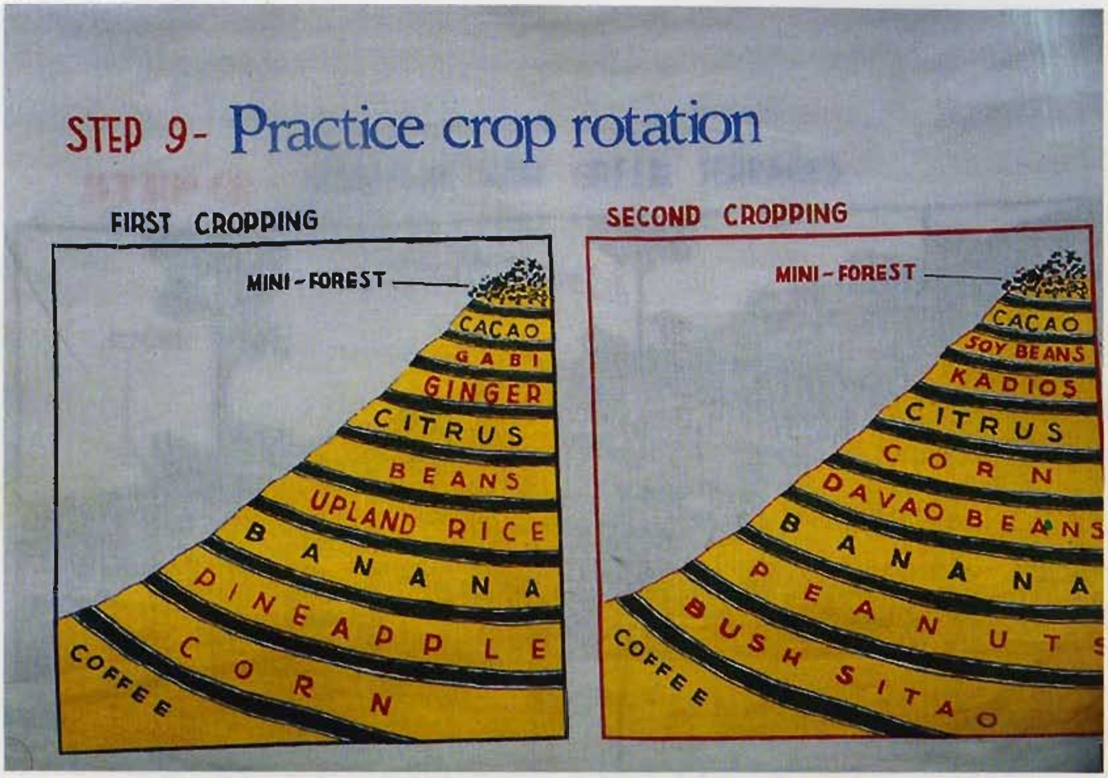

STEP 4 - Plant leguminous trees and shrubs
FAST GROWING TREE LEGUMES ON CONTOURS, BOUNDARIES AND TOP OF THE HILL


STEP 5 - Cultivate the strips alternately until hedgerows developed

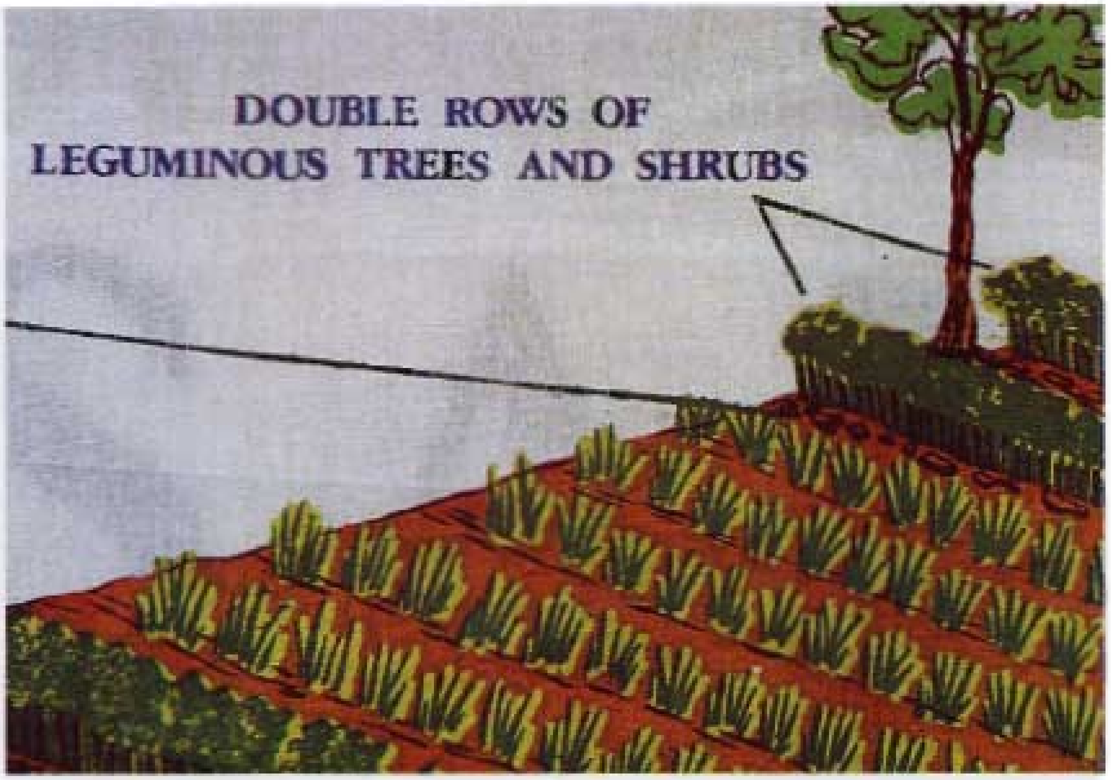

STEP 6
Plant permanent crops on every third strips
CACAO
CITRUS
BANANA

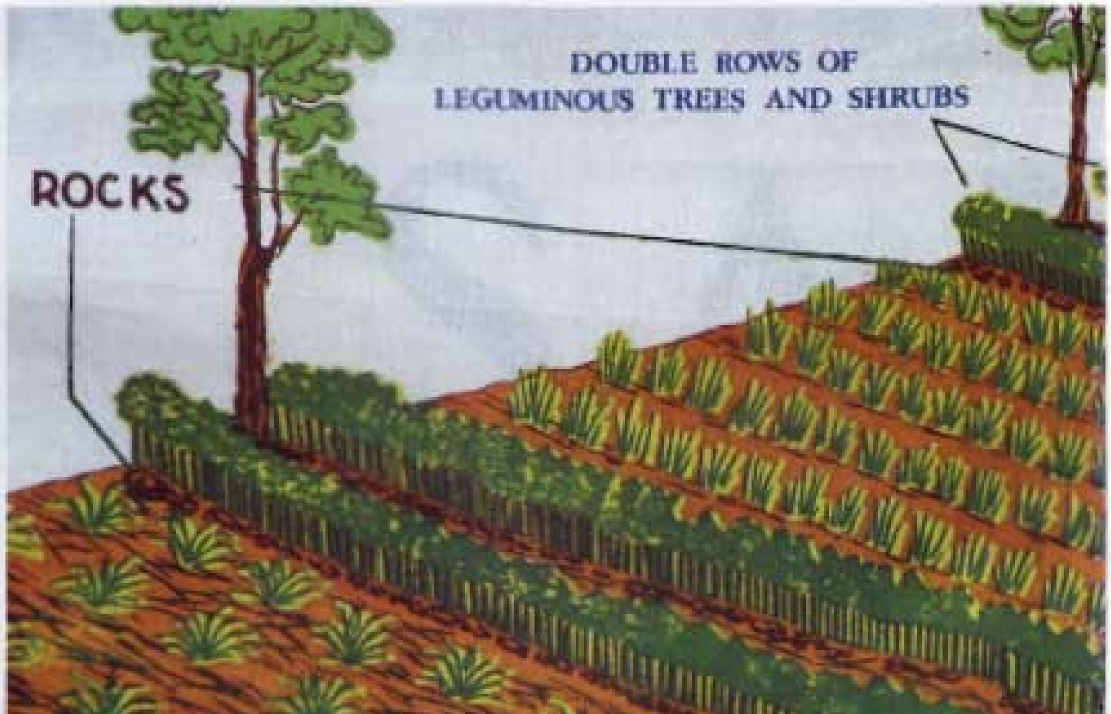

STEP 7
PLANT EARLY HARVESTABLE CROPS


STEP 8- Trim down hedgerows regularly
PILE UP LEGUMINOUS LEAVES AND TWIGS AT THE BASE OF YOUR CROPS.


STEP 9- Practice crop rotation
FIRST CROPPING
MINI-FOREST
CACAO
GABI
GINGER
CITRUS
BEANS
UPLAND RICE
BANANA
PINEAPPLE
CORN
COFFEE
SECOND CROPPING
MINI-FOREST
CACAO
SOY BEANS
KADIOS
CITRUS
CORN
DAVAO BEANS
BANANA
PEANUTS
BUSH SITAO
COFFEE


STEP 10 - MAINTAIN YOUR GREEN TERRACES
DOUBLE ROWS OF LEGUMINOUS TREES AND SHRUBS
ROCKS


DOUBLE ROWS OF
LEGUMINOUS TREES AND SHRUBS


DOUBLE ROWS OF
LEGUMINOUS TREES AND SHRUBS
ROCKS

# Annex 2

## THE CRITICAL CONSIDERATIONS FOR EVALUATING SALT

There are four problem areas in establishing the criteria for evaluating the results of the SALT and hedgerow systems.

i. Correct sampling from the experimental plots
ii. Correct conversion of biomass to a per hectare basis
iii. Evaluation methods for multiple outputs of SALT
iv. Extending evaluations over many cropping seasons.

i. On a typical SALT plot, difficulties will arise from the fact that all parts of the plot are no longer equivalent. Crops near the hedgerows are expected to be either better or worse than the crops outside the hedgerows' influence. Also, in a hedgerow-intercropping system, measurements of the crop rows in the centre of the alley and the row next to the hedge need to be taken to determine whether tree/crop interface effects are positive or negative.

ii. Comparisons between different crop-hedgerow combinations or SALT systems require calculations of yield on a per hectare basis. For example, comparing hedgerow intercropping systems with sole cropping, while converting yields from sample areas to yields per hectare, is one step where mistakes can usually be committed. The illustration shown in Figure 5.5 shows the correct sampling areas. In plots identified a,b,c, the harvest area is 4 x 8 = 32sq.m., but, in plot a, only four rows of maize are measured. As the spacing in between rows is 0.8m, it is tempting to take the width as 4 x 8m = 3.2m and the plot area as 8 x 3.2m = 25.6 sq.m. This would be incorrect because the area occupied by the hedges is ignored. Using this area would result in a per hectare yield inflated by 25 per cent.

iii. Another complexity involves evaluating more than one value of SALT. An obvious approach to the problem of multiple outputs is to produce an index that synthesises them into a single value. This is done by assigning weights to each characteristic, reflecting an assessment of their relative importance and then averaging them.

However, the approach using the "Land Equivalent Ratio - LER" has proven valuable. Consider a SALT hedgerow-intercropping system producing an annual crop plus fodder from hedges. If both these products are equally valuable, it can be compared with a system in which land is divided between sole blocks of annual crops and of fodder trees in a suitable proportion. The LER is a convenient method of comparing the biological productivity of these two arrangements by combining the two types of yield (Rao and Coe 1992). It is defined as the land area in the sole system that will be required to produce the same yields as one hectare of intercropped hedgerows. The following equation should be used for the calculations: **LER = Ci/Cs + Ti/Ts**.

Here Ci and Ti are crop and tree yields under intercropped hedgerows and Cs and Ts are yields in the sole system. The caution for using the equation is that the LER should be based on the most important products of the system (Rao and Coe 1992). The LER is only a relative measure and it should not be used as an indicator of the magnitude of the yields.

The LER has been illustrated here with a case example. The LER of *Leucaena* hedges producing fodder (dry weight) to a maize intercrop will be calculated as follows: if the yield of sole maize crop is 4T/ha grain and the sole *Leucaena* produces a biomass of 6T/ha and, on the other hand, the intercropped yields are 3.2T/ha of maize grain plus 2.4T/ha of *Leucaena* fodder, then the LER of the system will be - 3.2/4.0 + 2.4/6.0=1.2. This means that the productivity of one hectare of intercropped hedgerow is equivalent to that of 1.2 hectares under the sole system. In other words, hedgerow intercropping is 20 per cent more productive than the sole system ( Rao and Coe 1992).

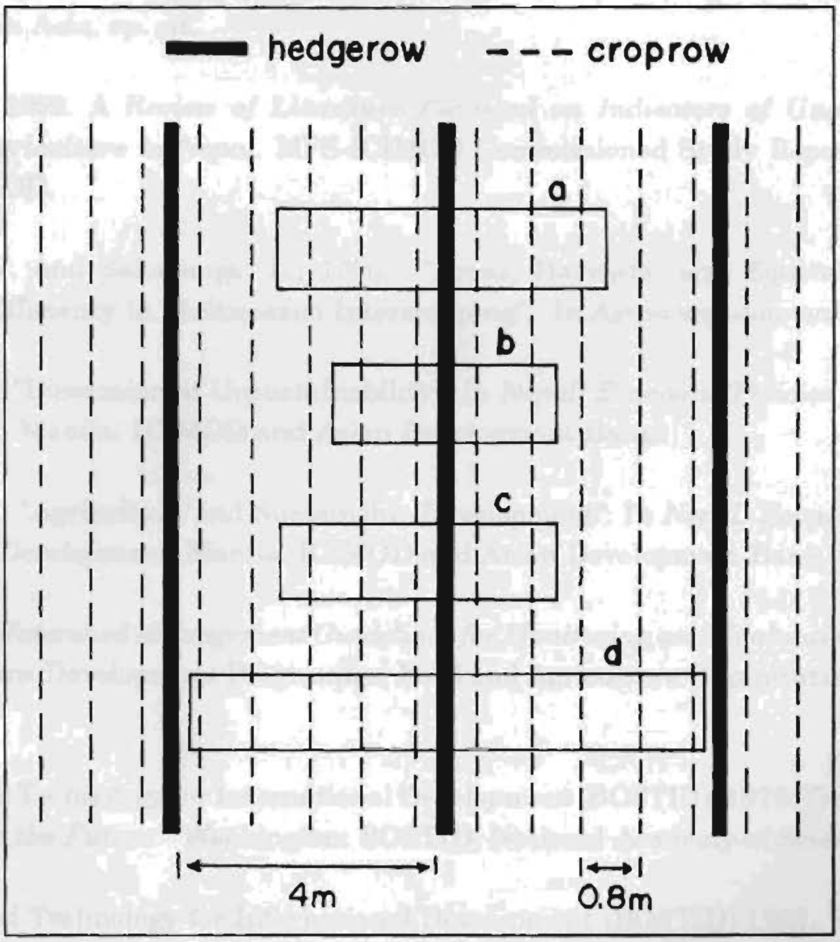
However, SALT field experiments are more complex than research confined to annual crops. Also, the SALT system delivers both services and products with different values and functions. This demands that different methods of evaluation be designed as required.

iv. Under diverse and rapidly changing conditions - particularly socioeconomic conditions, no one evaluation method for SALT can give all the answers. A SALT system that is performing well in one location may not be appropriate in another, and a system ranked as perfect today may not be regarded so tomorrow under changed circumstances. A comprehensive evaluation must also consider the economic and social aspects of SALT, along with the usual biological aspects. Such an evaluation requires accurate, long-term data collected over a minimum five-year period. Information over longer time periods would be still better.

Yet another reason favouring longer-term evaluation is the variation in weather that inevitably occurs from year to year. The relative performance of different SALT systems could be quite different under different weather and agroecological conditions. While it may not be possible to establish rules for the number of growing seasons necessary to evaluate different systems, the evaluation must include the usual range of climatic conditions on the site.

The two faults with short-term evaluations of SALT are: one, it would be lacking in information about the long-term potential of SALT and, two, it faces the risk of inaccurate conclusions due to the short-term vagaries of climate. In addition, if SALT systems are judged based on short-term results, not only will the findings not be promising but the important aspects of sustainability may also be overlooked.

Therefore, it is essential to evaluate SALT systems over a sufficiently long period, typically for a minimum of five years. There are two main reasons for this. First, many of the potential benefits of SALT are long term. Obvious examples are soil erosion control and fertility maintenance, for which one may document the impact within a few seasons, but for which the real effects can be seen over a long period only.




SALT plot sampling technique for biomass evaluations: c and d are correct sample areas for measuring crop yields, but a and b are incorrect.

## REFERENCES


Aneeksamphant, C. and Boonchee, S., 1992. "Management of Sloping Lands for Sustainable Agriculture in Thailand". In IBSRAM, *Management of Sloping Lands for Sustainable Agriculture in Asia*, op. cit.

Bajracharya, B.B., 1992. *A Review of Literature Focussed on Indicators of Unsustainability of Mountain Agriculture in Nepal*. MFS-ICIMOD Commissioned Study Report. Kathmandu, Nepal: ICIMOD.

Balsubramaniam, V. and Sekayange, L., 1990. "Areas, Harvests, and Equivalency Ratio for Measuring Efficiency in Multiseason Intercropping". In *Agronomy Journal*. 82: 92-519

Banskota, M., 1992. "Dimension of Unsustainability". In *Nepal: Economic Policies for Sustainable Development*. Manila. ICIMOD and Asian Development Bank.

Banskota, K., 1992. "Agriculture and Sustainable Development". In *Nepal: Economic Policies for Sustainable Development*. Manila. ICIMOD and Asian Development Bank.

Bhatta, B.R., 1990. *Watershed Management Guidelines for Monitoring and Evaluation*. Kathmandu: United Nations Development Programme, Food and Agriculture Organisation of the United Nations.

Board on Science and Technology for International Development (BOSTID), 1979. *Tropical Legumes, Resources for the Future*. Washington: BOSTID, National Academy of Sciences.

Board on Science and Technology for International Development (BOSTID) 1993. *Vetiver Grass, A Thin Line Against Erosion*. Washington : National Research Council, National Academy Press.

Brooks, K.N., 1993. *Challenges in Upland Conservation : Asia and the Pacific*. RAPA Publication No. 1993/5. Bangkok: Regional Office for Asia and the Pacific (RAPA), Food and Agriculture Organisation of the United Nations (FAO).

Capistrano, L. N.; Durno, J.; and Moelino, I., 1990. *Resource Book on Sustainable Agriculture for the Uplands*. Philippines: International Institute of Rural Reconstruction (IIRR).

Carson, B. 1992. *The Land, The Farmer, and The Future*. ICIMOD Occasional Paper No. 21. Kathmandu: ICIMOD.

Castro, C. (ed.), 1991. *Upland Conservation in Asia and the Pacific*. RAPA Pub. No. 1991/15. Bangkok: Regional Office for Asia and the Pacific (RAPA), FAO.

Chan, C., 1981. *Evaluation of Soil Loss Factors on Cultivated Sloping Lands of Taiwan*. ASPAC Technical Bulletin No. 55, 283 p.

Collect, J. and Boyd, J., 1977. *Eight Simple Surveying Levels.* Agricultural Equipment Leaflet No. 42. London: Intermediate Technology Publications.

Cuevans, V.C., 1991. *The Continuing Problem of Shifting Cultivation in the Philippines: A Human Ecology Analysis.* IEESAM Bulletin, Vol. XI, No. 1-2. Los Banos, Laguna, Philippines: IEESAM.

Central Soil and Water Conservation Research and Training Institute (CSWCRTI), 1982. *Twenty-five Years of Research on Soil and Water Conservation in Southern Hilly, High Rainfall Regions.* Monograph No. 4. Dehradun, India: CSWCRTI.

Das, D.C. and Maharjan, P.L., 1988. *Terracing in the Hindu Kush-Himalaya : A Reassessment.* ICIMOD Working Paper No. 10. Kathmandu, Nepal: ICIMOD.

Denholm, J., 1991. *Agroforestry in Mountain Areas of the Hindu Kush-Himalayan Region.* ICIMOD Occasional Paper No. 17. Kathmandu, Nepal : ICIMOD.

Dodette, J.B. and Sinyle, J.W., 1990. "Soil and Moisture Conservation Technologies". In Doolette, J.B. and Magrath, W. (eds) *Watershed Development in Asia.* World Bank Technical Paper No. 127. Washington D.C.: IBRD.

EL-Swaify, S.A., 1987. "Soil-based Concerns for Soil and Water Conservation Research and Development in the Tropics". In Jantawat, S. (ed.), *Soil Erosion and Its Counter Measures.* Bangkok: Soil and Water Conservation Society of Thailand.

FAO, 1986. *Highlands Reclamation Study Ethopia.* Int. Doc. Rome:

FAO 1991. *Shifting Cultivators: Local Technical Knowledge and Natural Resource Management in the Humid Tropics.* Community Forestry Note No. 8. Rome: Food and Agriculture Organisation of the United Nations (FAO).

Fujisaka, S., 1992. "The Role and Impact of Socioeconomic and Policy Research in Effecting Technology Adoption". In Blair, G. and Lefroy, R. (eds), *Technology for Sustainable Agriculture on Marginal Uplands in South East Asia.* Canberra: Australian Centre for Agricultural Research.

Fujisaka, S. and Cenas, P.A., 1993. "Contour Hedgerow Technology in the Philippines: Not Yet Sustainable". In *Indigenous Knowledge and Development Monitor*, Vol. 1 (1): 14-16.

Garrity, D.P., 1989. "Hedgerow Systems for Sustainable Food Crop Production on Sloping Lands: Elements of a Strategy". In *Proceedings of the Workshop on the Development of Upland Hilly Areas in Region XII*, Bansalan, Davao del Sur, December 20-22, 1989.

Ghidyal, B.P., 1981. "Soils of the Garhwal and Kumaon Himalaya". In *The Himalaya : Aspects of Change*, 120-127 pp. Lall, J.S. and Moddie, A.D. (eds.), New Delhi : India International Centre and Oxford University Press.

Halliday, J. and Nakao, P.L., 1982. *The Symbiotic Affinities of Woody Plants under Consideration as Nitrogen-fixing Trees.* Hawaii: Hawaii's Hiftal Project, University of Hawaii.

Hoey, P.M., 1993. "Technical Aspects of Sustainable Farming Systems in the Highlands. In *Proceedings of the Completion Seminar of the Thai-Australia Highland Agricultural and Social Development Project*. Adelaide, Australia: AACM International Ltd.

Hurni, H, and Tato, K. (eds), 1992. *Erosion Conservation and Small-scale Farming*. Missouri, USA: International Soil Conservation Organisation and World Association for Soil and Water Conservation.

International Board for Soil Research and Management (IBSRAM), 1992. *Management of Sloping Lands for Sustainable Agriculture in Asia, Phase I (1988-91).* Network Document No. 2. Bangkok: Asian Development Bank (ADB) and Swiss Development Cooperation.

International Institute for Rural Reconstruction (IIRR), 1992. *Soil and Water Conservation Technologies and Agroforestry Systems.* Agroforestry Information Kit (ATIK). Silang, Cairte, Philippines: IIRI

Jodha, N.S., 1993. "Enhancing Food Security in a Warmer and More Crowded World: The Factors and Processes in the Fragile Resource Zones". Paper for the NATO/OEC Workshop on "Climate Change and Food Security," July 11-17, 1993, Oxford.

Jodha, N.S. 1992. "Mountain Perspective and Sustainability: A Framework for Development Strategies". In Jodha, N.S.; Banskota, M.; and Partap, T. (eds.), *Sustainable Mountain Agriculture: Perspectives and Issues*, Vol. I. Delhi: Oxford IBH Co. and ICIMOD.

Jodha N.S. and Partap, T. 1993. "Folk Agronomy in the Himalayas: Implications for Agriculture Research and Extention". In *Rural People's Knowledge, Agricultural Research, and Extension Practice*. Research Series, Vol 1, No. 3. London: International Institute for Environment and Development (IIED).

Jodha, N.S. and Shrestha, S. 1994. "Towards Sustainable and More Productive Mountain Farming". Paper presented at the ICIMOD 10th Anniversary Symposium on Mountain Environment and Development: Constraints and Opportunities, ICIMOD, Kathmandu, Nepal, December 1-2, 1993.

Kiepe, P. and Young, A. 1992. "Soil Conservation through Agroforestry: Experience from Four Years of Demonstrations at Machakos, Kenya". In Hurmi, H. and Tato, K. (eds), *Erosion Conservation, and Small-Scale Farming*, 303-312 pp. Missouri, USA: International Soil Conservation Organisation (ISCO) and World for Soil and Water Conservation (WASWC).

Kiepe, P., 1992. "More Low Cost Methods for Making Contour Lines". In *Agroforestry Today*; 4 (3): 16-17.

Kuchelmeister, G., 1989. *Hedges for Resource Poor Land Users in Development Countries*, 256 pp. Eschoborn, Germany: GTZ Pub.

Lal, R.; Kang, B.T.; Moorsmann, F.R.; Tuo, A.S.R.; and Mommaw, J.C., 1974. "Soil Management Problems and Possible Solutions in Western Nigeria. In *Proceedings of the Seminar on the Soil Management and Development Process in Tropical Africa*, February 10-14, Centre International de Agricultural Tropical, Cali, Columbia.

Land Resources' Mapping Project, 1986. *Land Systems, Land Utilisation and Agriculture-Forestry Reports*. Ottawa, Canada: Kenting Earth Sciences Ltd.

Laquihon, W., 1988. *Factors Affecting Adoption of SALT by the Farmers*. Report of the MBRLC Study (unpbublished). Mindanao, Philippines: MBRLC.

Liao, M.C., 1981. "Soil Conservation Measures for Steep Orchards in Taiwan. In *South East Asian Regional Symposium on Problems of Soil Erosion and Sedimentation*, 301-310 pp.

Lu Rongsen, 1992. *Seabuckthorn: A Multipurpose Plant Species for Fragile Mountains*. ICIMOD Occasional Paper No. 20. Kathmandu, Nepal: ICIMOD.

Lu, R.S., 1992. *Seabuckthorn : A Mountain Specific Option*. Unpublished Working Paper. Kathmandu, Nepal: ICIMOD.

Lu, R.S., 1994. *Plastic Film Technology (PFT) for Improving the Uplands*. ICIMOD Occasional Paper No. 24. Kathmandu, Nepal: ICIMOD (In press).

Maas, J.M., 1992. "The Use of Litter-mulch to Reduce Erosion on Hilly Land in Mexico". In Hurni, H. and Tato, K. (eds.) *Erosion, Conservation, and Small-scale Farming*, 383-391 pp. op. cit.

Mac Dicken, K.G., 1981. "Leucaena as a Fallow Improvement Crop: A First Approximation". Paper presented at the Agroforestry and Fuelwood Workshop, East-West Centre, Honolulu, November 1981.

Maskey, R.B.; Joshi, D.; and Maharjan, P.L.; 1992. "Management of Sloping Lands for Sustainable Agriculture in Nepal. In Sajjaapongse, A. (ed.), (IBSEAM/ASIANLAND), *Management of Sloping Land for Sustainable Agriculture in Asia, Phase - I, 1988-91*. Bangkok: International Board for Soil Research and Management (IBSRAM), Asian Development Bank (ADB), and Swiss Development Cooperation (SDC).

Moberg, J.P., 1972. "Some Fertility Problems in the West Lake Region of Tanzania, Including the Effects of Different Forms of Cultivation on the Fertility of Some Ferrosols". In *East African Agricultural and Forestry Journal*, 38 (1): 35-46.

Moges Worku Bekele and Thomas, D.B., 1992. "The Influence of Surface Residue on Soil Loss and Runoff". In Hurmi, H. and Tato, K. (eds), *Erosion, Conservation, and Small-scale Farming*, op. cit., 439-452 pp. op. cit.

National Afforestation and Eco Development Board (NAEB), 1993. *Conceptual Agroforestry Models for Hills (Chamba District)*. Solan, H.P., India: Regional Centre.

Panday, Kk., 1992. *Sustainability of the Environmental Resource Base and Development Priorities of a Mountain Community*. ICIMOD Occasional Paper No. 19. Kathmandu, Nepal : ICIMOD.

Paningbatan, E. and Camia, R.A., 1990a. *Management and Rehabilitation of Degraded Hilly Lands in the Philippines*. A Progress Report presented during the Training Workshop on Soil Conservation and Agroforestry. Los Banos, Laguna, Philippines: PCARRD.

Paningbatan, E. and Camia, R.A., 1990b. *Management of Degraded and Sloping Lands for Sustainable Agriculture in Indonesia*. A Progress Report presented during the Training Workshop on Soil Conservation and Agroforestry. Los Banos, Laguna, Philippines: PCARRD.

Pei Shengji, 1985. "Preliminary Survey of Swidden Cultivation in the Tropical Areas of Yunnan, China, from the Ethnoecological Point of View". Paper presented at the Workshop on Rural Ecosystems Research, Nanjing, China.

Pradhan, M.L.; Chand, K.; and Maharjan, P.L., 1969. *Soil Survey of Kanchanpur District*. Nepal: Soil Science, Department of Agriculture, HMG/N.

Rao, M.R.; James, H.R., 1990. Discovering the Hard Facts: Agronomic Considerations-Part II. *Agroforestry Today*, 2 (2): 12-15.

Rao, M.R. and Coe, R., 1992. "Evaluating the Results of Agroforestry Research". In *Agroforestry Today*, 4 (1): 4-9.

Regmi, P.P., 1982. *An Introduction to Nepalese Food Plants*, 14-45 pp. Kathmandu, Nepal: Royal Nepal Academy.

Regmi, K.W., 1991. "Soil Fertility Maintenance for Crop Production in the Mid Hills of Nepal". In *Proceedings of the Workshop on Soil Fertility and Erosion Issues in the Middle Mountains of Nepal*, Sponsored by IDRC, Kathmandu, Nepal, April 22-25, 1991.

Rekasem, B. and Rerkasem, K., 1993. "Legumes for the Highlands". In *Proceedings of the Completion Seminar of the Thai-Australia Highland Agricultural and Social Development Project*, op.cit.

Roder, W.; Calvert, O.; and Dorji, Y., 1992. "Shifting Cultivation Systems Practised in Bhutan. In *Agroforestry Systems*, 19: 149-158.

Roder, W.; Calvert, O.; and Dorji, Y., 1993. "Effect of Mound Burning on Selected Soil Parameters in a Grass Fallow Shifting Cultivation System in Bhutan". In *Plant and Soil*, 149: 51-58.

Rodriguez, B.S. and Napoleon, F. De. L.P., 1992. "Conservation Practices for Horticultural Production in the Mountainous Regions of Venezuela" In Hurmi, H. and Tato, K. (eds), *Erosion, Conservation, and Small-scale Farming*, op. cit., 393-405 pp.

Scheewe, W., 1992. *Nurturing the Soil, Feeding the People: An Introduction to Sustainable Organic Agriculture.* Davao City, Philippines: CRUST Foundation Inc.

Shah, P.B. and Shreier, H., 1991. "Nutrient Deficiency and Soil Fertility Issues". In *Proceedings of the Workshop on Soil Fertility and Erosion Issues in the Middle Mountains of Nepal, Jikhu Khola Watershed*, April 22-25, 1991.

Shah, P.B.; Shreier, H.; Brown, S.J.; and Riley, K.W.; 1991. *Proceedings of the Workshop on Soil Fertility and Erosion Issues in the Middle Mountains of Nepal, Jhikhu Khola Watershed*, April 22-25, 1991.

Shah, S.G. and Friend J.A., 1992. "Mixed Crop Systems in the Himalaya". In Pearson, C.J. (ed.) *Ecosystems of the World: Field Crop Ecosystems.* Amsterdam: Elsevier Publ.

Shakya, P.B.; Upreti, R.P. and Vaidya, S. 1991. *Fingermillet in Nepal: Importance, Utilisation, and Farming Systems in a Socioeconomic Context.* Nepal: National Hill Crops Research Programme.

Sharma, P. and Partap, T., 1993. "Population, Poverty, and Development Issues in the Hindu Kush-Himalayas". Paper presented at the International Forum/Symposium on *Development of Poor Mountain Areas*, March 22-27, 1993, Beijing, China.

Shrestha, S. 1992. *Mountain Agriculture : Indicators of Unsustainability and Options for Reversal.* Mountain Farming Systems Discussion Paper No. 32. Kathmandu, Nepal : ICIMOD.

Shrestha, S. and Katwal, B. 1992. "Farmers' Strategies in the Middle Hills of Nepal". In Jodha, N.S. et al. (eds.) *Sustainable Mountain Agriculture*, op. cit.

Singh, V., 1992. *Dynamics of Unsustainability of Mountain Agriculture.* Report of the MFS-ICIMOD Commissioned Study in the Garhwal Himalayas, India. Kathmandu, Nepal: ICIMOD.

Smith, J.W. 1982. *The Agricultural Systems in the Hills of Nepal: The Ratio of Agricultural to Forest Land and the Problem of Animal Fodder.* APROSC Occasional Paper No. 1. Kathmandu, Nepal: APROSC.

Smyle, J.W. and Magrath, W.B. 1990. "Vetiver Grass - A Hedge Against Erosion". Paper presented at the American Society of Agronomy Annual Meeting in San Antonio, Texas.

Swarup, R. 1991. *Agricultural Economy of the Himalayan Region, Kumaon Himalaya.* Almora: G.B. Pant Institute of Himalayan Environment and Development, Nainital, India, and Gyanodya Prakashan.

Styczess, M., 1992. "Effects of Erosion on Soils and Growing Periods in Nigeria". In Hurmi, H. and Tato, K. (eds.), *Erosion, Conservation, and Small-scale Farming*. Missouri, USA: International Soil Conservation Organisation (ISCO) and World Association of Soil and Water Conservation (WASCWC).

Subedi, M.R.; Subedi, K.D.; and Gurung, G., 1991. "Soil Fertility Thrust Towards Sustainable Agriculture: Experiences of Lumle Regional Agriculture Centre. Pokhara, Nepal". In *Proceedings of the Workshop on Soil Fertility and Erosion Issues in the Middle Mountains of Nepal, Jhikhu Khola Watershed*, sponsored by IDRC, Kathmandu, Nepal, April 22-25, 1991.

Tacio, H.D., 1988. "SALT : Sloping Agriculture Land Technology". In *ILEIA Newsletter*, Vol. 4. No. 1, Netherlands.

Thai-Australia Highland Agricultural and Social Development Project (TAHASD), 1993. Contour Grass Strips - An Erosion Control Measure for the Hill Tribe Farmers: Principles and Method. Adelaide, Australia: AACM International Pvt. Ltd.

Tang Ya., 1992. *Sloping Agricultural Land Technology (SALT) in Ningnan County, Sichuan, China.* Final Report of the Project.

Tegene, B., 1992. Effects of Erosion and Properties and Productivity of Eutric Nilosols in Gununo Area, Southern Ethiopia", 229-242 pp. In Hurmi, H. and Tato, K. (op. cit.), *Erosion, Conservation, and Small-scale Farming*.

Thinley, S., 1991. "Upland Conservation in Bhutan". In Castro, C. (ed.) *Upland Conservation in Asia and the Pacific*. RAPA Publ. 1991/15. Bangkok: FAO.

Upadhyay, K.P., 1988. *Shifting Cultivation in Bhutan : Present Situation and Alternatives*. Field Document. TCP/BHU/6653. Rome: FAO.

UMWP, 1993. *A Sustainable Solution for the Soil Erosion Problem: Sloping Agricultural Land Technology (SALT)*. Pamphlet. Kandy, Sri Lanka: UMWP-GTZ Project.

Watson, H.R. and Laquihon, W.A., 1985. "Sloping Agricultural Land Technology (SALT) as Developed by the Mindanao Baptist Rural Life Centre". Paper presented at the workshop on Site Protection and Amelioration Roles of Agroforestry. Los Banos, Laguna, Philippines: Institute of Forest Conservation of the University of the Philippines, UPLB.

Weber, F. and Hoskins, M.W., 1983. *Soil Conservation Technical Sheets*. Moscow, Idaho (U.S.A): University of Idaho.

Willey, R.W., 1985. "Valuation and Presentation of Intercropping Advantages". In *Experimental Agriculture*, 21:119-34.

Withhams, L.S. and Walter, B.J., 1987. "Controlled Erosion Terraces in Venezuela". 177-187 pp. In Moldenhaver, W.C. and Hudson, N.W. (eds), *Conservation Farming on Steep Lands*. Ankeny, Iowa: Soil and Water Conservation Society and World Association of Soil and Water Conservation.

Yadav, Y., 1992. "Farming-Forestry-Livestock linkages : A Component of Mountain Farmer's Strategies". In Jodha, N.S. et al. (eds.), *Sustainable Mountain Agriculture*, op. cit.

Yanhua, L., *Dynamics of Highland Agriculture*. ICIMOD Occasional Paper No. 22. Kathmandu, Nepal: ICIMOD.

Young, A., 1989. "Ten Hypotheses for Soil Agroforestry Research". In *Agro-forestry Today*, 1(1): 13-16.

Young, A., 1989. *Agroforestry for Soil Conservation*. Wallingford U.K.: International Council for Research in Agroforestry in Cooperation with CAB. International and ICRAF.

## About the Authors

Dr Tej Partap is a professional staff member of the Mountain Farming Systems' Division of ICIMOD. As an ecologist, he has been working in the Sustainable Mountain Agriculture Programme of ICIMOD for the past seven years. Formerly, while working as a researcher at the Department of Biosciences, Himachal Pradesh University, Shimla, his work focussed on underexploited mountain crop resources and their crucial role in sustaining mountain agriculture.

The Rev. Harold R. Watson is Director of the Asian Rural Life Development Foundation, an affiliate of the Mindanao Baptist Rural Life Development Centre, based in Kinuskusan, Bansalan Davao del Sur, the Philippines. He is a pioneer worker who introduced efforts for developing a number of regenerative technologies for small upland farmers. He, along with his team at Mindanao, have been experimenting with various SALT models since the 1980s.

## Founding of ICIMOD

ICIMOD is the first International Centre in the field of mountain area development. It was founded out of widespread recognition of the alarming environmental degradation of mountain habitats and the consequent increasing impoverishment of mountain communities. A coordinated and systematic effort on an international scale was deemed essential to design and implement more effective development responses based on an integrated approach to mountain development and mountain environmental management.

The establishment of the Centre is based upon an agreement between His Majesty's Government of Nepal and the United Nations Educational Scientific and Cultural Organisation (UNESCO) signed in 1981. The Centre was inaugurated by the Prime Minister 1984, with the support of its founding sponsors:

**HMG Nepal, the Government of Switzerland, the Federal Republic of Germany, and UNESCO.**

The Centre, located in Kathmandu, the capital of the Kingdom of Nepal, enjoys the status of an autonomous international organisation.

## Participating Countries of the Hindu Kush-Himalayan Region

- Nepal
- India
- Bhutan
- Bangladesh
- China
- Pakistan
- Myanmar
- Afghanistan

**INTERNATIONAL CENTRE FOR INTEGRATED MOUNTAIN DEVELOPMENT (ICIMOD)**

4/80 Jawalakhel, G.P.O. Box 3226, Kathmandu, Nepal

Telephone: 525313
Facsimile: (977-1)-524509

Telex: 2439 ICIMOD NP
Cable: ICIMOD NEPAL