SOIL AND WATER CONSERVATION

FOR SMALL FARM DEVELOPMENT IN THE TROPICS

by GERALD G. WILLIAMS

illustrated by Beth Williams

Peace Corps
Information Collection and Exchange

February 1994

R0084

Information Collection and Exchange

The Peace Corps Information Collection and Exchange (ICE), a unit of the Center for Field Assistance and Applied Research (the Center), makes available the strategies and technologies developed by Peace Corps Volunteers, their co-workers, and their counterparts to development organizations and workers who might find them useful. ICE works with Peace Corps technical and training specialists to identify and develop information of all kind to support Volunteers and overseas staff. ICE also collects and disseminates training guides, curricula, lesson plans, project reports, manuals, and other Peace Corps-generated materials developed in the field. Some materials are reprinted "as-is"; others provide a source of field-based information for the production of manuals or for research in particular program areas. Materials that you submit to ICE become part of the Peace Corps' larger contribution to development.

This publication was produced by Peace Corps Center for Field Assistance and Applied Research. It is distributed through the Center's Information Collection and Exchange unit. For further information about ICE materials (periodicals, books, videos, etc.,) and information services, or for additional copies of this manual, please contact ICE and refer to the ICE Catalog number that appears on the publication:

Peace Corps
Center for Field Assistance and Applied Research
Information Collection and Exchange
1111 20th Street, NW Room 1200
Washington, DC 20526

Tel: 202.692.2640
Fax: 202.692.2641

Abridged Dewey Decimal Classification (DDC) Number: 631.4

Share your experience!

Add your experience to the ICE Resource Center. Send your materials to us so that we can share them with other development workers. Your technical insights serve as the basis for the generation of ICE materials, reprints, and training materials. They also ensure that ICE is providing the most up-to-date innovative problem solving techniques and information available to you and your fellow development workers.

Soil and Water Conservation for
Small Farm Development
in the Tropics

Peace Corps
Information Collection and Exchange
February 2000
R0084

BACKGROUND AND ACKNOWLEDGEMENTS

Small farmers in developing countries often face problems with crop production because they are relegated to steep, difficult to farm areas. Many of these problems can be eased through farming practices that save their top soil and ensure an adequate supply of water for their crops. This manual should be helpful for all categories of agricultural extension Peace Corps Volunteers -- those without previous training in soil science as well as those with such background.

It provides easily grasped explanations of basic soil management principles relevant to Peace Corps activities in low input agricultural production projects. It seeks to equip the Peace Corps Volunteer with appropriate tools in the absence of more sophisticated alternatives. It also provides a consolidated and updated alternative to existing ICE materials, such as R0008, "Soils, Crops and Fertilizer Use" and R0062, "Soil Conservation Techniques for Hillside Farms." It is also useful as a technical resource for trainers.

We would like to thank the author, Dr. Gerald Williams, who volunteered a substantial amount of his own time and resources over the past two and a half years to produce this manual. With this manual he made a significant contribution to improve the lives of people in many parts of the world through environmentally sound farming practices, in which he believes very strongly, and to which he has dedicated his career. Dr. Williams, his wife Ella Florence Williams and several of their children spent considerable time and effort in creating this manual, and the they are commended for their effort

THE PURPOSE OF THIS BOOK

The primary audience for this manual is the Peace Crops generalist who will be working with small farmers of the humid and sub-humid tropics. Others who could benefit from it are Peace Corps trainers and agricultural specialists working among small subsistence-level farmers, especially those with sloping land. Program supervisors, program planners, extension workers and certain high school or university agriculture teachers will also find it helpful.

Soil and Water Conservation for Small Farm Development in the Tropics focuses on field work. It contains many specific methods and techniques to help small farmers conserve soil and water and to increase crop yields at the same time. It also contains a few vital concepts which give some understanding of the dynamics of erosion. These enable the volunteer to adapt techniques to individual field conditions.

Field workers in the tropics find that results from studies or field research in temperate climates often do not transfer to the tropics. Therefore, the information given here reflects the latest scientific and technological findings in tropica1 soil and water conservation. Recommendations are largely based on farm research, testing and demonstrations in Third World tropical countries plus the recommendations of experienced agriculturists there.

The information concentrates on conditions in the humid and sub-humid regions, since the arid and semi-arid regions present separate and unique conditions of their own.

The most lasting successes come from one farmer teaching another. Therefore, this manual encourages using small farms and fields as classrooms, and urges training farmers to teach their neighbors (i.e., to "show and tell"), using their own farm demonstrations, their own methods right on their own fields, their own problems and successes. These farms might be called ~ demonstration farms.

The farmer's first priorities must be to increase food production and to reduce risk of crop failure. Therefore, throughout this manual, I try to couple soil and water conservation with these primary farmer goals.

This manual will be used throughout the tropics of the world. Any recommendations made should be adapted to local conditions and needs. Even if you have little or no agriculture background, do not be discouraged. This book can help you! Much of it is written especially with you in mind.

- Don't let the first two chapters intimidate you. Stick with them! The first two chapters (The Soil--Sustainer of Life, and Soil Erosion by Water) give you basic concepts you need, and also the very latest findings. With them under your belt, you will be able to adapt conservation techniques to individual field conditions. The rest of the book gets you out in the field--and you will be glad you read those first two chapters.

- Take some time to look over the Table of Contents. Note the items covered. Check for useful information in the Appendix, which contains many valuable field techniques you will need. Appendix A teaches basic procedures. The Appendix also lists other resources, including audiovisuals you can order. The Bibliography lists valuable supplemental books which you may want to use along with those in your PC-ICE catalog.

- Nearly all field procedures come with detailed 'how to" directions and/or refer you to additional resources. Notice that many sketches clarify the methods as you go. You will find a number of basic procedures or guidelines in The Tool Kit (Appendix A).

A Request for Your Help

I'd like very much to hear any of your suggestions about this manual-- your special needs or other concerns. How can I improve it? Also, I would really appreciate knowing any different conservation or soil fertility improvement techniques which you see working successfully among small farmers in your location. Also special success stories you are finding. Thanks for your help.

Write to:

Gerald G. Williams
Route 7 Box 327-B
Florence, AL 35630 USA
Phone: (205) 757-8179

PREFACE

As the numbers of people on earth double and triple, the world's resources of food and water are becoming stressed beyond their limits. At least two essentials for life itself--our soil and our water--are in immediate serious danger. Can we remedy this, and still provide the urgent needs of the world's people?

Topsoil--the Source of Food for the World

Twenty centimeters more or less of topsoil covering the earth's crust produce the food which keeps us alive. This vulnerable topsoil is rapidly washing and blowing away. As more and more people need food, water, fuel and shelter, they destroy vegetative cover and decimate forests, escalating topsoil loss and water runoff.

Soil erosion is a silent creeping crisis we seldom hear about. Yet each year, 24 billion tons of topsoil is lost. Since 1950, the world has lost a great deal of the topsoil from its cropland. The FAO estimates that soil erosion probably will have caused a decline of 25% in agricultural production between 1975 and 2000. **Day by day, we have less topsoil to produce the food to feed more mouths!**

Water Resources

Our water resources are also suffering an alarming depletion. Some aquifers in many nations are only a few decades from exhaustion. Many rivers and streams are dwindling. Others continue to fill with silt. The deserts are spreading, with their grim toll in drought and starvation.

Most of this bleak picture comes from misuse, overuse, and lack of proper husbandry or conservation. However, the situation, while alarming, is not hopeless. In this manual we give you some feasible ways to help.

Why Do We Concentrate on the Small Tropical Farmer?

Failure to deal with the problems of the poor, small tropical farmer causes serious worldwide consequences. Small subsistence farmers are often pressured into farming poor quality land just to live. They eke out livings on steep slopes which are subject to excessive water runoff and soil erosion. They clear several millions of hectares of forested hillsides for farmland each year. Such land often soon becomes degraded and unfit for use.

Hundreds of millions of such farmers are living in desperate conditions. Their number escalates daily. By weight of numbers and the desperation of their plight, small subsistence farmers are major contributors to loss of topsoil and water quality. The numbers of them are so vast that much of the solution must come from them.

What Are the Special Problems of the Very Poor Farmer?

- Small subsistence farmers do not have the knowledge or the capital to profit from most advanced technologies. By and large the Green Revolution has passed them by.
- They cannot afford risk. They have little money and no source of credit. Starvation is often only a crop failure away. Therefore they are rightly distrustful of drastic change.
- They live in a world circumscribed protectively by tradition.

- They often live in distant, inaccessible places and therefore have trouble marketing crops.
- They have only simple hand tools, their own labor and that of their families.
- The very poor can only farm for survival; they often cannot consider the welfare of the soil or the water supply.
- They do not have the knowledge to better their lot and have little way to learn new methods on their own.

THE GOOD NEWS

Improved technologies developed in recent years can change the lives of subsistence farmers. These technologies are <u>appropriate</u>: they begin with farmers in their actual life situations. They use the simple tools of the farmers; they do not require mechanization or large-scale procedures. They call for little or no investment of capital. The techniques and concepts are simple, and build on the farmers' present knowledge and traditions. They are used by thousands of small farmers in Africa, Asia, and Latin America. They work!

The other good news is that <u>farmers learn from farmers</u>. A demonstration on one farm that greatly increases yields and conserves soil and water will motivate other farmers to copy. If these farmers are also successful, hundreds will be following the leader. Only a little yeast can leaven a whole loaf.

The "appropriate technologies" described in this manual can increase food crop production and conserve soil and water at the same time. The result can be <u>sustainable farming systems</u>, and enhanced health and welfare for millions of farm families.

TABLE OF CONTENTS

Acknowledgements ii

Preface iv

The Good News v

INTRODUCTION ix
- Topsoil--Source of Food for the World ix
- Water Resources ix
- Why Do We Concentrate on the Small Tropical Farmer'? ix
- What Are the Special Problems of the Very Poor Farmer'? x
- The Good News x

CHAPTER 1 THE SOIL: SUSTAINER OF LIFE 1
2 SOIL EROSION BY WATER 45
3 COMBATING RMNFALL SPLASH EROSION WHILE INCREASING CROP YIELDS 79
4 CHANGING THE LANDSCAPE TO CONSERVE SOIL AND WATER 109
5 AGROFORESTRY SUSTAINABLE FARM SYSTEMS 175
6 HELPING FARMERS ON VERY STEEP SLOPES: A SPECIAL NEED 231
7 SOIL EROSION BY WIND 265

APPENDIX 279

DETAILED CHAPTER CONTENTS

1 THE SOIL: SUSTAINER OF LIFE 1
- The Soil: Its Formation and Characteristics 1
  - What Are Some of the Functions of Soil'? 1
  - A Look at a Soil Profile 2
  - The Formation of Soil 6
    - How Long Does Topsoil Take to Form? 6
  - Major Factors Affecting Soil Formation 6
    - How Are Soils Formed'? 6
    - What Factors Affect Soil Formation'? 8
    - Which Soil-Forming Factors Can Farmers Influence'? 11

The Make-Up of the Soil 12
Soil Texture 12
What Is Soil Texture? What Determines Soil Texture Types? 12
How Are Soils Classified According to Texture? 12
Why Is Soil Texture Important to the Farmer? 12
Soil Particles--the Three Components of Soil Texture 14
How to Identify Sand, Silt, and Clay Particles 14
Characteristics of Sand, Silt, and Clay Particles 15
Recognizing Soil Texture on the Farm 16
More about Clays 20
Temperate and Tropical Clays 20
Classification of Clays in the Tropics 20
How to Deal with Clay Soils 21
Acidity in Tropical Soils 22
Soil Acidity and the pH Scale 22
Plant Growth Problems of Acid Soils 23
How to Deal with Toxicities and Deficiencies of Tropical Acid Soils 23
Soil Organic Matter: A Blessing for the Small Tropical Farmer 24
How Does Organic Matter Form'? 24
Humus 25
What Is Humus? How Is It Formed'? 25
What Is the Importance of Humus'? 25
Organic Matter in Soils in the Tropics, Compared to
Soils in the Temperate Zones 26
Why Should Much Plant Material be Returned to the Soil? 26
How to Obtain and Keep High Levels of Organic
Matter in Fields 27
Some Soil, Water, and Plant Relationships 28
Plant Nutrient Requirements and Soil Fertility 28
The Sixteen Chemical Elements Essential to Plant Growth 28
Why Is Good Soil Fertility a Key to Optimum Plant Growth'? 29
What Plant Nutrients Are Often Deficient in Soils in the Tropics'? 29
How Much Fertilizer Is Needed'? 29
How to Help Farmers with Soil Fertility Needs 35
Soil Testing 35
Where Will the Soil Sample Be Analyzed'? 35
When Should Soil Samples Be Taken'? 36
How to Take a Representative Soil Sample from a Field 36
Contents of Organic and Commercial Fertilizers 38
Other Plant-Soil-Water Relationships 39
Plant Processes Important to Plant Life and Growth 39
Soil Moisture--Its Relationship to Plant Life and Growth 39
Field Capacity 39

Available Soil Moisture 40
What Variables Affect Plants' Moisture Needs'? 41
Average Daily Temperature, Light, Humidity: Their Effect on Plant Growth 41
Ambient Temperature 41
Soil Temperature 42
Light 42
Humidity 43

CHAPTER 2 SOIL EROSION BY WATER 45

How Does Soil Erosion Work? Can the Farmer Prevent It'? 45
Characteristics of Soil Erosion By Water 45
Types of Erosion by Water 45
Raindrop Splash Erosion 47
Rill Erosion 47
Gully Erosion 47
Stream Bank Erosion 47
The Universal Soil Loss Equation 49
This Is the Universal Soil Loss Equation 49
A Look at these Six Factors which Affect Erosion 50
Erodibiity of the Soil 50
Rainfall Intensity and Amount 51
Percent of Slope--Steepness of Slope 51
Length of Slope 56
Land Management Practices 56
Crop Management Practices 56
A Soil Erosion Primer 57
Some Key Research Discoveries 57
The Effect of Raindrop Impact 57
A Classical Field Experiment 60
What Rainfall Splash Energy Does 60
The Effect of Raindrop Size 61
The Effect of Raindrop Terminal Velocity 63
What Is Terminal Velocity'? 63
Why Is Terminal Velocity Important'? 63
How Far Must Raindrops Fall to Reach
Terminal Velocity'? 63
Soil Surface Protection 63
Acceptable Erosion 64
Is Acceptable Erosion the Same for All Farms'? 64
What Is an Acceptable Amount of Erosion'? 64
How Can We Ensure Long-Term Soil Erosion Control'? 65
Water Runoff: Rainstorm Water Runoff from Land 65
What Do We Mean by Water Runoff? 65
What Does It Do'? 65
Factors Affecting Runoff 68
The Intensity and Duration of Storms 68
The Infiltration Rate of the Soil 68

The Water Holding Capacity of the Soil 70
The Slope of the Land 70
The Vegetation on the Land 70
The Farmer's Conservation Practices 70
What Should Be Done about Runoff Water'? 73
The Rainfall and the Rainfall Calendar 73
Why Do You Need to Know about Rainfall in Your Area'? 73
How to Make and Use a Rainfall Calendar 73
A SPECIAL WORD BEFORE YOU START CHAPTERS 3 AND 4 77
Motivating Small Farmers to Use Erosion Control Methods 77
Two Approaches to Reducing Soil Erosion and Water Runoff 77
One Approach: Changing Degree of Slope and Length of Slope--Changing the Physical Shape of the Land 78
A Second Approach: Dissipating Raindrop Splash Energy 78
Is Water Runoff Control Necessary with Either Approach[9] 78

CHAPTER 3 COMBATING RAINFALL SPLASH EROSION WHILE INCREASING CROP YIELDS (KEEPING THE SOIL COVERED TO PREVENT EROSION) 79

The Benefits of a Live or Dead Vegetative Cover on the Soil 79
Does Soil Cover Really Prevent Erosion Significantly'? 79
Good Ways to Protect the Soil with a Cover 79
Field Litter 80
How to Use Field Litter to the Maximum 80
Mulch 80
Mulch: What Is It'? 80
How to Make and Use Mulch 80
Minimum Tillage 83
What Is Minimum Tillage'? 83
Why Use Minimum Tillage'? 83
Is Minimum Tillage Feasible'? 83
In-Row Tillage: a Form of Minimum Tillage 86
What is In-Row Tillage'? 86
How to Establish In-Row Tillage 86
Special Advantages of In-Row Tillage 92
Cover Crops--Especially Green Manure Cover Crops 92
What Is a "Cover Crop"'? 92
What is a "Green Manure Cover Crop"'? 94
What Makes Legumes Special'? 94
Green Manure Cover Crops--A Boon to the Farmer 94
How to Choose a Good Green Manure Cover Crop 96
How to Locate Suitable Species of Green Manure Cover Crops 97
How to Plant and Grow Green Manure Cover Crops 100
Crop Combinations and Planting Times 100

Do Green Manure Crops Reduce the Land Area
Available for Food Crops'? 100
Good Ways to Utilize the Green Manure Cover Crop 101
Compost 101
What Is Compost'? 101
How to Make Compost 101
Other Types of Compost Piles 104
Good Crop Growing Practices: A Summary 104
Develop High Soil Fertility and Keep the Soil Covered 104
How to Increase Fertility 106
Use Intercropping 106
Make a Rainfall Calendar and Apply It 107

CHAPTER 4 CHANGING THE LANDSCAPE TO CONSERVE WATER AND SOIL 109

The Key Concept of this Approach 109
What Physical Changes to Land Surface Help Conserve Water and Soil'? 109
Farm Drainage Control Ditches 110
Diversion Drainage Ditches 110
Supplementary Contour Drainage Ditches 110
The Main Control Drainage Ditch (Exit Drainage Ditch) 110
How to Control Drainage Ditch Flow 112
Where Should the Drainage Water from the Field Go'? 114
Contour Ditches for Barriers 114
How to Construct Contour Ditches (Catchment Ditches) 114
Advantages of Contour Ditches 116
Disadvantages of Contour Ditches 120
Contour Barriers 120
Dead Barriers 120
Dead Barriers of Logs, Limbs, Bamboo Poles, Other Poles 120
Earth Banks for Barriers 122
Ways to Use Earth Banks 122
Rock Walls 122
Advantages of Rock Walls 122
Solid Rock Walls 125
Special Advantages of Solid Rock Walls 125
Special Disadvantages of Solid Rock Walls 125
Loosely Constructed Stone Walls or Barriers 126
Special Advantages of Loosely
Constructed Stone Barriers 126
Disadvantages or Special Considerations 126
How to Construct a Loose Rock Barrier 126
Low Row Ridges and Row Beds Used on the
Contour as Mini-Barriers 129
Advantages 129
Disadvantages 129

Live Barriers 130
How to Establish Suitable Live Barriers 130
Types of Contour Live Barriers 131
Legume Trees and Shrubs as Barriers 131
Advantages of Legume Trees and Shrubs 131
Disadvantages of Legume Trees and Shrubs 132
How to Guard Against Diseases or Insects of Legume Trees 132
Is *Leucaena leucocephala* still recommended for planting'? 132
How to Construct Live Barriers of Leguminous Trees 135
How to Maintain Tree or Hedge Rows 141
Grass Barriers 141
Unpalatable Grasses 141
Vetiver Grass *(Vetiveria zizanioides)* 143
How to Start a Vetiver Grass Barrier 143
Palatable Grasses 143
Advantages of Grass Barriers 143
Disadvantages of Grass Barriers 144
How to Establish Palatable Grasses as Live Barriers 144
Contour Bench Terraces 148
What Are Bench Terraces'? 148
Types of Bench Terraces 148
Continuous Bench Terraces 148
Advantages of Continuous Bench Terraces 148
Disadvantages of Continuous Bench Terraces 149
The Continuous Standard Bench Terrace 151
When and How to Use the Standard Bench Terrace 151
The Inward Sloping Bench Terrace 151
The Outward Sloping Bench Terrace 151
The Irrigation Bench Terrace 154
Discontinuous (Intermittent) Bench Terraces 154
Orchard Terraces 154
Advantages of Orchard Bench Terraces 158
Disadvantages of Orchard Bench Terraces 158
Individual Terraces (Bench Platform Terraces) with Contour Ditches 158
Advantages of Individual Platform Terraces 158
Disadvantages of Individual Platform Terraces 159
How to Plan and Construct Bench Terraces 159
Precautions When Constructing Bench Terraces 159
Continuous Bench Terraces--Planning and Construction 163
Inverse Continuous Terraces--Planning and Construction 170

Individual (Platform) Terraces-- Planning and Construction 173

CHAPTER 5 AGROFORESTRY: SUSTAINABLE FARMING SYSTEMS.... 175
The Need for Agroforestry: an Overview 175
Two Different Concepts of Tree Growing 175
Tree Planting Which Failed: What Was Wrong? 175
Social Forestry--Forestry to Help the Small, Poor Farmer or Villager 176
Why Is Deforestation Becoming a Serious World-Wide Concern'? 176
Why is Deforestation Increasing so Drastically[9] 177
What is 'Slash and Burn" or "Bush Fallow" Farming'? 177
Why Is Bush Fallow (Slash and Burn) Breaking Down'? 178
What Can We Offer as a Replacement'? 178
What You Can Do as a Peace Corps Volunteer 178
Agroforestry What It Is and What It Does 179
What Is Agroforestry? 179
The Benefits of Trees in Agroforestry Systems 179
Trees as Replenishers of the Land 179
Trees as Crops and Income for the Small Farmer 180
Systems of Tree Planting for the Small Farmer 183
How to Establish Agroforestry in Your Area 185
Requirements for Success with Agroforestry 185
How to Get Started 185
Desirable Types of Trees 187
Legume Trees 187
Multipurpose Trees 188
Fruit Trees in the Family Compound 188
Some Desirable Fruit Trees 188
Some Answers to Farmers' Concerns about Growing Trees 189
How to Grow Trees 189
Why Have a Community Agroforestry Seedling Nursery'? 196
How to Establish the Community Seedling Nursery 196
Alley Cropping 204
What Is Alley Cropping'? 204
Special Advantages of Alley Cropping 206
Disadvantages and Special Requirements of Alley Cropping 206
How to Establish Alley Cropping 206
Desirable Characteristics for Trees Used In Alley Cropping 211
Field Research Observations on Alley Cropping 213
Other Observations about Alley Cropping 214
Case Study: a Successful Agroforestry Program in Ghana 215

CHAPTER 6 HELPING SMALL FARMERS ON VERY STEEP SLOPES: A SPECIAL NEED 231
Appropriate Technology for Steep Slopes 231
How to Conserve Soil and Water 231
How to Keep and Increase Soil Fertility 236
Integrated Diversified Farming Systems for Steep Slopes 239
Combining Conservation Methods with Mixed Farming Systems 239
Brainstorming the Possibilities for Steep Slopes 239
Make Preliminary Evaluations 239
Consider and Analyze Various Possibilities 239
Grow Other Marketable Crops and Products 239
Grow Cool Season Crops 239
Grow More Tree Products 241
Encourage and Develop Cottage Industries 241
Raise More Animals 241
Ruminant Animals 241
Non-Ruminant Animals 243
Some Precautions 246
Ways to Develop Additional Markets for Animals 245
Investigate Using Irrigation 245
How Do You Get Water to the Farm'? 245
The SALT System: a Success Story 246
Setting Up the SALT System on Farms 248
Basic Requirements which the System Meets 248
Advantages of the SALT Method 249
Different Forms of the SALT Method 249
How to Install the SALT Method--Ten Steps 250
Make an A-Frame 250
Locate the Contour Lines 250
Prepare the Contour Lines 251
Plant Seeds of Nitrogen-Fixing Trees 251
Cultivate Alternate Strips 251
Plant Permanent Crops 251
Plant Short-Term Crops 253
Trim Nitrogen-Fixing Trees 253
Practice Crop Rotation 253
Build Green Terraces 253
More about SALT 253
A World Neighbors Case Study: The Guinope Program, an Integrated Development Program in Honduras 259
The Problem 259
Organization **in** Action 259
Methodology 260
The Technologies Used 260
Results 261

Problems •
Cost and Benefits 263
The Future of the Program 263
CHAPTER 7 SOIL EROSION BY WIND 265
What is Wind Erosion’? 265
How Serious Is Wind Erosion’? 265
How Have Farmers Helped Cause Wind Erosion’? 265
What Parts of the World Are Especially Susceptible’? 266
Under What Conditions Can You Find Wind Erosion’? 266
The Mechanics of Wind Erosion 267
Suspension
Salutation
Creep
Amounts of Soil Moved by the Wind Processes 270
What Factors Affect Wind Erosion’? 270
Wind Velocity 2’Aj
Soil Texture--Soil Structure 270
Smoothness of Soil Surface 271
Dryness of Soil 271
Amount of Vegetative Cover on the Soil 271
How to Fight Wind Erosion 271
Basic Recommendations to Farmers 271
How to Carry Out These Recommendations 271
Follow Good Land Use Practices 271
Develop and Keep Good Soil Structure 272
Leave a Rough Surface on the Plowed Field 272
Keep Vegetative Cover on the Soil Surface 273
Practice Water Conservation 274
Use Tree Windbreaks 275
How to Control Wind Erosion with Trees 275
Choose Suitable Tree Species 275
Consider Multipurpose Trees and Alley Cropping 275
In Summary: Use Excellent Land Husbandry 276
What are the Benefits from Growing Windbreaks’? 276
Learning from the Experience of Others 277
The Niger Experience 277
Experience from Egypt 277
Handling Problems in Establishing Windbreaks 277

APPENDIX
A Basic Tool Kit of Techniques for the Field 279
How to Measure Rainfall Intensity and Total Rainfall 279
How to Make a Simple Rain Gauge 279
How to Measure Steepness of Slope 280
How to Calculate Slope 280

How to Make the Measurements 280
How to Measure Slope with a Hand-Held Abney Level or Inclinometer 281
How to Measure Slope with a Carpenter's Level 281
How to Measure Slope with a String Level 282
How to Measure % Slope with an A-Frame which Has Been Calibrated 282
The A-Frame: How to Make It and Use It 283
How to Make a Simple A-Frame Field Level and Calibrate It 283
How to Find Contour Lines Using the A-Frame 284
How to Control Gullies 285
How to Plan Small Farm Fertility Programs if Soil Testing Labs and Commercial Fertilizer Are Not Available 286
How to Test Soil Acidity with a Quick Test on the Farm 286
How to Estimate Fertilizer Requirements without a Soil Test Laboratory 288
How to Supply Required Plant Nutrients from Compost, Manure, Mulch, Green Manure Cover. Crops, etc 288
Appropriate Composition of New, Wet Manure 289
How to Double Check Soil Fertility Status while Crops are Growing 289
Use Row Testing 290
Read Hunger Signs of Plants 290
Signs of Nutrient Deficiencies in Plants 291
Aids to Diagnosis: A Summary 293
How to Use the Hunger Signs 293
How to Inoculate Legume Seeds with *Rhizobium* Bacteria Before Planting 294
How to Treat Tree Seed Before Planting 294
How to Determine Suitable Soil and Water Conservation Needs and Technologies 295
How to Roughly Determine the Rainfall Infiltration Rates of Soils 295
How to Distinguish Usable Soil Depth 295
How to Choose the Appropriate Methods of Soil and Water Conservation for a Given Situation 296
A Guide to Choosing the Appropriate Soil and Water Technologies 297
B Sources of Technical Information and Support 301
C Sources of Seeds 304
D Sources for *Rhizobict* Inoculant 307
E Sources for Appropriate Technology, Simple Equipment 308
F Filmstrips, Slides and Other Helps 309
G Some Weight and Measure Equivalents or Conversions 311
H Examples of Alley Cropping Research 313

CHAPTER 1

THE SOIL - SUSTAINER OF LIFE

The economic strength and health of a nation depend to a great extent on how well its agriculture can feed and clothe its people. A nations welfare nearly always depends ultimately on its soil. Since rocks determine the nature of our soils; since the soils determine our food; and since the quality of food determines the health of our bodies, the entire structure rests on fertile soils.

Food has always been ‘fabricated soil fertility’. Great civilizations remained great only as long as their soils remained fertile. Dense human populations developed where fertile soils existed. Even today “life-lines” extend around the world to connect rich soils with large cities needing food.

The diversity of soils makes for wide variations in the yield and the quality of one crops growing on them. A **nation’s soils are the starting point for the formulation of any policy which leads to lasting agricultural development.**

THE SOIL: ITS FORMATION AND CHARACTERISTICS

A General Definition: Soil is the outer layer of the earth’s surface which supports life. It is made up of mineral particles, organic matter, water and air.

What Are Some of the Functions of Soil?

- Soil is a medium in which plant roots grow.

- A soil anchors plant roots so that the plant can withstand winds, water, heat, cold, and other forces which might tear it down.

- The soil is a storehouse of plant food. It must supply nutrients essential for normal plant growth: nitrogen, phosphorus, potassium, calcium, magnesium, sulfur; and certain trace elements such as iron, manganese, molybdenum, copper, zinc, and chlorine.

  In addition to the nutrients in the soil, of course, green leaf plants must have carbon dioxide, oxygen, water and sunshine for growth. These and other requirements are discussed later in this chapter.

- A healthy soil acts as a reservoir of water for thirsty plants. Each soil has a specific water holding capacity (the capacity to store and supply water).

- A well developed soil has a honeycomb of connected pore spaces (pore spaces, micro channels--cracks--crevices) which act as conduits for much rainwater to enter and pass through the soil to greater depths.

- The pore space and the external surface of the millions of small soil particles retain considerable useable water called available moisture.

- This same honeycomb of connected pore spaces provides <u>room for plant roots</u> to grow; keeps air around the roots so they have oxygen for their metabolic activities; and allows CO_2 from root respiration to escape to the soil surface and surrounding atmosphere.

- A healthy soil provides a home for many millions of different types of
  ~ Just as some of the microbes in the human digestive tract do, some of these microbes perform activities which are essential.

- Largely due to microbial activity, the topsoil is an <u>intensive transformer</u> of all the waste ~ it collects. Chemical elements are separated out of combinations and reunited into compounds. The cells and exudates from microbes cause the tiny soil particles to stick together to form more stable soil aggregates. Stable soil aggregates lead to good structure. As a result, more of the rain enters the soil body; less runoff occurs; and soil erosion is reduced.

  Fueled by the "heat" from decay of plant residues, the enhanced activity of the microbes purges the soil of unwanted organic compounds.

- The soil also contains many small animals such as earthworms, termites, insects, some helpful and some harmful.

A LOOK AT A SOIL PROFILE

Soil profiles are <u>vertical cross-sections of soils</u> in depth. You can see a soil profile on a steep exposed roadside bank or the side of a deep drainage ditch. You will see various layers of soil or rock, one on top of the other.

<u>The Topsoil</u>

The uppermost layer of soil, the <u>topsoil</u> is usually from 10 to 40 cm in depth. It is darker in color and more crumbly than the subsoil just beneath it. This crucial top layer contains most of the organic matter from vegetation. It has most of the plant nutrients, partly because <u>organic matter</u> is a much richer storehouse of nutrients than mineral particles alone. In addition, the organic matter helps. create the type of soil structure in the topsoil necessary for growing plant roots. Most of the <u>roots of</u> <u>food crops grow in the topsoil</u>.

Unfortunately (sometimes disastrously) the topsoil erodes more easily than the next layer of soil. It is especially vulnerable because of its location at the top where it is readily exposed to damage from rainfall splash and wind. The topsoil is the farmer's life insurance and wealth. It should be judiciously protected!

The Subsoil

The layer immediately below the topsoil is the subsoil. Subsoils usually have more clay than topsoils. Ideally, the subsoil holds considerable soil moisture and plant nutrients, though not nearly as much as the topsoil. It is usually more compact and contains less organic matter, which makes it less dark than the topsoil.

- Soils vary greatly in their depth of topsoil and subsoil. The depths and of the soil layers and their properties can vary greatly in different parts of the same fields.

- Some subsoils are relatively rich in plant nutrients, and others are very poor. Some hold much available moisture; some do not. Some are very acid, so much so that it restricts growth of many crops. Check the pH (pH measures soil acidity) of the farmer's subsoil as well as of the topsoil.

I recently visited a land resettlement project in humid tropical Asia where several thousand families had been moved to homestead the land. No one had realized that the topsoil would erode very quickly, or that the subsoil was very acid. The very thin topsoil had soon washed away, leaving a very acid subsoil. The acidity was so strong that most food crops could not grow. Since no one could obtain limestone to neutralize that soil, the entire project had failed within five or six years. I saw many abandoned villages. The thousands of resettled people had moved away. Such land should have remained in forest in the first place.

However, the majority of the soils in the tropics are good soils and produce excellent yields under the proper management. Careful checking wherever possible is important for good management and dependable results.

- As you learn more about soils, keep the subsoil in mind as (1) the future source of topsoil (2) the present soil moisture reserve storage and (3) hopefully some soil nutrient reserve storage. Subsoils which allow roots to grow deep add much to the farm's potential productivity. Not only the topsoil, but also the subsoil is very important.

The Soil Parent Material

Below the subsoil you may find crumbling or hard rock--sandstone, limestone, or other material--which is the soil parent material from which the soil has weathered. It remains potential additional soil for the distant future.

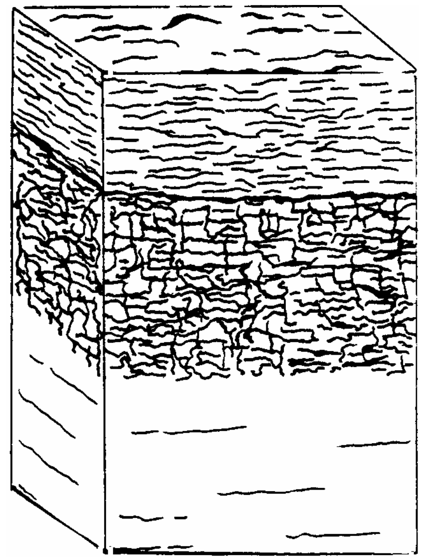


Figure 1-1. Soil profile. This sketch of a soil profile shows three layers which are, from top to bottom: topsoil, subsoil, and parent material.

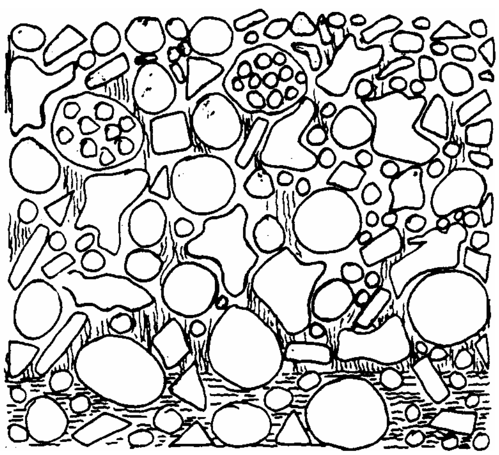


Figure 1-2. A healthy soil has good structure which has particles of mineral and organic matter interlaced with pore space for air and water and room for roots to grow. Small channels or passageways allow for passage of air and water from top to bottom.

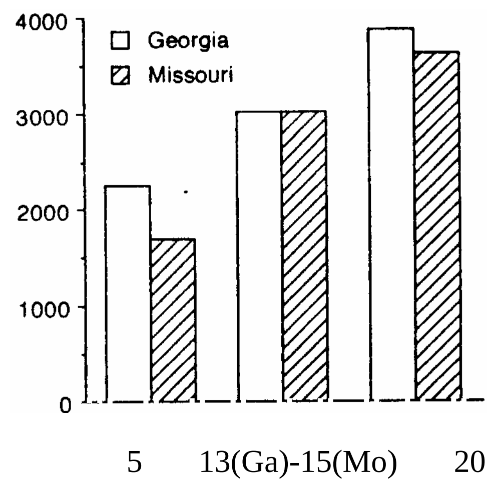


Figure 1-3. Field research results showing crop response (yield) to depth of topsoil. The results in the graph on the left come from work done recently in the tropics. Note here that crop yields go down as more soil is lost to erosion. The graph on the right gives results from work done many years ago in the United States in Georgia and Missouri. It shows that the deeper the topsoil is, the higher the yields. (Left graphs modified from work of El-Swaify et.al., 1982. Right graphs combined and modified from work of D. D. Smith et.al., 1948 and A. P. Barnett et al., 1956.)

How Long Does Topsoil Take to Form?

The conditions which help form topsoil vary widely; therefore, the formation time varies a great deal. Under natural conditions (i.e., undisturbed conditions) in a temperate climate, one inch (25 mm) of topsoil takes from several hundreds to several thousands of years to form.

When people break up and aerate the soil, and manage it in an excellent manner (using plenty of manures, crop residues, compost, green manure, and commercial fertilizers and preventing loss of any soil by erosion) less than 100 years may be required.

However, when people break un the soil and do not protect and replenish it, soil loss--not gain--takes place. Today, throughout the world such destructive practices are producing seriously degraded land in alarming quantities.

Conditions differ in the tropics, and, depending on rainfall and temperature, the net length of time for soil formation may be considerably shorter than for the temperate region.

MAJOR FACTORS AFFECTING SOIL FORMATION

How Are Soils Formed?

1. Weathering. Soils are formed in place by a weathering process from parent materials such as limestone, coral, sandstone, basalt, etc. At various places, different rocks are exposed to more or less attack by physical and chemical sources.

   Such rock-mineral weathering of parent material results from: (1) its (physical) disintegration into smaller particles like gravel, sand and silt. (2) its (chemical) decomposition to release compounds. Some elements are very soluble and chemically active. Others stay in place in different forms, or recombine. For instance, the element sodium is very soluble. It leaches out (washes out) of the profile, goes to the sea and accumulates there. Clay (also very active chemically) is a secondary residual mineral which is found in the topsoil and subsoil and stays there. (We will discuss the great importance of clays later.) Limestone is a recombination mineral which has stayed in place--in fact it is still a parent material.

   These physical and chemical processes, termed weathering, proceed at different rates depending upon the nature of the rock-mineral and the intensity of the forces of weathering.

soil profile where the rock is breaking up. At the very top of the bank is a very thin layer of

Figure 1-4. The man standing by the rock bank (parent material) is pointing to the zone in the subsoil. All of the topsoil has eroded, and only a thin layer of subsoil remains. The land has been abandoned. (Picture by author.)

2. Deposition of vegetation and animal life. In addition to forming from minerals as parent materials, soils form from deposits of vegetation and animal life laid down through the centuries. The amount varies. Some soils such as peat contain a very high proportion of organic material from vegetation.

3. Deposition of soils by water or wind. Certain soils have formed from the deposits of particles moved by streams and seas, or by winds. This gives rise to a mixture of minerals from different parent materials which have been moved from their original sites.

What Factors Affect Soil Formation?

Soils vary greatly from place to place: hundreds of sub-types of soils have formed due to the many variables involved in their formation. Soil formation is a dynamic and on-going process. At any one site layers develop in the soil profile as a result of six major agents:

1. The Characteristics of the Parent Materials

- Soils form from many types of rocks with different mineral content. Most of the soils of the world are underlain with limestone, shale and/or sandstone from which they were derived. In some of the mountainous regions of the world soils have formed from old lava (basalt). Some soils on ocean islands also are of volcanic origin. Others have been formed from coral deposits.

- The nature of the parent rock strongly affects the mineral content and acidity of the soil. Some. rocks like sandstone and granite, for example, make more acid soils than do limestone or volcanic basalt.

- Alluvial soils are soils which have been transported by water and deposited elsewhere. Such soils, usually composed of topsoil accumulated in layers of various depths, are usually very fertile. We know of the deep, rich alluvial soils in many river valleys and deltas--for example, the Mississippi Delta in the United States, the Nile Delta in Egypt and the Ganges Delta in India. Rich soils still yield profusely along the Nile and the Ganges rivers after at least five thousand years of crop production, primarily because the soils are rejuvenated through periodic flooding, leaving rich topsoil deposits.

- Loess soils are formed from soil particles which have been blown to new locations by the wind and have been deposited to varying depths. Loess soils are often silty, sometimes fairly fertile, but highly erodible. Many soils along the Missouri-Mississippi River Bluffs originated in this manner.

- The many climates in the world--the variations in temperature, rainfall, wind and humidity--make or unmake the many kinds of soils. Rainfall and temperature, especially, affect soil formation.

- Climate and Weathering

  The higher the temperature and the rainfall, the more rapid and complete the weathering process. (You will find the most weathered soils near the equator.)

- At higher temperatures, chemical and biological processes accelerate. The speed of chemical reactions doubles for every 10^0C rise in temperature.

- The <u>more rainfall</u>, the <u>more leaching</u> occurs and the more weathered the soil becomes. Leaching washes deeper into the soil profile many nutrients not held by the soil.

- This all means that a soil from the same parent material and of the same chronological age is more weathered (i.e., more 'mature") if located in the high rainfall tropics than, say, in the U. S. or Europe.

- <u>Climate and its effect on vegetation</u>.

  Temperature and rainfall also determine what vegetation, and how much of it, will grow. This in turn affects the amount and type of organic matter in the soil, and the soil fertility.

  For example, in those humid regions where rainfall exceeds evaporation, tree growth is favored. Where evaporation exceeds rainfall, grasslands are the dominant vegetation. Thus forests grow on soils where most of the soluble nutrient elements have been leached from the root zone, or carried by water to the sea. In grasslands enough rain falls to dissolve some of the minerals; but not enough has fallen to leach the nutrient elements from the soil profiles. Thus <u>forest solid</u> are <u>acid,</u> while <u>grasslands</u> are <u>neutral or alkaline</u>.

3. <u>Time</u>

Soils change over time. The weathering process takes hundreds to thousands of years. Soils vary in age tremendously. For example, a river valley might have thousands of hectares with young, very recently deposited alluvial loamy topsoil only 500 years old and several meters deep.

Underneath this might be long-weathered soil many thousand years old. The nearby hillside soils might also have been weathered for thousands of years.

<u>Topography</u>

The regional and local topography strongly influences soil formation.

- The elevation and slope of the land affects the temperature. High elevation or exposure to shade from high mountains will lower temperatures, which will lower the rate of soil weathering and the amount of vegetation produced for organic matter.

- The micro-climate on one side of the mountain or steep hill can be quite different from that on the other. The amount and intensity of sunshine, rainfall, and the prevailing winds can be very different on opposite sides of a mountain. One side may have plentiful rainfall, and the other side suffer from drought. In the tropics on high hilly land near the ocean, land on the ocean sides of hills may experience intense frequent rains, and the inland side may receive very little rainfall. On different parts of an island as small as Puerto Rico a person will find both rain forest and arid conditions.

For example, in the United States: Compare the temperature, rainfall and vegetation along the west coast of California to the desert conditions on the eastern side of the Sierra Nevada Range (in Nevada and Arizona) where the lands are entirely cut off from the ocean breezes and moisture.

- Soil formation on the sunny, warmer south slope of a hill is faster and more complete than on the north side of the same hill.

- Some minimal erosion occurs over the years under natural conditions on hillsides. However, if vegetation covers the hillsides, good soils form and accumulate.

- Because of the slope, hillside soils are usually well drained. Poor drainage may exist in depressions and pockets in the lowlands, resulting in limitation of plant growth due to inadequate air space in the pores of the soil. In the tropics the well-drained soils (yellows, orange and reds) are usually found on slopes of rolling land, and the grey and some black soils in the poorly drained areas.

5. Vegetation: Different Types of Trees. Shrubs. Grasses. etc.

The soil reflects the kind of vegetation which has grown on it over the years. In the natural environment, much of the vegetation returns to the earth and decomposes to become part of the organic matter in the topsoil.

- Soils formed under grassland and less rainfall will differ from soils formed under forests and higher rainfall. Even within forests, different varieties of trees may help produce different soils.

- Forest soils have accumulations of leaves and litter on their surface. Microbial decay produces strong acids which dissolve nutrient elements from the minerals more completely, leaving silicate clays and oxides of iron and aluminum.

- Grasslands accumulate residues at considerable depth. This is due to the penetration of their fibrous root systems (which go deep, spread out and later decompose) as well as to the organic matter from the tops. Even so, the acids released by microbial growth enhance the breakdown of nutrient-containing minerals.

6 Land and Crop Management by the Farmer

The present soil fertility, soil structure, and topsoil depth of a particular farmer's field depend to a great extent on the answers to such questions as:

- Is the topsoil eroded or still intact?

- What farming practices does the farmer use? What practices have the farmer's ancestors followed? Have they terraced the land or farmed it on the contour?

- Have they rotated the crops? What kinds of crops have they grown and what fertilizers, if any, did they use?

- Especially, have they used 1~.gum~ in their crop rotation? (See later chapters for information on legumes as producers of nitrogen.)

Which Soil-Forming Factors Can Farmers Influence?

Farmers can influence mainly the vegetation and the land management. However, these two factors produce far-reaching effects. Later we shall examine the disastrous land losses resulting from deforestation, continuous farming of the land by slash and burn methods without adequate fallow (resting) time, and other soil-depleting practices.

On the other hand, farmers can benefit the soil amazingly with good land and crop practices. Farmers can not only preserve the topsoil that is there, but actually make it much better! Improved practices can even greatly shorten the time to form new topsoil. This is vital, because the topsoil is the key to future food needs of the farmer and his family.

THE MAKE-UP OF THE SOIL

A healthy topsoil will usually consist by volume of about 50% pore space (which contains air and water). The remaining space will be filled with soil particles of mineral materials and organic matter (ordinarily, about 1% to 4% or 5% organic matter and 45% to 49% mineral particles). A peat soil or other organic soil, however, can be composed of as much as 30% to 50% organic matter).

SOIL TEXTURE

What is Soil Texture? What Determines Different Soil Texture Types?

If you have ever collected sand in your shoes at the beach, and almost lost your shoes when they stuck in muddy clay, you already know how soils vary in texture. The term “soil texture’ describes the relative proportion of sand. silt. And clay particles in a soil.

Although the soil contains organic matter, air and water, scientists do not consider these when classifying soils according to texture. They consider only proportions of the sand, silt, and clay particles in any given soil.

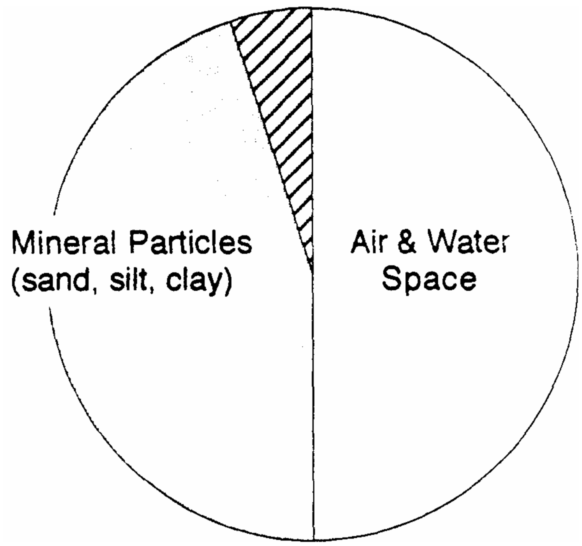
Why is Soil Texture Important to the Farmer?

- The texture of the soil greatly affects the soil in many of its relationships to plants and to water: how much water it retains; how well water drains from it; how fertile the soil is; how easily the soil can be tilled; what crops can be produced; how large the crop yield is; how susceptible the soil is to erosion.

- Soil texture tends to change with depth. Usually a ~iah~i1 or deeper soil will have a higher proportion of clay than the topsoil. Note that soil textures can vary in different locations in a single field. Farmers need to be aware of this when they are dealing with soil and crop management.

How Are Soils Classified According to Texture?

Soils are usually classified into three main types: sandy, loamy, and clayey. There are many sub-classes, but for your farmers' needs, being able to recognize the three general classes may often be enough.



Basic Components of Soil

Figure 1-5. Basic components of soil. The volume of a very good topsoil will usually consist of about 50% air, water, and space; 45% mineral matter; and 5% organic matter.

Table 1-1 Textural Classes Of Soil**

SANDY SOILS*

Sands (CT)
Loamy sands (CT)

LOAMY SOILS*

Sandy loams (CT)
Fine sandy loam (CT)
Very fine sandy loam (MT)
Loam (MT)
Silt loam (MT)
Silt (MT)
Clay Loam (FT)
Sandy Clay loam (FT)
Silty Clay loam (FT)

CLAYEY SOILS*

Sandy clays (FT)
Silty clays (FT)
Clays (FT)

***** "Coarse-textured" (CT), "medium-textured" (MT) and "fine-textured" (FT) are often used to describe soil texture. Coarse-textured and fine-textured soils are also called light" and "heavy" soils respectively. (Sand is light soil; clay is heavy.)

**This chart is from David Leonard, Soils. Crops. and Fertilizer Use. 4th ed., 1986, p.13. (USPC Reprint R0008)

Soil Particles: the Three Components of Soil Texture

1. How to Identify Sand. Silt. and Clay Particles

• The mineral particles in the soil vary tremendously in size, from clays which are the smallest, through silts, sands, which are the largest and most coarse. Scientists classify soil particles (sand, silt, clay) according to size, plus some chemical characteristics.

The following table shows the classification of particle sizes and the names used by most soil scientists in the United States. Sizes are measured by shaking soils through mesh screens, going from small to large. The finer clay particles are determined by the time it takes for them to settle out of the "muddy" water.

Name

Clays
Silt
Very fine sand
Fine sand
Medium sand
Coarse sand
Very coarse sand
Gravel
Size in millimeters

000. 0.002millimeters or less
0.00 0.002 to 0.05 millimeters
0.05 0.05 to 0.1 millimeters
0. 0.1 to 0.25 millimeters
0.25 to 0.5 millimeters
0. 0.5 to 1.0 millimeters
1. 0 to 2.0 millimeters
Above 2.0 millimeters

2. Characteristics of Sand. Silt and Clay Particles

Sand

- Sand will feel gritty when you hold moist soil in your hand and squeeze a bit of it. It ranges in size from 0.05 to 2.0 mm.
- Mixed particles of sand laid side by side might equal about 125 particles per inch. Very coarse sand particles side by side might only be 25 or 30 particles to the inch.
- Most sands are quartz (silicon dioxide). They have few plant nutrients and hold very little moisture for plant use.
- Sands in the soil help keep space available for air and water to circulate around plant roots.
- Sands help make the soil more workable when moist. Sands in the soil improve ease of tillage.

Silt

- Most of these very fine particles also are made of quartz. However, they would measure about 500 to more than 5,000 (or many more) particles to the inch if laid side by side.

- Since silt particles are so much smaller than sand, they have more total surface exposed for a given volume. This greater external surface gives them more chemical activity and water holding capacity than sand. Often some silt particles are coated with clay and therefore contain more plant nutrients than sand.

- Silts serve as mineral reserves for release of nutrients to the clay and organic fractions of the soil.

<u>Clays</u>

- Clay particles are very small. If laid side by side, 10,000 to 12,000 clay particles or many more would be required to measure an inch. Therefore the exposed surface area is very great.

o Clays can hold much more available soil moisture and nutrients than silt or sand.

- Clays are <u>active chemically</u>. They have <u>negative</u> **(-)** electrical ~ wh4rh attract and hold <u>positive electrical (+) charges</u> of plant nutrients as potassium K+, calcium Ca++, magnesium Mg++ and many others. Each type of clay has a certain holding (storage) capacity for positively charged plant nutrients, called <u>cation (+) exchange capacity</u>.

- Soils which formed under intensive weathering contain clays with fewer negative charges. This strongly affects their management.

- In addition to the negative charges, <u>some tropical clays</u> will also have some few positively charged (+) sites. These clays therefore also <u>negative ion fertilizers</u> such as nitrate nitrogen **(-).**

- Because clays hold much of the plus (+) charged nutrients, and some tropical clays also hold a little of negative **(-)** charged plant food, they are truly <u>special soil particles.</u>. They attract and <u>hold many plant nutrients</u> and <u>keep them from washing</u> (leaching) below the plant root zone.

- Heavy clay soils are difficult to plow. The moisture content has to be just right. (We have all seen the stickiness of modeling clay and its ability to dry hard.) Most farmers prefer for clay soils to have a certain percent of sand in them to make them easier to till.

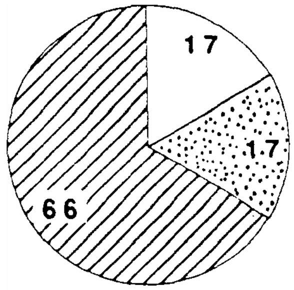
3. <u>Recognizing Soil Texture on the Farm</u>

Often the farmer may only need to recognize his soil as being mostly sand, loam, or clay. However, the graphs and tables on the next two pages will help you identify these more specifically. Take your notes to the field with you and practice determining soil types in various locations.

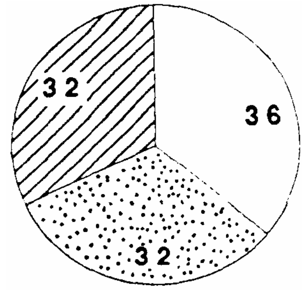
SAND

SILT

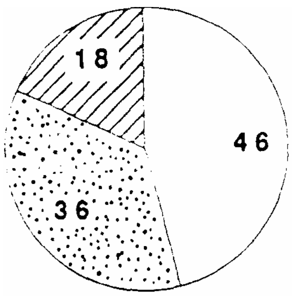
CLAY

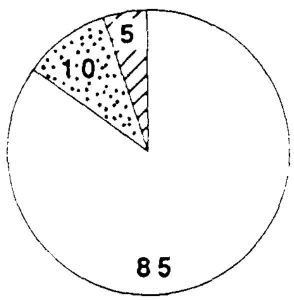


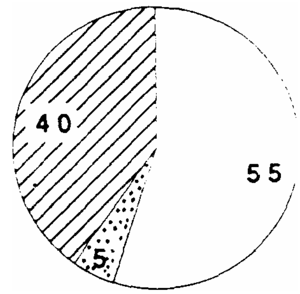
CLAY



CLAY LOAM



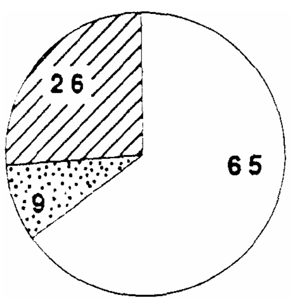


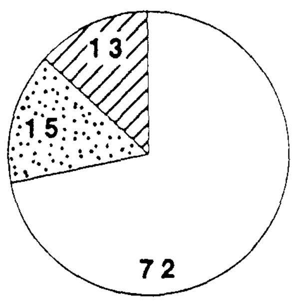


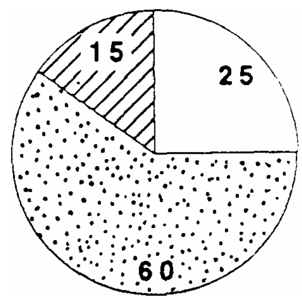
SANDY CLAY

LOAM

LOAMY SAND







SANDY CLAY LOAM

SANDY LOAM

SILT LOAM

Figure 1-6. Names of soil textures according to % clay, silt, and sand. The pie graphs give you the percent of the clay, silt and sand in some of the primary soils you may encounter. The numbers you see are approximate. For example, a sandy soil needs to have a large amount of sand to be classified “sandy”, whereas a much smaller percentage of clay gives a soil “clay” characteristics. Compare a clay loam to a sandy loam on these pie charts.

Table 1-3 Determinin2 Soil Texture in the Field*

SOIL TYPE	Visual Appearance	Squeeze test	Feel When Moist**
SAND	Loose, single-grained	When dry and squeezed, it falls apart when released. If wet, it crumbles readily when touched.	Gritty
SANDY LOAM	Loose	When dry and squeezed, it falls apart easily when released. If wet, it forms a cast that crumbles without careful handling.	Gritty
LOAM	Few clods	When dry and squeezed, it forms a cast that needs careful handling, If wet, the cast can be freely handled without breaking.	A bit gritty but slightly putty-like (plastic)
SILT LOAM	Cloddy, but clods are easily broken	Same as above.	Only slightly plastic or gritty; feels like talcum powder.
CLAY LOAM	Cloddy and lumpy when dry	When wet and squeezed, it forms a cast that holds together under heavy handling.	Plastic; forms a ribbon when rubbed between forefinger and thumb, but it breaks easily.
CLAY	Hard lumps or clods when dry.	The wet cast can be tossed and caught without breaking.	Very plastic and sticky; forms a ribbon easily.

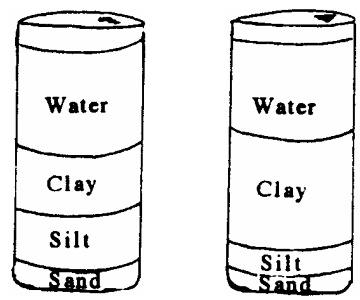
***** Leonard *ibid* p. 15.

****** If dry, add water drop by drop, knead the soil to break down all clumps until soil feels like moist putty. If too wet, add dry soil to soak up the water.

Clay
Silt

Sand

A



B **C**

Figure 1-7. Sketch of a simple method to approximate the percent of sand, silt, and clay in a given soil sample. Take a glass jar or bottle and fill it about 1/3 full of soil from a representative soil sample. Fill the vessel with water. After securing the lid, mix the soil and water thoroughly by continuing to reverse the ends of the jar. Continue this for about 5 minutes. Set the sample on a level shelf or table. Do not move it for 24 hours.

You will find that the sand will settle to the bottom, the silt will be next, and the clay will be on top. What might ‘soil A” be called, according to the pie graphs? Would you agree that “A” could be a sandy loam? Soil “C” a clay? How would you classify soil “B”?

MORE ABOUT CLAYS

Clay particles, the "magicians" of the soils, are also the plant food-plant nutrient bankers. They keep plant nutrients in storage until plant roots withdraw them. They are chemically active. Since they are so tiny, their outside surfaces add up to a tremendous total surface per unit volume of soil. One cubic centimeter of clay particles can have at least one square meter of total surface to be used for plant nutrient and moisture storage!

Clays are vital, since they, and organic matter, are the chief mechanisms in the soil £~r holding most plant nutrients. They prevent leaching of positively charged plant nutrients. Without clays and organic matter, plant nutrients would wash right through the soil.

Temperate and Tropical Clays

THC terminology "temperate clays" and "tropical clays" may be confusing to you. Some "temperate clays", which are the clays of Europe and the United States, occur also in the tropics. They are found only in the lower rainfall, less weathered soils of the tropics. More common in the tropics are the "tropical clays". These are the more weathered clays, found only in the more weathered soils of the tropics. Temperate and tropical clays differ both in some characteristics and in the degree of weathering of the soil which they help comprise.

We know much more about temperate climate clays than about tropical clays. Only recently have many scientists have begun to seriously study tropical highly weathered clays. They find that these are more complex and variable than the temperate climate clays.

Classification of Clays in the Tropics

1. The Layer Silicate System Clays

- These are clay soils typical of the temperate zones. They also occur in younger soils in the tropics. They are the younger type, less weathered clays. These clays have strong negative charges. That is, they attract and hold captions (positive plant food ions) such as Calcium Ca (++), Potassium I **(+),** Ammonium N (++++), Magnesium Mg **(++),** etc. They do not normally attract and hold significant nitrate **(-)** or other negatively charged plant nutrients.

- Most of these layer silicate system clays not only have a high capacity to attract and hold positive charged plant nutrients but are also able to release them for plants to use when needed. They are the best clays of the tropics, with the most nutrient storage capacity.

- These tropical clays are very different. The entire clay particles consist of iron or aluminum oxides or allophone (hydrous silicate of aluminum, a gel-like amorphous material). The acidity of the soil strongly influences them.

- They vary in their capacity to hold positive (+) charged plant nutrients, They may also attract and hold some negative ions such as nitrate **(-).**

- These are the oldest and most weathered clays of the tropics, and the least desirable. However, they can still be productive under the right management. An example is growing rubber trees on rather acid soils.

3. Oxide-Coated Layer Silicate Systems

- The majority of tropical soils may fit in this category, which is intermediate between the two above. These clays have (1) layer silicate systems and (2) layers of silicate platelets which are partially covered with oxide chemicals. Very thin films of iron and aluminum oxide gels may be attached to the silicate layers or between the silicate lattice layers. The silicate layers have a negative **(-)** charge, and the oxide gel coating under acid conditions also has a negative charge **(-),** but may have some (+) positive charges in addition, as indicated above.

- The anion exchange capacity of some of the oxides runs about half as much as the cation exchange capacity. (Anions are negatively charged chemical ions; cations are positively charged ions.) In other words, some nitrate **(-)** fertilizer and other negative charged nutrients can be captured by some of these clays, as well as positively charged nutrients such as potassium (+) fertilizer.

How to Deal with Clay Soils

- Most clay soils hold nutrients, but in the tropics some soils may not hold enough. Sometimes soils, even clay soils, particularly the old weathered clays, need a lot of enrichment. It is very important to add organic matter to them in quantity. Also keep in mind that small farms on hillsides often have shallow soils which also need enrichment. Therefore you will want to encourage building up organic matter in their soils. Also, if a soil testing laboratory is available, stress soil testing to determine which nutrients are low.

  If a soil testing laboratory is not available, you can at least test for soil acidity yourself. See the Tool Kit in the Appendix for sources of materials to test soil acidity.

- Keen as much organic matter as possible in all soils, including the clay soils. This will help improve soil structure and greatly increase plant nutrients.

ACID1TY IN TROPICAL SOILS

Some of the soils in the tropics in their natural state are acid. The majority of the cultivated soils, however, are not strongly acid. Early farmers and ranchers chose the better soils free of serious acid problems. Nowadays, population pressures are forcing more and more people to farm marginal lands, some of which may have medium acid to strongly acid soils.

Soil Acidity and the pH Scale

In rating the acidity of a soil, we use a soil acidity scale called the pH Scale. In it, pH **7** is neutral, below pH 7 is acid, and above pH 7 is alkaline. The scale is a logarithmic function (not a straight line relationship if plotted on regular graph paper). In other words, a pH of 4 is 10 times more acid than pH 5 and 100 times more acid than pH 6. A pH 9 is 10 times more alkaline than pH 8 and 100 times more alkaline than pH 7.

The more acid soils are usually found in the heavier rainfall areas and the more alkaline soils in the arid and semi-arid regions. A large percentage of the soils of the tropics have a pH 6 or below. By and large, tropical Asia and Africa apparently have less hectares of acid soils than tropical America. Even so, keep in mind that Latin America and Asia have developed successful, sustained soil management systems in many regions. One indication of their success is that these countries have sustained increases in per-capita food production in the tropics.

Table 1-4, Soil Acidity Values, The pH of Soils

pH Value	Degree
8.2 - 8.6	Strongly Alkaline
7.5 - 8.2	Medium Alkaline
7.0 - 7.5	Slightly Alkaline
7.0	Neutral
7.0 - 6.4	Slightly Acid
6.4 - 5.8	Moderately Acid
5.8 - 5.2	Medium Acid
5.2 - 4.7	Strongly Acid
4.7 - 3.8	Very Strongly Acid

***** Modified from H. B. Sprague, PC - ICE - FC 029, p.[15]

Plant Growth Problems of Acid Soils

Some major plant growth problems associated with very strongly acid, strongly acid, and certain medium acid soils are: (1) aluminum toxicity (2) manganese toxicity (3) calcium deficiency (4) magnesium deficiency. Any one of the four can limit plant growth. The very acid soils of the tropics often have high aluminum levels which are toxic to some food crop plants. Aluminum toxicity is often the major problem in low pH soils.

How to Deal with Toxicities and Deficiencies of Tropical Acid Soils

1. Aluminum toxicity decreases plant growth and actually harms the plant roots. The farmer can correct this by adding enough finely ground limestone to the topsoil of the field to bring the soil acidity up to pH 5.5 - 6.0 in the top 15 cm of soil. Another alternative is to grow the native plants which tolerate these acid conditions.

2. Manganese toxicity can occur in acid soils high in soluble manganese. Adding enough limestone to the soil to adjust the topsoil acidity to pH 5.5 - 6.0 in the top 15 cm of soil will take care of it.

3. To correct calcium deficiency in soils, the farmer can add finely ground limestone as a calcium fertilizer. Applying this as a general application to adjust the pH of the whole field may be impractical. Rather, the farmer can place the limestone along the side of the plant row, 10 cm to the side and buried 10 cm deep. This method of fertilizer application is called “side dressing.

4. Side dressing with a fertilizer like dolomite limestone, which contains both magnesium and calcium will correct magnesium deficiency in a soil as well as the calcium deficiency.

5. Finding crops which can handle high acidity is one partial solution to problems from acid soil. Certain crops (or even a different variety of a susceptible crop) can tolerate such soils. Many plants already growing in the tropics do much better with problems of soil acidity than crops such as soybeans which have been introduced from other regions.

Some crops which adapt well to many local acid soil conditions are: pineapple, coffee, tea, cassava, cowpeas, black beans, sweet potatoes, some sorghums, some varieties of rice and watermelons. Other plants with acid tolerance are Guinea grass *(Panicum maximum)*, Jaragua *(Hyparrhanea rufa)*, molasses grass *(Melinutif7ora)*, tropical kudzu *(Puera phaseolides)*, *Stylosanthes humilis*, and *Desmodium intortum*.

Many of the food crops above do not form a completely balanced diet, especially of complete proteins. However, certain combinations do (such as black beans plus unpolished rice). If forced to use acid land, the farmer may have to grow what will grow, and supplement the diet from other sources, possibly small animals such as rabbits, Guinea pigs, and poultry.

SOIL ORGANIC MATTER--A BLESSING FOR THE SMALL TROPICAL FARMER

Soil organic matter originates from plant materials and also some animal materials. Their breakdown performs vital functions for plant growth. The soil depends upon organic matter, often laid down naturally in surface litter, for continual replenishment and rebuilding the fertility and productivity of the soil. Keeping organic matter content high is an important consideration in sustaining the soil. Yet this is often sorely neglected by farmers.

How Does Soil Organic Matter Form?

The more plant residues (tree leaves, crop litter, etc.) left to accumulate on the topsoil or be worked into it, the more organic matter results (until it reaches an equilibrium with temperature and moisture). The rate of decomposition, however, also determines this. Rapid decomposition will use up organic matter faster.

1. Deposits of plant residues

- Forests tend to deposit more litter than crops do. Therefore, when farmers clear forest lands and put in crops, the land receives back much less plant material into its topsoil. If the quality of topsoil is to remain constant or to improve, farmers must add extra amounts of organic matter in addition to the food crop residues. (See succeeding chapters on compost, green manure crops, alley cropping, etc.)

2. Decomposition of plant residues

- Various micro-organisms decompose plant or animal residues on or in the soil, breaking them down to organic matter which becomes an integral part of the topsoil.

- Replacing forests with crops reduces the amount of plant residue returned to the soil. In addition, cultivating the land mixes more air, more oxygen, into the soil, which more than doubles the rate of organic matter decomposition and the breakdown of plant materials.

- Rates of decomposition are faster in warm, wet tropical regions than in dry, cool ones. The organic matter breaks down and burns up faster. Under the wet-dry season conditions of much of the tropics, organic decomposition slows down during the dry season, much as it slows in cold winter months in temperate climates. In the tropical areas with wet-dry season patterns, organic material decomposes about 1/4 to 1/2 as fast as it does in tropical moist areas with no dry season. The actual rate of reduction depends on the length of the dry season.

HUMUS

What is Humus? How is It Formed?

Humus is the temporary end product of organic matter decomposition, produced by microbial action in the soil. There is more life below the surface of a soil than there is above it! One tablespoonful of soil contains billions of microbes. Many different kinds exist, with each kind doubling every 20 minutes when its preferred food (plant residue) is supplied. Most microbes like proteins and sugars, while others get energy from celluloses. Few digest fats, waxes and lignin. These, along with dead microbial cell materials, become humus.

What is the Importance of Humus?

- Humus has almost miraculous powers in the soil. As organic matter decomposes, it releases various plant nutrients into the soil and the soil solution for plant consumption, including nitrogen and phosphorus. Humus packs powerful negative charges--more than 20 times as much as some of the old weathered tropical clays. It can therefore store much larger amounts of positive charged plant nutrients such as Calcium (Ca^{-++}), Potassium (K^+), Magnesium (Mg^{++}) and others, as well as certain trace elements, (Iron, Zinc, etc.)

  - It reacts with clays as well as with the cations.

Organic Matter in Soils in the Tropics. Compared to Soils in Temperate Zones

Under natural forest conditions, the percent of organic matter in the top 20-30 centimeters of soil is about the same in the tropics and in moderate climate soils--from 1% or 2% to 3% or 5%. Under continuous rainfall and warmer temperatures, more plant growth takes place and is left on the ground in the tropical forests. However, it also decomposes much faster in the tropics. The net results are that organic levels in natural forest soils may tend to be comparable for many moderate and tropical conditions.

Why Should Much Plant Material Be Returned to the Soil?

We cannot stress too much the urgency of maintaining a high level of organic matter content in the farmer's soil because:

1. High levels of organic matter increase plant nutrients in the soil and increase crop yields.

2. Organic matter greatly increases water holding capacity of sandy soils. More water is kept available for plants to use. More plant growth results.

3. High levels of organic matter supply most of the cation (+) exchange capacity for topsoils of highly weathered tropical clays and for sandy soils. That is, their negative (-) charges hold the (+) charged plant nutrients.

4. Organic matter also furnishes most of the nitrogen and sulfur and much of the phosphorus (which are not positively charged) where commercial fertilizers are not used.

5. Organic matter interacts with clays in a number of ways to improve the old, highly weathered tropical clay soils.

6. Organic matter improves the soil structure, which increases space for plant root growth and allows better aeration. It improves the tilt of the soil. (Tilt refers to the ease with which a soil can be cultivated. If the soil is crumbly, the plant roots penetrate it easily.)

7. In some soils, organic matter keeps much phosphate from being tied up ("fixed")--i.e., it keeps phosphate available for plants to use. It also helps keep many micronutrients available for crop roots to absorb.

8. In some soils, organic matter with its slower release schedule prevents leaching of nutrients. It differs from commercial nitrogen fertilizer which is released all at once when it receives the first rain. (Much leaching can occur with commercial nitrogen. Therefore, the farmer should apply split applications--two or more applications instead of one--of commercial fertilizer according the plant's expected growth rate and need.)

9. In most soils, by improving structure, organic matter increases the infiltration rate (the rate at which water enters the soil). This conserves rainwater and reduces the amount of runoff water during rainstorms, which **reduces soil erosion.**

How to Obtain and Keen High Levels of Organic Matter in Fields

1. Do not burn the fields to clear them for planting. In many parts of the world, farmers burn the grass plus stalks left after harvest. Sometimes thick smoke haze extends for miles. Burning weeds and post-harvest trash saves labor, but valuable organic material goes up in smoke!

2. Leave post-harvest trash, stems, leaves, etc. on the ground. This residue acts as a partial mulch, helps fight "raindrop splash" erosion and eventually becomes more soil organic matter.

3. Use as few tillage operations as possible. Avoid breaking un the soil or its cover. Begin to think about Minimum Tillage (discussed in Chapter 3).

- A single, very heavy rainstorm can wash away much of the organic matter from a bare, cultivated steep slope.

- Tilling the soil also increases the rate of oxidation (the rate of metabolism, the rate of burning up organic matter).

4. Keep a cover on the soil in every way possible.

- Protect the soil from "raindrop splash erosion" (more about this in the next chapter).

- Protect the soil from excessive heat. A hot, bare, moist soil burns up organic matter quickly. The sunshine raises soil temperatures excessively and increases microorganisms' activity to very high rates. A lot more organic matter burns up.

- Mulch the soil. A mulch shades the soil; usually feeds it (depending on the material in the mulch); and helps protect it from erosion.

- Keep the soil covered with vegetation.(See Chapter 3.)

SOME SOIL, WATER AND PLANT RELATIONSHIPS

Crops and soils work together along with air ($C0_2$), sunlight and water in a unique kind of "factory". The soils provide nutrients and water to the plants; sunlight supplies the energy; the air supplies the $C0_2$ the plants use these "raw materials" to manufacture products (the crops). The crops then give back benefits of organic matter to the soil.

The effective functioning of this unique interacting system depends upon a number of factors. For photosynthesis and other processes, plants must have sunlight; carbon dioxide from the air; water and air in the soil for the roots; appropriate temperatures for growth; and sixteen essential chemical elements.

PLANT NUTRIENT REQUIREMENTS AND SOIL FERTILITY

The Sixteen Chemical Elements Essential for Plant Growth

For optimum plant growth and crop yield, plants must have sixteen elements --plant nutrients--in sufficient amounts. Plants require some of the elements in only minute trace amounts. However, all of them must be present in the amount needed. If not, the plant does not grow normally, or may not grow at all.

Table 1-5. Chemical Elements Necessary for Plant Growth

Macronutrients

Carbon	C
Hydrogen	H
Oxygen	0
Nitrogen	N
Phosphorus	P
Potassium	K
Calcium	Ca
Magnesium	M
Sulfur	S

Micronutrients

Iron	Fe
Boron	B
Copper	Cu
Manganese	Mg
Zinc	Zn
Molybdenum	Mo
Chlorine	Cl

Plants require the first nine elements, the macronutrients, in relatively large amounts. They require the micronutrients, or trace elements, in minute trace amounts. Air and water supply carbon, hydrogen and oxygen to the plant. The rest of the elements come from the soil.

Why is Good Soil Fertility a Key to Optimum Plant Growth?

- Good soil fertility is one of the first stepping stones for successful small farm development. A highly fertile soil not only produces excellent yields, but also enhances soil and water conservation.

- Good soils produce abundant crops, with healthy root growth. This in turn helps keep the soil in good condition, and much potential organic matter is available. The higher the yields and the more lush the plant growth, the greater the amount of organic matter that can be left in the field after harvest time.

What Plant Nutrients Are Often Deficient in Soils in the Tropics?

Many soils in the tropics will have adequate supplies of all the required nutrients, except nitrogen. phosphorus. potassium and calcium.

If you look on commercial fertilizer bags in developed countries, you will see N- P- K written across the middle of the bag. Figures written under each letter give the percent of each element contained in the bag. For example, 10 - 10 - 10 under the letters N - P - K means that the material contains 10% nitrogen fertilizer, 10% phosphorus fertilizer and 10% potassium fertilizer. In some developing countries this may not be practiced.

How Much Fertilizer Is Needed?

What nutrients do different types of crops extract from the soil each year? What nutrients do they need at different yield levels?

The tables which follow give you some idea of fertilizer nutrients extracted by different crops at different production levels.

Table 1-6 Nutrient Removal by Major Tropical Crops

Crop	Part	Yield* (tons/ha)	N	P	K	Ca	Mg
Cereals							
Corn							
	Grain	1.0	25	6	15	3.0	2.0
	Stover**	1.5	15	3	18	4.5	3.0
	Total	2.5	40	9	33	7.5	5.0
	Grain	4.0	63	12	30	8.0	6.0
	Stover**	4.0	37	6	38	10.0	8.0
	Total	8.0	100	18	68	18.0	14.0
Rice							
	Grain	1.5	35	7	10	1.4	0.3
	Straw	1.5	7	1	18	2.6	2.2
	Total	3.0	42	8	28	4.0	2.5
	Grain	8.0	106	32	20	4.0	1.0
	Straw	8.0	35	5	70	24.0	13.0
	Total	16.0	141	37	90	28.0	14.0
Sorghum							
	Grain	1.0	20	0.9	4	4.0	2.4
	Straw	1.2	6	0.4	2	4.6	3.2
	Total	2.2	26	1.3	6	8.6	5.6
	Grain	8.0	135	10.0	27	16.0	9.6
	Straw	8.0	35	4	13	18.0	12.8
	Total	16.0	200	14.0	40	34.0	22.4
Finger Millet							
	Grain	1.1	17	5	59		
Root Crops							
Cassava							
	Roots	8.0	30	10	50	20	10
	Roots	16.0	64	21	100	41	21
	Roots	30.0	120	40	187	77	40
	Whole Plant	59	64	19	176	102	26
Potatoes							

	Roots	12.0	52	10	80	22	14
	Roots	22	120	20	166	40	26
	Roots	40.0	172	34	232	70	48
	Whole Plant	62.0	147	19	403	60	31
Sweet Potatoes							
	Tubers	44.0	77	14	224	4	9
	Roots	16.5	72	8	88		
<u>Grain Legumes</u>							
Beans							
	Dry Beans	1.0	31	3.5	6.6		
Soybeans							
	Beans	1.0	49	7.2	2.1		
	Peanuts	1.0	49	5.2	27		
<u>Grasses</u>							
Guinea							
	Above ground	10.0	107	27	180	78	49
	Above ground	23.0	288	44	363	149	99
Elephant							
	Above ground	10.0	144	24	180	35	30
	Above ground	25	302	64	504	96	63
<u>Other Crops</u>							
Sugar cane (2 yr crop)							
	Above ground	100	75	20	125	28	10
	Above ground	200	149	29	316	55	58
Cotton (Seeds)		0.8	30	4.4	7		
Coffee							

	Dry beans	1.0	25	1.7	16	1	2
Tea							
	Dry leaf	0.6	31	2.3	15	2	
Tobacco							
	Cured Leaf	1.0	116	14	202		
Rubber							
	Dry latex	3.0	7	1.2	4	4	
Cacao							
	Dry beans	0.5	10.	2.2	5	1	1
Oil Palm							
	Fruit	15.0	90	8.8	112	28	
Bananas							
	Bunches	10.0	19	2.0	54	23	30
	Stem and leaves	--	20	1.3	22	1	3
	Total	--	39	3.3	76	24	33
	Bunches	30.0	56	6.0	161	70	82
	Stem and leaves	--	29	4.0	65	2	8
	Total	--	39	85	10.0	72	90
Pineapples (Fruits)		12.5	9	2.3	29	3	
Coconuts							
	Dry copra	1.2	60	7.2	40		

*Yields of cereals, grain legumes and grasses on a dry weight basis; root crops and bananas at 15 - 20% dry matter. (used with permission from Properties and Management of Soils in the Tropics, Pedro A. Sanchez, p. 200 to 203.)

**Stover = stalks and leaves of crops like corn, excluding leaves.

Some Uses for this Chart

- The farmer can profit from knowing the nutrients taken out of the soil by his different crops. He will begin to realize the amount removed in the grain, root or fruit he uses; also the nutrient value of the stalks, leaves, and straw which can be left in the field.

  Notice, for example, that corn stalks contain much nitrogen and potassium. They will return some of that to the soil if they are left as mulch on the surface. On the other hand, sorghum stalks have very little potassium in the straw.

- Knowing plant withdrawals along with soil test results gives a picture of fertilizer needs. It can also help the farmer determine which plant materials to put into compost piles. If he has a choice, which plant residues will contribute the most plant nutrients to the compost?

- The farmer can also get a feel for how much manure or compost will be needed to replace the N - P - K withdrawn in the grain, fruit and roots. See the Table 1-7 “Plant Nutrient Content of Some Common Organic Fertilizers’ and Table 1-8 “Plant Nutrient Content of Some Common Commercial Fertilizers’. A corn grain yield of 4 tons/Ha withdraws 63 Kg N/Ha and 30 Kg KJ Ha. How much compost will be required to offset the withdrawal?

- These tables show which crops deplete certain nutrients most heavily--how much is removed from the soil.

- . A high yield draws much more from the soil than a low yield. For example, one ton of corn grain draws 25 Kg of nitrogen fertilizer per hectare and 15 Kg of potassium fertilizer. A seven-ton yield draws 128 Kg/N/Ha and 37 Kg/K/Ha. Cassava also feeds heavily on potassium as compared to other nutrients it withdraws.

- • There is great variation between plants in amount of different nutrients withdrawn. Finger millet withdraws four times as much potassium per ton of grain as maize. Corn grain withdraws almost twice as much nitrogen as it does potassium, whereas cassava takes out much more potassium than nitrogen.

- In case of high nutrient-depleting crops, special attention must be given to soil testing.

  Caution: The tables are a rough guide, not meant to substitute for soil testing where soil testing is possible. They do show the advantage of rotating a crop like corn with a legume like beans which produces nitrogen for its own use, leaves some in the soil, and uses very little potassium.

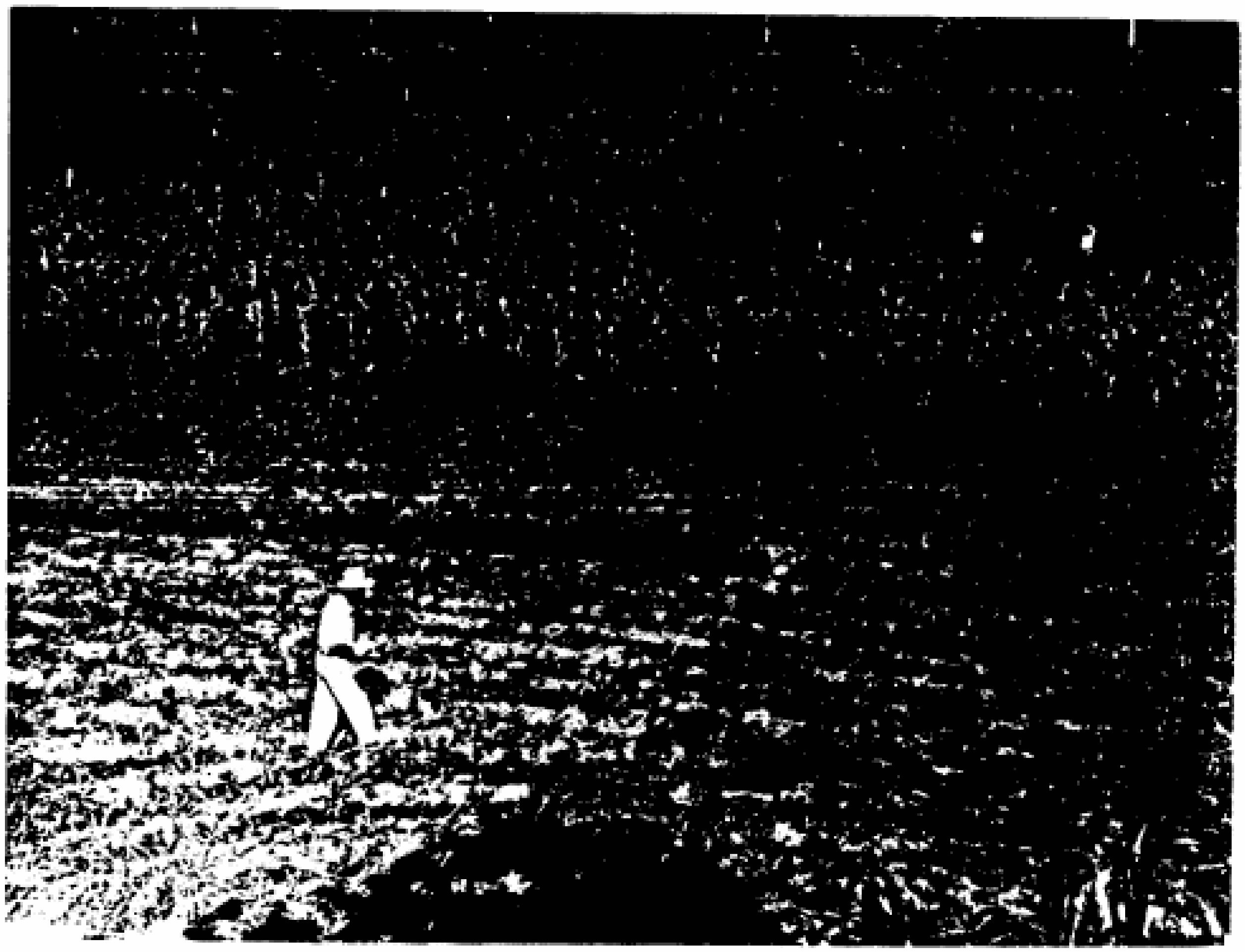


Figure 1-8. Crop rotation is one way to improve soil fertility and soil structure. Here you see beans (a legume) in rotation with maize. The legume has different nutrient requirements than maize, and it fixes nitrogen fertilizer. Because of this, the maize will have higher yields the following year, when it will be planted where the beans are now growing. Not only has soil fertility been enhanced, but organic matter has been increased, which results in better soil structure. (Picture courtesy of World Neighbors)

How to Help the Farmer with Soil Fertility Needs

- If commercial fertilizers are available to the farmer at affordable prices, and soil testing laboratories are available, help take soil samples, and send them to a soils laboratory for testing. Be sure to specify the crops to be grown.

- Even if the farmer cannot afford or obtain commercial fertilizer, show the farmer how to take samples and send them to the laboratory. He will still need to know how much organic fertilizer, manure and compost the soil needs. Again, this assumes a lab is available.

- In some countries, the extension service or soils laboratory will give you recommendations and amounts of fertilizer to apply per hectare.

- If no soil testing lab is available, you can find instructions in Appendix A which will help you.

- Remember that the farmer must cycle as much organic matter as possible back into, or on top of, the soil. It should be remembered that returning crop residues and some manure back to the soil from which it came may help maintain, but does not build soil fertility. Where soils are naturally low in nutrients, considerable additional nutrients must be added. Check Table 1-6 for estimates of nutrients removed from the field by crops and Table 1-7 for contents of nutrient organic fertilizers.

SOIL TESTING

In collecting a soil sample, the farmer will find that getting a truly representative sample of his field's topsoil fertility condition requires much care. He will need to collect an accurate composite sample which represents fertility conditions in various parts of his field (covering 1/2 hectare or more).

Where Will the Soil Sample Be Analyzed? Who Makes Fertilizer Recommendations?

- The determinations from laboratories can sometimes be inaccurate. There is a lot of room for error. Where possible, send duplicate samples to two laboratories for recommendations.

- Check with the Peace Corps Associate Director for Agriculture for details. Also check with extension or research soil specialists.

- Visit the soils laboratory before taking samples there. Obtain and follow their instructions.

- The farmer should test his soil every second or third year.

- He should take the sample long before planting time, allowing time for the sample to reach the lab, for the analysis and the recommendations to be made, for fertilizer to be purchased and to be on the farm several weeks before planting time.

<u>How to Take a Representative Soil Sample from a Field</u>

1. If the farmer's land is divided into both hillside and bottom lands, treat them as two different fields. The farmer should take representative composite samples of each one, with 15 to 20 sub-samples coming from each field. He will send two separate composite samples to the laboratory, one for the hillside field, one for the bottom land field.

2. Take 15 to 20 small individual <u>vertical samples</u> from the crop rooting depth of the soil in each field. This is usually to a depth of 15 to 25 cm. Take the samples randomly across the entire field.

   a. These samples can be taken with a <u>special soil auger</u> so that a sample 3 cm diameter to a 25 cm depth is collected. Or take a similar sample with a spade, shovel, or hoe.

   b. If you are using a <u>shovel</u> dig the holes 25 cm deep to expose a vertical wall. Then push the shovel down vertically, taking a slice 3 cm thick from the wall for the full depth. As you lift it from the hole, keep the layer of soil intact in the shovel by bending the shovel handle backward toward you until the soil is level.

   c. Take the 3 cm thick layer of soil (which is still held level in the shovel to keep it from sliding out), and remove all soil from the shovel except a vertical center strip 3 cm wide by 3 cm thick extending the length of the shovel blade.

   d. This single sample contains an equal amount of soil from each unit of depth. Take this individual sample and place it by itself in a clean bucket. Mix it very thoroughly.

3. Repeat this process at 15 or 20 random locations across the field. As you collect individual samples, mix each one, and then add it to the total composite sample, mixing that well also. Be sure this large, total composite sample (15 to 20 sub-samples) is mixed very thoroughly. Take extreme care that all clods are broken, all stones removed, and the soil is uniform and smooth. You now have your composite sample to take to the soil lab.

4. Take the required amount for the laboratory (usually 2 or 3 normal cups full). Place in a suitable carton or clean glass jar, and label it with the farmer's name, address and date.

5. Make a map and record of the farm.

   a. Show where the samples were taken. Describe the field, the slope, etc. and include a brief crop history (crops grown last year, amount of fertilizer used the last two years, etc.). <u>Indicate the crops to be grown the coming season</u>. Write this information on the same sheet as the map, on the bottom or on the back.

   b. Write the farmer's name, address, and the date on the map. Also write the name of the technician who assisted with the sample taking.

   c. Make a copy of the map and all the information for the farmer to keep in a file (a good way to begin teaching the farmer how to keep records.)

6. Deliver the jar and the map to the laboratory.

To familiarize the farmer with commercial fertilizers you might play with some fertilizer number relationships. The following are examples of the amount of different fertilizers required to be equivalent to 100 Kg of elemental nitrogen fertilizer.

100 Kg “N” fertilizer = 300 Kg Ammonium Nitrate
100 Kg “N” fertilizer = 666.6 Kg Calcium Nitrate
100 Kg “N” fertilizer = 217.3 Kg Urea

or

100Kg “N” fertilizer = 2,940 Kg Chicken Manure
100 Kg “N” fertilizer = 7,142 Kg Compost

<u>Caution</u>: When fertilizing with high concentrations of commercial fertilizers or fresh animal manures, mix the fertilizer with the soil near the plant or near the freshly planted seed. Do not place in direct contact with either. Otherwise it can burn the plants. For more information on fertilizer use, see PC-R008, <u>Soils, Crops, and Fertilizer Use</u>.

The Contents of Organic and Commercial Fertilizers

Table 1-7. Plant Nutrient Content of Some Comm on Organic Fertilizers

Source	N	P_2O_5	Percent of 1(20	CaO	MgO	S
Activated sewage sludge	5.6	2.6	—	**2.5**	1.5	0.4
Digested sewage sludge	1.6	7.3		**0.1**	0.3	—
Bone meal	2.7	25.0		**3.4**	0.7	
Cottonseed meal	6.8	2.4		**—-**	1.7	0.2
Compost*	1.4	0.9		**32.0**	0.7	0.1
			1.6	**0.4**		—
			0.2	**5.0**		
Animal Manures	0.6	0.3	0.6	0.3	0.2	0.7
	0.5	0.3	0.4	0.8	0.1	1.4
	0.7	0.2	0.7	1.1	0.2	0.7
	3.4	3.4	2.8	2.7	0.8	0.7

Cattle
Hog
Horse
Chicken

* Keep in mind that the values of compost will vary depending on the quality of materials used in making it. However, for good crop yields, great amounts of compost are needed if animal manures or commercial fertilizers are not available.

**Taken with permission from 'Soil Fertility--Key to Abundant Food" by Victor Kilmer, from Our Land and Its Care (The Fertilizer Institute) p. 61.

Table 1-8. Plant Nutrient Content of Some Commerci al Fertilizers

Source	N	P_20_5	1(20	CaO	MgO	S
Ammonium Nitrate Ammonium Nitrate	33.5	~	**0**	7	4	—-
Limestone Mixtures	20.5					
Ammonium Sulfate	21.0	~	**0**			
Calcium Nitrate	15.0					
Sodium Nitrate	16.2	~	**0**	7.3	4.	0.4
Urea	46.0			0.3	—	23.7
Bone Meal	2-4.5	~	**0**	19.4		0.2
Normal Super phosphate	—			0.1	1.5	0.07
Concentrated Super phosphate		~	**0.2** **—**	—	0.05 —	—
Potassium Chloride	—	~		20-25		0.1
Potassium Sulfate			**0.2**	20.4	0.4	11.9
Potassium Nitrate	—	**~-28**	**0.2**		0.2	
Diammonium Phosphate		**18-20**		13.6		1.4
Monoammonium Phosphate	—IS		**0.4**	0.1	0.3	

Dolomite	16-20	**42-50**	**60-62**	0.7	0.1	17.6
Limestone	11	**----**	**50.**	0.6	1.2	0.2
	—		**44.**	—	0.4	—
		----	**—**		—	
	—			1.1		2.2
		----	**0.2**	21.5	0.3	0.3
			----	31.7	11.4	0.1
		48-53			3.4	
		48	**0.3**			
		—				
		—				

Ibid., p. 56. Used with permission.

OTHER PLANT-SOIL-WATER RELATIONSHIPS

Plant Processes Important to Plant Life and Growth.

- Photosynthesis uses the chlorophyll in the green leaves of plants, sunlight, C02 and water to produce sugars. From sugars the plant makes the carbohydrates, proteins and many complex products needed for plant life, reproduction and growth.

- At the same time, (1) plant roots take up the needed nutrients and moisture from the soil, and (2) the plant system sends from the leaves back to the roots the sugars and other chemical products needed for energy and growth. For normal growth to occur, the nutrients and moisture from the roots as well as the products from photosynthesis must be available to all parts of the plant at the same time.

- Two systems within the plant transport the materials for plant processes. One carries water and chemical nutrients from the root zone to all parts of the plant. Simultaneously, the other conveys the products of photosynthesis to the growing points throughout the roots and the plant system. For the transport system to work well, the plants must get enough moisture at all times to keep the plant cells turgid.

- Transpiration from the leaves affects the plant. The surface of the plant leaves have openings or pores which allow gases to pass back and forth between the air and the plant tissue. The openings, called “stomata”, allow water vapor to leave the plant and air to enter it. Highly sensitive guard cells control the opening and closing of the stomata. They open the stomata in daylight hours and close them at night. Even in the sunlight the guard cells will close or partially close the stomata when the plant is under moisture stress, thus protecting the plant cells from excessive desiccation.

The water lost from the plant is said to have been “transpired”. The combination of water loss through evaporation from the soil surface and water loss through the plant is called “vapor-transpiration”.

Soil Moisture and Its Relationship to Plant Life and Growth

Field Capacity

As a quantity of rainfall water or irrigation water moves down through the soil pore spaces, it saturates the entire soil mass. After the rain stops, or irrigation is finished, the soil water continues to drain, pulled by the force of gravity. Usually most of the drainage has stopped after 24 hours. The soil moisture is then at “field capacity” (the amount of soil moisture a given soil will hold against the pull of gravity). Most of this remaining moisture can be used for plant growth.

The amount of moisture in a soil at field capacity should not change significantly for several weeks--if no plants are growing, if a heavy mulch is on top of the soil, and if no additional water is added.

Available Soil Moisture

Suppose that seeds are planted into a soil at field capacity through a mulch, with minimum disturbance of the soil. The mulch on the surface keeps wind and sunshine from evaporating the soil moisture. Under these controlled conditions the amount of water available for use by the crop depends upon two things: (1) the water holding capacity of the soil and (2) the rooting depth of the soil and plants.

We call most of this ~ the “available soil moisture’. It is that ‘mount of water the plants can extract from a soil before the plant becomes extremely wilted.

The “permanent wilting point” is the point at which the soil moisture remaining in the soil is held so tightly by adsorption by the soil particles that the plant can no longer extract water and becomes severely wilted. Unless the plant receives water, it will soon die.

Available soil moisture is the difference in the soil moisture content at field capacity and the amount of moisture at permanent wilting point. Available soil moisture for plant use is expressed in inches of water available per foot of soil depth; or cm of water per meter of soil depth. Notice the large difference between sands and loams, or sands and clay soils, in the following table.

Table 1-9 Available Water Holding Capacity of Soils

Soil Type Sands	Inches Available Soil	Moisture for Plant Use
		Millimeters per meter depth 21-63
	Inches per foot depth 0.25 - 0.75	
Fine loamy sands	1.40 - 1.70	**117- 142**
Clay Loams	1.75 - 2.50	**146- 208**
Clays	2.00 - 2.60	**167-217**

What Variables Affect Plants' Moisture Needs?

The water use rate varies with the amount of sunshine and wind, the water content of the air (humidity), the stage of plant growth and the amount of moisture evaporated from the soil surface.

When the soil is bare a large amount of water evaporates from the soil surface due to sunshine and wind. As we all know, hot sunshine dries out bare soil quickly, even more quickly if a dry wind is blowing. However, a mulch cover over the soil can prevent much water loss, except for loss from transpiration through the plant leaves.

- Low-growing crops will usually use less water than a tall crop like corn with many leaves rising into the air. More leaf surface means more transpiration.
- Crops use more water during the stages of pollination, seed formation, and maturation of fruits, seed pods or ears. At this time, the nutrient and moisture needs of plants are at their peak.

Table 1-10. Average Daily Water Requirements for Field Crops in mm Per Day (assuming good growing weather and full sunshine)

Very young plants			3	or	4 ram! day
Fast-growing field (when	crops	at peak use	6	to	10 mm/day or more
grains are	filling-	maturing)....			

AVERAGE DAILY TEMPERATURE, LIGHT AND HUMIDITY: THEIR EFFECT ON PLANT GROWTH

The temperature of the air and soil greatly influence plant growth as well as determine what crop varieties will grow where.

Ambient Temperature

- The day and night ambient temperature (temperature of the air in the shade) affects not only the growth of different species of plants but even which ones can grow. The requirements for different species of crops vary widely.
- Some crops like cabbage are cool season crops. In the United States cabbage grows best in the spring and fall. In the tropics (where four yearly seasons are lacking) it does best in the mountains where days are warm and nights are cool. Fruit trees usually do better with cool nights than with warm ones. Some other crops can do well with warm days and nights. Some plants are cold weather hardy while others are not.

Soil Temperature

- The best soil temperature for plant growth varies widely from species to species. However, most plants fall into the range from 200 to **300** C.

- The soil temperature affects plant roots. Plant roots of different species have specific ranges of temperature in which they grow well. In the tropics most food crop roots in the topsoil grow better in a cool moist soil under a mulch than in a very hot soil fully exposed to the direct tropical sunshine.

- Soil temperature also affects micro-organisms living in the soil. As the soil temperature increases from about 50 C to about 300 C, the rate at which micro-organisms decompose organic matter increases. In the above range, the rate of micro-organism activity will increase two or three times for each rise of 100 C in soil temperature.

  If the soil surface is shaded and kept cooler. root growth will increase and the decomposition of organic matter will be diminished. (It remains to be useful to the soil longer.)

- Direct Sunshine on bare soil greatly increases the soil temperature for a depth of several centimeters.

- A good mulch or other ground cover does more than protect the soil from raindrop splash erosion and eliminate soil moisture evaporation from the surface. Mulch also lowers the soil temperature, which slows the decomposition of organic matter in the soil and encourages root growth in the cooler topsoil for many species of plants.

Light

- Different plant species vary greatly in their requirements for light. Some plants require full sunlight to maximize their photosynthetic processes. Some do well in partial shade, while some others can even thrive in full shade. Knowing the light requirements of various species becomes highly important when growing plants together, side by side, or some beneath shade, in the farmer's field.

- Light affects plants in other ways. The length of daylight (day length) or the length of night control the ability of some plants to produce flowers and fruits. Some species do well with either short or long days. Check with local PCV specialists before introducing plants from outside the region.

Humidity

- Hot, dry air increases the plant's loss of water (transpiration rate). The plant will use much less water with high humidity. Although high humidity decreases plant transpiration rates, it can have a negative influence on plants by creating an ideal environment for certain plant diseases to grow.

CHAPTER 2

SOIL EROSION BY WATER

Hundreds of millions of small tropical farmers struggle to produce enough food for their families. Most of them farm very small plots of land, 1/2 to 2 hectares, often on steep slopes. Too often the soil is infertile and/or shallow.

Severe erosion steals the life-giving topsoil every time a strong rainstorm hits these hillside fields. If the soil is unprotected many *farms* can lose 3 cm of topsoil annually and more than 6 cm in severe storm years.

Seventy-five percent of the roots of food crops of hill farms are in the top 25 cm of soil. They obtain much of the needed plant food and soil moisture from this limited layer. If the top 25 cm washes off, the family must soon abandon the land.

How Does Soil Erosion Work? Can the Farmer Prevent It?

Researchers and field workers have been studying erosion for most of the twentieth century. They have revolutionized our understanding of what causes erosion--and have given us new techniques to fight it. Many of these techniques can increase crop production at the same time. **Even the small, poor farmer can afford to use the new methods.**

In this chapter we **will look at erosion** itself. Please study this chapter carefully. It gives you the basic, proven concepts you will need in order to adjust conservation methods to the many different farming conditions you will encounter. It may well be the single most important chapter in the entire book.

You will "get out in the field' in all the remaining chapters. In Chapters 3 and 4 you will learn on-the-farm methods which can save the soil and at the same time increase food production.

CHARACTERISTICS OF SOIL EROSION BY WATER

Soil erosion by water is the force of water dislodging soil particles and transporting them elsewhere. The deposit may be left on the same field, or several kilometers away, or at some very distant point (once it reaches a large stream).

Types of Erosion by Water

The four major types of soil erosion by water are: raindrop splash erosion. nil erosion. gully erosion, and stream bank erosion.

Figure 2-1. Farming steep slopes in Central America. See two brothers here, one below in the distance. They are preparing to follow a recommended program to conserve soil and water to improve yields of corn and beans. Since the soil is shallow, bench terraces cannot be used. These farmers will use a combination of contour ditches, rock barriers and live barriers. See Chapter 4 (Photograph by author.)

1. Raindrop splash erosion

Early conservationists used to call this sheet erosion. Since it does not leave rills or scars on the soil surface, they thought that water running over the surface in sheets had gently removed the soil particles.

We now know that the great force of individual large raindrops splashing the soil initiates erosion. This type of erosion is widespread. In fact, the energy of raindrop splash is the main mechanism of erosion. But good management can successfully handle or prevent it.

2. Rill erosion

This is caused by raindrop splash plus relatively large amounts of rainfall water flowing on the soil surface and finding escape routes down the hillside. Water flows to the lowest place, however small the depression. Since the field soil surface is not completely smooth, water will seek the low places. This water is the system which carries away soil particles. Soon more and more water gathers, building up greater depths and speed, and forming small channels as it carries soil particles away. It begins to leave micro-gullies called rills. As raindrops continue to fall and splash, the micro-gullies cut deeper. Each successive rain contributes to the micro-gully system. Unchecked, it continues to build throughout the crop-growing season.

Land management and crop management can do a lot to eliminate "raindrop splash" and nil erosion on the farmer's field.

3. Gully erosion

Hydraulic forces of large volumes of deeper rainwater running swiftly downhill can carve out gullies. Storm after storm deepens the cuts. Ultimately, if unchecked, another Grand Canyon is in the making! Much smaller gullies, however, cause serious and increasing damage. Here again, some simple, inexpensive methods can prevent this. The best gully control is prevention!

Note that rill erosion and gully erosion take place only after the raindrop splash has initiated the erosion.

4. Stream bank erosion

Swift running water in creeks and rivers can undercut stream banks. Large volumes of water in gullies may also cause gully banks to undercut and fall into the water.

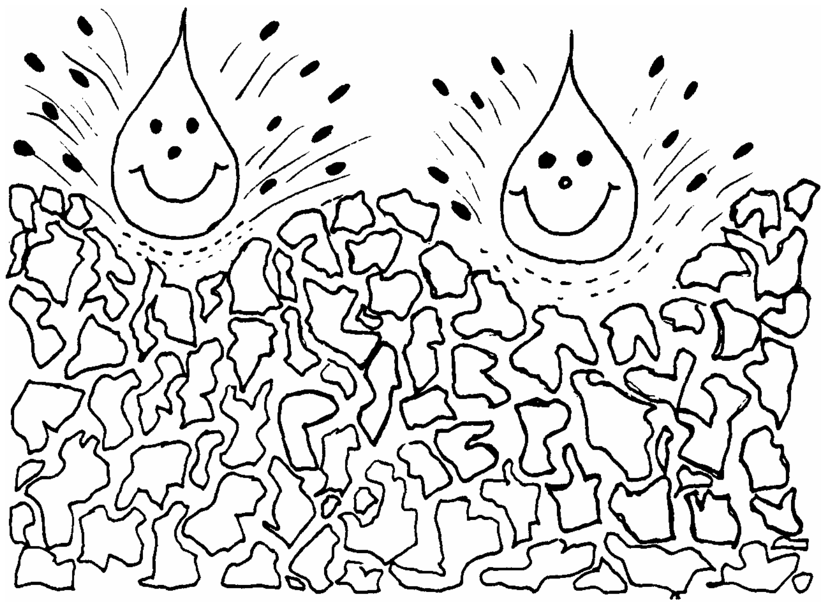


Figure 2-2. Soil erosion begins when very large raindrops bombard the unprotected soil, loosen soil particles, and destroy the soil structure. Runoff water carries the loosened soil particles away.

THE UNIVERSAL SOIL LOSS EQUATION

During the last 60 years, scientists have determined that six factors work to produce erosion by water. Using quantified figures for each, workers can predict how much erosion will occur on a given field.

Scientists in the United States, calculating from 20 years' work and 10,000 small-field plot years, have put the erosion factors into a formula. They can use this in the United States to predict soil loss quite accurately. However, conditions in the tropics do not necessarily correlate with those in the United States. The formula cannot be considered accurate for the tropics at this time. However, it can be used to make some very good estimates.

Even though you do not have exact figures for all the factors in tropical conditions, the formula will help you keep the individual components of soil erosion in mind, and will be helpful in explaining it to others.

This Is the Universal Soil Loss Equation:

A=RxKxLSxPxC

Translated, the equation's terms mean:

A = Total soil loss in tons of soil per acre (or metric tons per hectare).

R = Erosivity of the rainfall--its force to erode the soil. The heavier the rainfall and the longer its duration, the larger this factor is.

K = The easier a particular soil erodes, the larger this factor. It is a number, ranging from 0.00 to 0.69, which quantifies how much a particular soil will erode. The higher the figure, the more easily the soil erodes.

L = Length of the slope--the distance the rainwater runs down the hillside before some barrier or ditch stops it. As slopes get longer the depth (volume) and speed of the running water increases, and the water more easily cuts micro-gullies or even large gullies.

S = The steepness of the slope, given as percent of slope. The steeper the hillside, the greater the percent slope, and the faster runoff water carries soil particles away.

P = Practices of land management. Does the farmer use terraces, contour barriers and drainage ditches? Does he farm the land on the contour? Such methods are rated by a number which compares particular conservation practices to the worst possible practice (which is plowing and planting with crop rows running up and down bare slopes). The more effective the land management practice, the lower this number is (the less the erosion).

C = Crop management practices. Do crop leaves and crop growing practices protect the soil surface from large raindrops which cause erosion? Here again, the better the practices, the smaller the numerical rating, the less the erosion.

Total erosion (in tons per hectare), then, is the product of intensity and duration of rainfall, erodibility of the soil, % slope, length of slope, conservation practices, and crop management.

Human beings cannot do much to alter the first two factors (rainfall erosive and soil erodibility). However, they can change the other four factors a great deal. Note that the factors are miaitip1i~.d, not added. Each one affects the erosion process heavily.

A Look at these Six Factors which Affect Erosion

1. Erodibility of the soil

- Soils of different types and textures vary in their susceptibility to rainfall erosion. Some types of soil erode more easily than others. The ease of erodibility of different soils is hard to predict without actually seeing them. As a rule, sandy-silty soils and many other soils with poor structure erode

- Soils with good structure have adequate pore space and connected internal channels for water to penetrate rapidly instead of running off the surface. Organic matter in the soil greatly improves soil structure.

- Experimentally measured soil erodibility factors mentioned above have been determined for U. S. soils, and good estimates made in other countries. They vary from 0.00 to 0.69 (with the highest number being the most erodible). For tropical soils the range is believed to be from 0.00 to 0.55.

- In the tropics, the more weathered soils tend to be more resistant to erosion than the less weathered soils.

- The more weathered soils usually have good structure which is resistant to raindrop forces tearing soil particles free.

- Their infiltration rates (the rate water flows into and through them) are much higher. This reduces the amount of water running off the field. If the water does not leave the field, it cannot transport soil particles, hence less erosion occurs.

- Some studies show that more weathered soils may have infiltration capacities of more than 200 mm of rainwater per hour, while some less weathered soils have infiltration capacities of less than 20 mm per hour. During a heavy rainstorm much more water will run off the surface of the soils with low infiltration rates and much more erosion will occur.

- As you drive or walk along roads and trails in your host country, look for differences in soils and the amount of soil erosion, especially after storms. Which soils seem eroded most? Be wary, though. Often the way the farmer uses the land may overshadow soil types as the chief cause of erosion.

- Hopefully, your PGV agricultural specialist will have some local soils information to share with you.

2. The Rainfall Intensity and Amount

- The amount and intensity of rainfall the farmer's fields receive varies from year to year. This will vary greatly in a given storm and among the storms in a year. The heavier the rainfall and the larger the drops, the more soil is lost. The heavy storms bring mostly large raindrops.

- Important research findings on the destructive force of raindrop energy can help small farmers save much more of their topsoil in ways they can afford. Understanding these findings can give you the keys to solving erosion problems.

- When are the most intense rains in your location? What measures can farmers take to protect the soil during these periods?

Bare soil • Many tropical rainstorms will have intensities of more than 50 mm rainfall per hour. Most of these storms are primarily composed of large raindrops.

3. The Percent of Slope--Steepness of Slone

- The amount of erosion enlarges dramatically with increased steepness of the hillside (higher percent of slope). Increasing steepness of slope increases the speed of flowing water. Swiftly flowing water transports much more soil than slow-moving water. It quickly sweeps away soil dislodged by rainfall splash. Any practice which reduces the steepness of the slope will reduce the rate of water runoff and the soil erosion.

The following table shows soil erosion measured in 3 different locations and different soils under different but comparable rainstorms. All measurements were taken on bare soil fully exposed to the storms. Note

Table 2-1. Tropical Soil Erosion Studies with Different Soils, Different Rainstorms and Different Slopes in Different Countries**

Case I. Northern Mountain Range Trinidad

Bare Soil	Slope	Erosion Soil Loss (metric tons/ hectare/year
Sandy clay loam		
(very high infiltration	11%	13 T/Ha/Yr
rate--resistant to	22%	35 to 49 T/Ha/Yr
erosion)	52%	68 T/Ha/Yr

Case II. Indonesia--Three Experiments. Different Locations

Bare soil	Slope	Erosion soil loss
Three different soils,	3.5%	100 T/Ha/Yr
All highly erodible	9%	469 T/Ha/Y
	10%	415 T/Ha/Yr
	14%	532 T/Ha/Yr

Case III. India

Bare soil	Slope	Erosion soil loss T/HaJYr
Moderately Erodible	0.5%	3 T/Ha/Yr
	1.0%	10 T/Ha/Yr
	3.0%	14 T/Ha/Yr

‘~Combined and modified from Suwardjo et. al., F. A. Uumbs et. al., V. Dhruva et. al., International Conference on Soil Erosion, 1983.

The Indonesian soil lost 532 tons per hectare per year at a 14% slope--a very moderate slope among hill farmers who often farm 60% slopes. The 532 tons of erosion per hectare takes away a layer of topsoil 48 mm thick, a tremendous loss of soil fertility and water storage capacity. Remember that, to maintain a sustainable system, a farm should not lose more than 10 or 11 tons per hectare per year of topsoil depth. Land without much topsoil cannot afford to lose even that amount.

Agricultural specialists need much more field research dealing with management of extremely steep slopes (those above 40%). An increasing number of small farms occupy slopes of 60% or more.

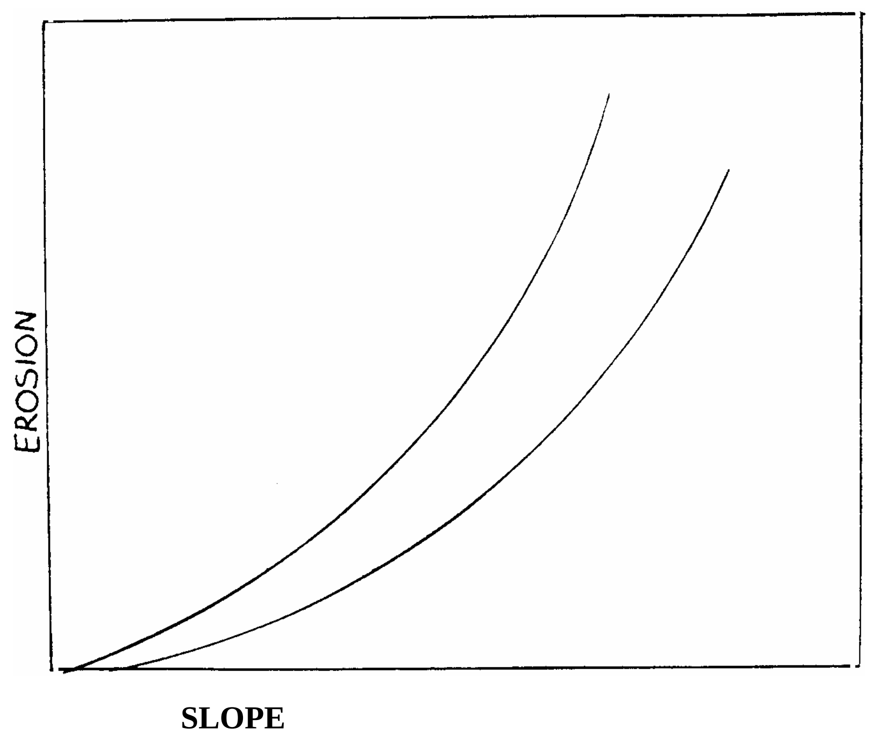


Figure 2-3. Erosion increases with increasing slope, even with great variation in erosivity of the soil.

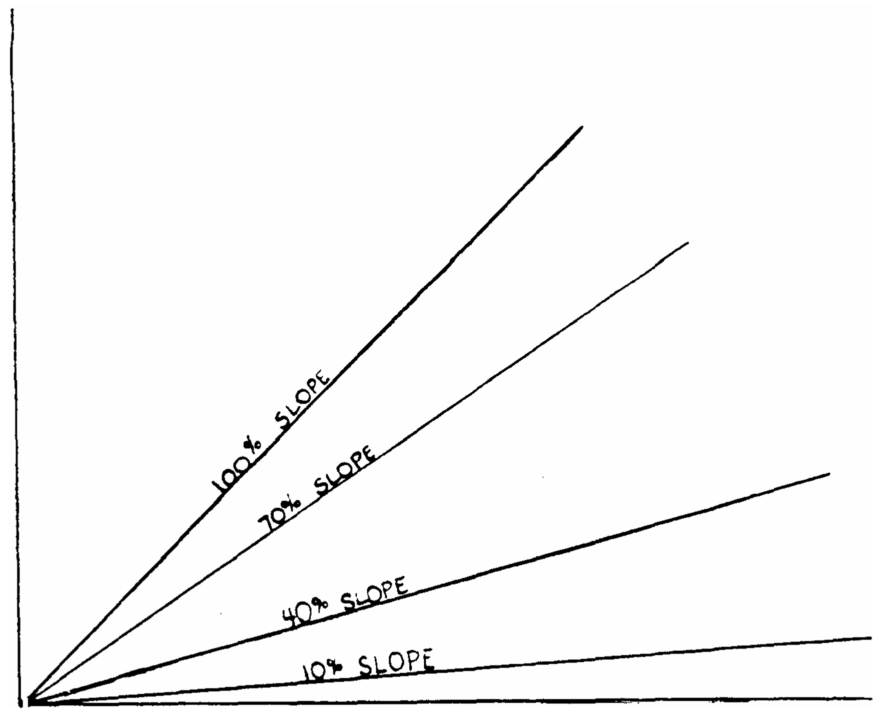
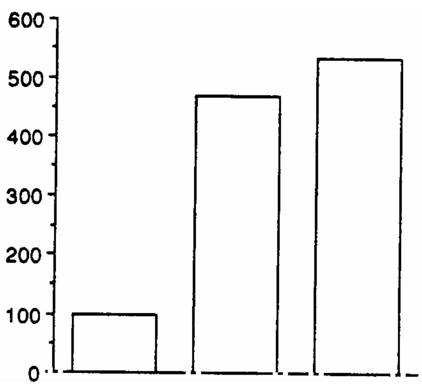


Figure 2-4. Visualizing percent slope. Visualizing steepness as related to the slope of a farmer's field. Think of each line as the actual slope of a field. Steepness increases as you go from zero to 10%, to 40%,to 70% to 100%. Note that a <u>100% slope line</u> makes a <u>45 degree angle</u> with the horizontal.



3.5 9 14
Slope

11 22 52
Slope

Figure 2-5. A graphic comparison of effects of percent slope on soils which vary greatly in susceptibility to erosion. In these two graphs, the susceptibility of one soil to erosion is obvious. Look at the amount of erosion on the highly erodible soil with only 3.5% slope. There is twice the erosion as compared with the other soil with a percent slope of 52%. The difference in erodibility of the soils is extremely important! A highly erodible soil should be covered at all times with grass or a dense stand of trees, and litter on the ground.

However, when each soil is considered independently, the percent slope remains a very important factor in the amount of erosion of that soil.

Especially: (a) the great differences among soils in resistance to erosion, from those highly resistant through those highly susceptible (b) the clear-cut responses to increasing steepness of slope in all cases (c) the large amount of erosion from a highly erodible soil at only a moderate slope.

- To maintain a sustainable system, a farm should not lose more than 10 or II tons per hectare per year--about 1 millimeter per year of topsoil depth.

4. Length of Slope

  - Under most conditions, increasing the length of the slope in the field increases soil erosion, but not as fast as increasing the steepness of slope. Nevertheless it is critical to keep length of slope within reasonable lengths. Longer slopes encourage rill erosion to occur. If neglected, this then generates gully erosion.

- How to deal with length and steepness of slope

  Appropriate field contour ditches, dead or live barriers (or combinations of these) can change length of slope. Some form of bench terrace can change both the percent and the length of slope. See Chapters 3 and 4 for detailed methods and for spacing between contour ditches or individual barriers.

5. Land Management Practices

Conservation land management practices being used (or not used) help determine the amount of erosion from a farmer's field. A farmer who plows and plants up and down slopes, creates ready-made pathways for runoff water to carry soil away quickly, and for gullies to form. Good management begins with installing contour drainage ditches, and plowing and planting rows on the contour, (i.e., placing the rows and ditches perpendicular to the direction the water, pulled by the force of gravity, runs down the slope).

6. Crop Management Practices

The farmer can protect the soil by covering it with growing vegetation, crop residues, etc.--the thicker the better! This keeps the rainfall from beating the soil. Small farmers can effectively and inexpensively save their soil by protecting it from large raindrops. You will find many crop management techniques, and ways to teach them to farmers in Chapters 3 and4.

A SOIL EROSION PRIMER

Exciting research discoveries show us the significant effects on soil erosion from the impact of rainfall energy. These understandings of what causes erosion have revolutionized recent soil conservation methods.

Soil erosion is much more manageable these days. New methods to control it are simple and affordable. Farmers can apply these findings even to <u>steep slopes</u> and <u>infertile land</u>.

SOME KEY RESEARCH DISCOVERIES

1. <u>The Effect of</u> <u>Raindrop Impact</u>

a. We now know that <u>raindrop slash energy is the chief agent in erosion</u>. If the soil is not covered, a large raindrop <u>acts like a small bomb</u>. It gouges out a crater, dislodges the soil and splashes it into the air. This is the beginning of soil erosion. When millions of very large rain drops hit the bare ground, they dislodge many millions of soil particles. They <u>force soil particles apart</u> from each other with detonating action, and <u>slash them upward and outward</u>. The runoff rainwater carries the loosened particles away. Raindrops continue to pound the surface, tearing more particles free from newly exposed soil. (See Figure 2-6.)

b. <u>The lighter. smaller soil particles go first</u>. In other words, clay particles and organic matter particles in the soil surface splash away. These <u>contain most of</u> <u>the plant nutrients</u> in the upper fraction of topsoil. You recall that organic matter in addition creates good soil structure. When many of the most valuable parts of the topsoil continue to splash out and wash away, the upper soil surface pays the price in and <u>poorer structure</u>.

c. <u>Large drop rainfall impact can seal the soil's surface</u>. Besides detonating and loosening particles, raindrops pound, then splash and mix the wet soil into a slurry. The raindrops' splash makes a paste on the surface of the soil. It begins to fill and seal soil air and water pores, <u>partially restricting</u> rainwater entry into the soil. This greatly <u>increases rainwater runoff</u> and <u>soil erosion.</u>

When the soil surface, now of poor texture, dries, it <u>forms a crust</u> which may impede the emergence of sprouting crop seeds. In addition, the hard soil crust accelerates water runoff during the next rainstorm.

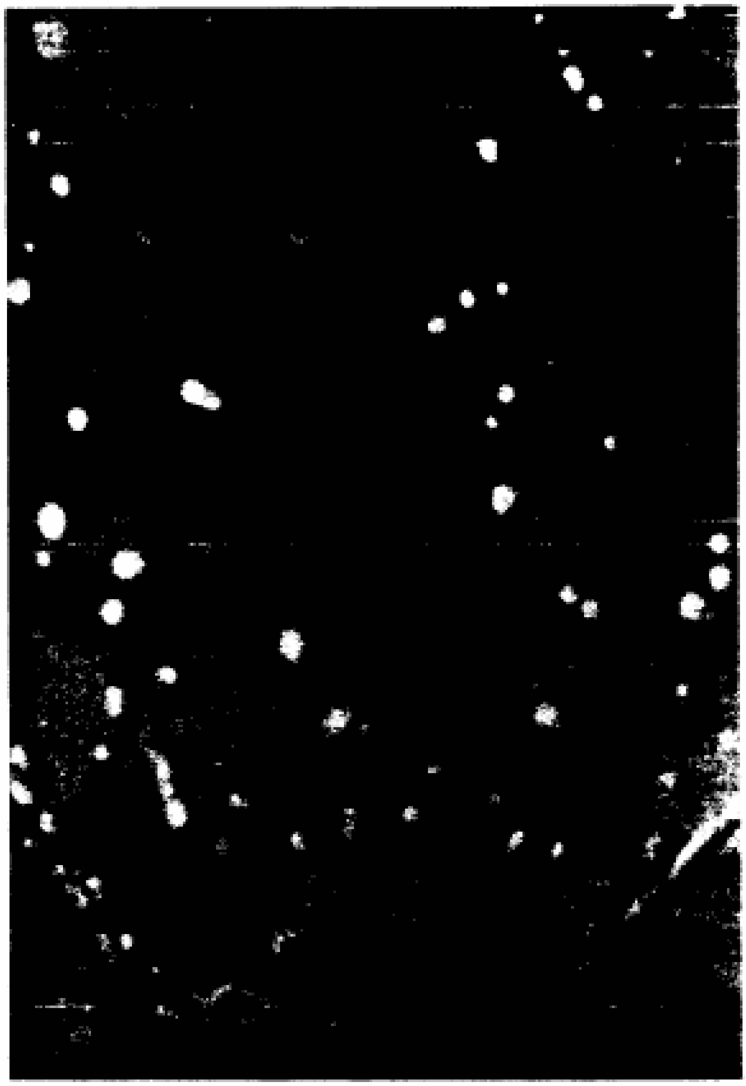


Figure 2-6. Photograph of a raindrop splash. This shows a large raindrop landing on unprotected soil, making a relatively deep hole and splashing soil particles up and away from the point of impact. Other drops will dig the hole even deeper. (Picture courtesy of U. S. Department of Agriculture.)

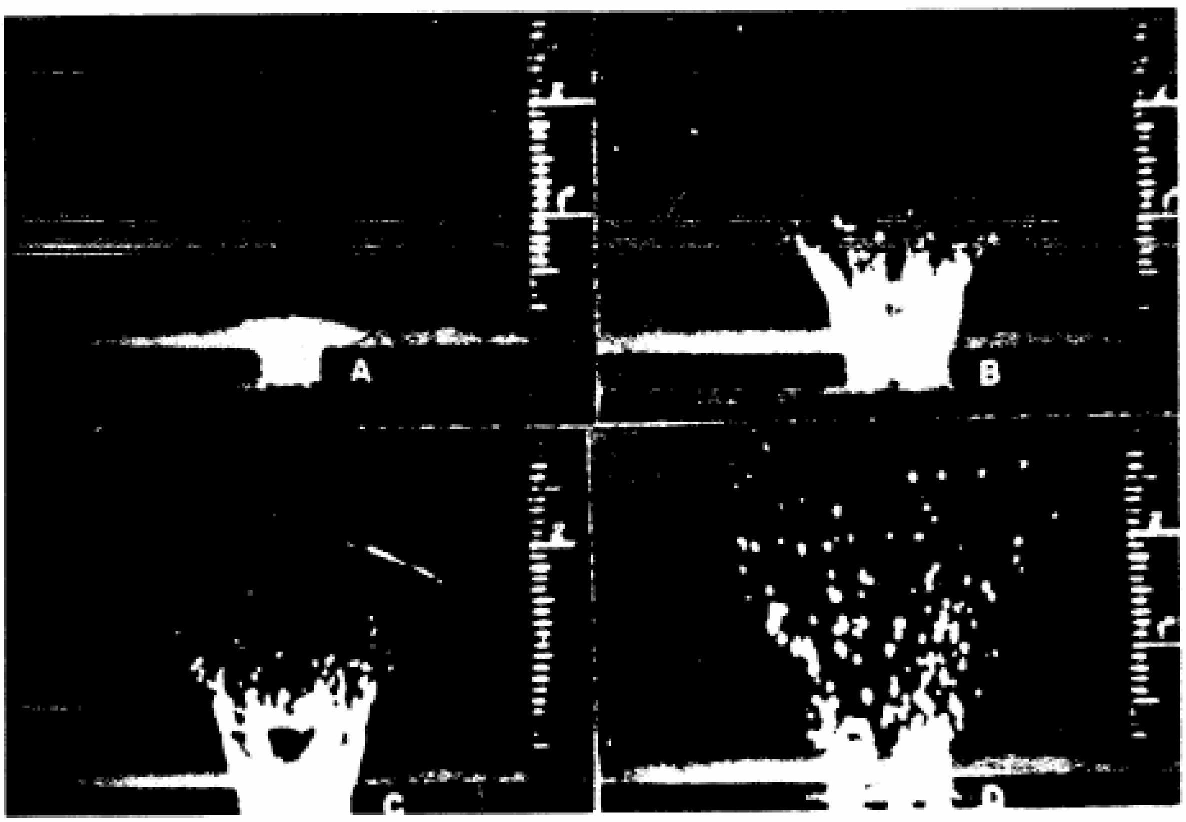


Figure 2-7. Time-lapse photographs of a large raindrop landing on the soil surface. The camera took these pictures in millionths of seconds. The picture in the upper left *(A)* was taken at 1/1,000,000 sec., (B) at 4/1,000,000 sec., (C) at 7/1,000,000 sec. (D) at 21/1,000,000 sec. after impact. Soil particles were scattered to relatively distant points. (Picture courtesy of U.S.

Department of Agriculture.)

A Classical Field Experiment

Some of the most significant experiments were conducted in the tropics by Norman Hudson. Wire mosquito netting was stretched across small plots of bare soil and suspended a few centimeters above the soil surface. Other similar plots of bare soil were left without cover. After several heavy rainstorms the soil loss from the bare soil plots without the mosquito net was 100 times more than from the plots protected with netting. The water runoff was also much greater from the bare soil plot. Plots covered with grass mulch gave the same results as the plots covered with the wire netting. Both netting and grass mulch absorbed the rainfall impact energy and the soil was not dislodged to cause significant erosion.

The same amount of water hit the soil in all three plots. However, the covering on the plots broke the large drops into small ones, resulting in a rainfall of very **gentle force. In the plots without cover, the soil absorbed the full energy from the large raindrops and was heavily eroded.**

What Rainfall Splash Energy Does

Hudson points out that raindrop energy from large raindrops is the main driving force behind erosion. He sees erosion as a work process requiring a lot of energy--tearing the soil particles loose, bouncing them high into the air, pounding the runoff water and the newly exposed soil and water mix, helping push the runoff water along down the hill, stirring up the runoff water, scouring the soil, transporting away the particles. The major source of energy for all of this is large raindrops. The energy from large raindrops is many times greater than from the equivalent amount of water running on the soil surface.

2. The Effect of Raindrop Size

- Large raindrops (raindrop splash energy) are usually the main culprits of erosion. Larger raindrops hit the earth with greater force.

- The size of raindrops in different storms varies greatly.

- Storms with larger raindrops cause the most erosion.

- The more intense the rainstorms, the larger the raindrops and the more energy in the rainfall.

- Hudson calculated the kinetic energy of intense rainfall as compared to that of water runoff. He showed that, under his given conditions, large raindrops with a terminal velocity of 8 meters per second could have 256 times as much kinetic energy as the runoff water flowing on the surface at 1 meter per second. **There** is **no doubt that rain drop energy is the major force involved in soil erosion by water.**

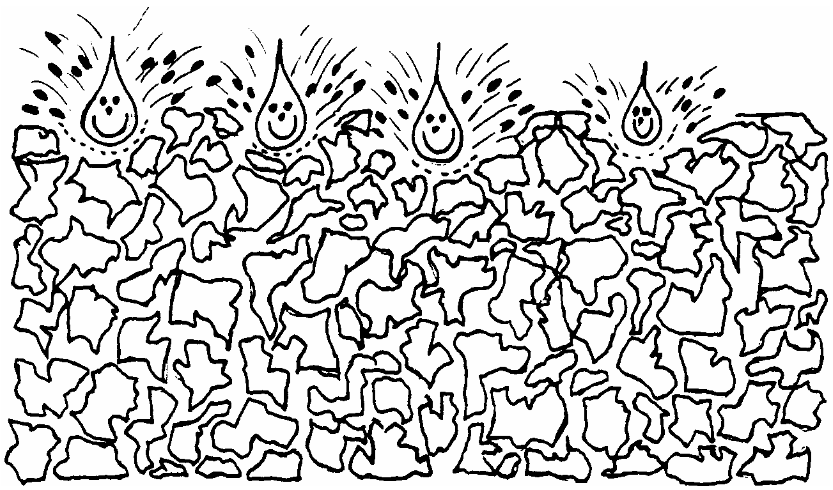


Figure 2-8. A raindrop splash field experiment. In field experiments conducted by Norman E. Hudson in East Africa, unprotected topsoil was exposed to heavy rainstorms (made up of mostly large raindrops). Much erosion occurred.

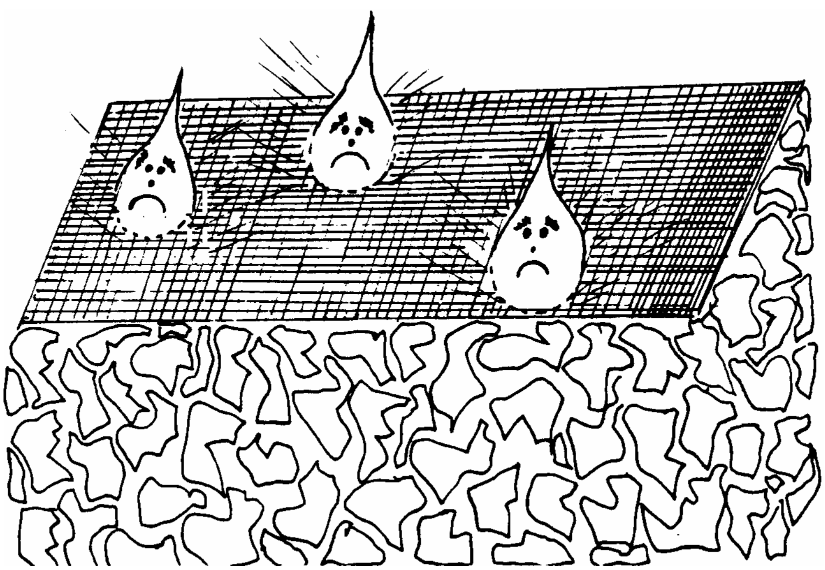


Figure 2-9. Other plots of the same soil alongside were covered with mosquito wire netting suspended a few centimeters above the soil surface. The netting absorbed the energy from the large raindrops. No significant erosion occurred.

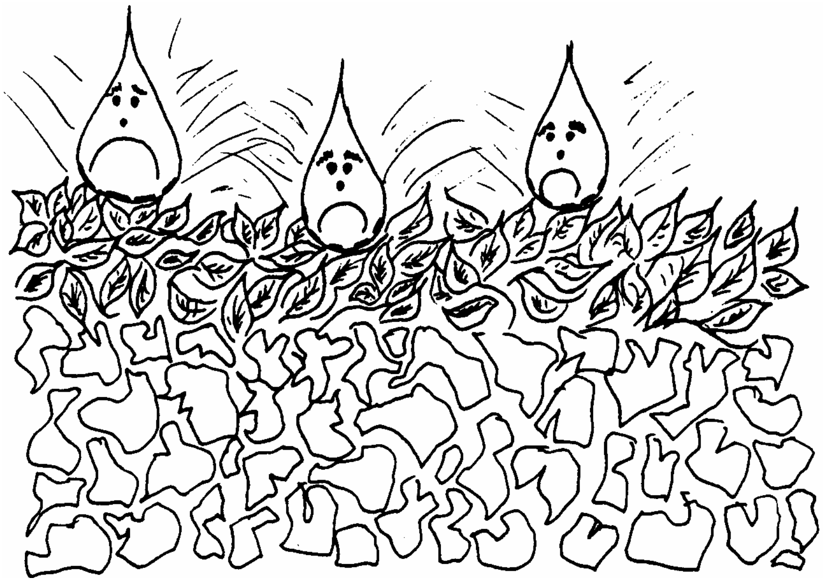


Figure 2-10.

Top sketch. Raindrops landing on grass mulch did not cause significant erosion.

For more information, see Soil Conservation by Norman Hudson, 2nd ed. Note especially Chapter 4.

- Studies by A. P. Barnett at Watkinsville, Georgia covered many years in the southeastern United States where rainfall is about 50 inches per year. He found that summer thunderstorms caused most of the soil erosion. Intense thunderstorms with mostly very large raindrops, totaled only 2~ of the annual rainfall but caused 85% the soil erosion.

3. The Effect of Raindrop Terminal Velocity What Is Terminal Velocity?

Terminal velocity is the maximum speed a falling raindrop can reach. Bodies falling through the air accelerate from the pull of gravity. They accelerate until the friction of the air balances the pull of gravity. At this point they have reached terminal velocity. They will strike the earth at this speed. They will never fall any faster. Large raindrops (up to 5-6 mm in diameter) fall at 8 to 9 meters per second--much faster than small raindrops.

Why Is Terminal Velocity Important?

A raindrop with high terminal velocity hits the soil with a much stronger force than one with low terminal velocity. The larger drops are much heavier. They reach a higher speed and much greater force than small drops. Billions of larger drops will be heavy enough and will travel fast enough at terminal velocity to detonate the soil on impact. Intense storms, which contain mostly large raindrops reaching high terminal velocities, cause heavy soil loss.

How Far Must Raindrops Fall to Reach Terminal Velocity?

They do not necessarily have to fall very far! Even though the leaves and branches of tall trees deflect the rainfall and break up the size of the drops, large drops re-form on the leaf surfaces and fall again, hitting the soil surface at terminal velocity. In a forest, low-growing vegetation and litter on the ground do more to fight erosion than the leaves growing on tall trees.

4. Soil Surface Protection

For many years, people believed erosion was caused solely by water running over the soil surface. We now know no significant erosion is initiated if the energy of the large raindrops striking the earth is dissipated.

ACCEPTED EROSION

Some erosion takes place even on undisturbed, protected land in the natural state and even when the land is level. Water causes some slight erosion under natural conditions or good management. Yet some land in its natural state often is highly fertile and has deep soil. Here topsoil replacement ~ topsoil loss. Farmers who manage carefully can often increase the topsoil's fertility and can also very slowly increase the topsoil depth if their farms have zero erosion.

Is Acceptable Erosion the Same for All Farms?

Certainly not! An acceptable rate of erosion on a particular farmer's field may be quite different from that on another farm. Consider the four soil profiles representing four farms A, B, C, and D in the following drawings. How about a farm A with only 6 cm depth of topsoil as compared to farm B with 35 cm topsoil? Obviously farm B has about five times the amount of topsoil, which means five times the nutrient capacity and soil moisture-holding capacity. If both farms lose another 6 cm of topsoil, farm A will be wasteland, but farm B will still be productive. The farmer whose field has only 6 cm topsoil must find ways to build up the topsoil. He really cannot afford to lose any more--whereas the farm on an alluvial soil with 35 cm topsoil would be able to lose a "break even" amount.

What is Ordinarily an Acceptable Amount of Erosion?

- Erosion under natural conditions or geological erosion happens at such a slow rate that, even though it has been going on for hundreds of thousands of years, the soil depth actually increases. Soil particles have been formed and accumulated faster than they have been removed. This natural soil-building process will build a depth of topsoil 25 mm (a layer about one inch thick) in about 100 years.

- Cultivating this layer in a very careful ideal way so that no erosion occurs can actually speed up the soil-building process, so that only 25 or 30 years is required to build 25 mm. Stirring the soil allows more air (more oxygen) to be available for the soil-forming processes, chemical and biological, to work faster. For soil cultivation plus soil build-up to happen in the tropics, the farmer must use the very best practices. including applying the recommended amounts of fertilizer when economically advisable or feasible, and growing plenty of green manure crops or using an agroforestry farming system. Wrong practices plus cultivation lead to soil loss, not build-up. The result can be serious soil erosion!

- If 1 mm of soil is being built in a year, we could reason that 1 mm could be lost to erosion and the soil building-soil loss would break even. This might be considered an acceptable erosion rate. One millimeter of topsoil over an acre weighs 5 tons, or 11 metric tons per hectare. So our soil erosion goal for small farmers might ordinarily be to control their soil loss to one mm depth per year, or less than II metric tons per hectare per year.

  This is a challenge but not impossible, especially if there is a good demonstration program where one successful farmer shows many neighbors that it can be done.

- You would be achieving great success if you could help farmers hold to I millimeter loss per year. Some farmers may do this with proper soil testing, green manure crops, mulching, contour ditches, live barriers and minimum tillage. Hopefully, some are already using animal manures compost recommended rates of commercial fertilizers, and pest control. (Note: pest control is important for increasing vegetative cover of the soil as well as for increasing crop yields.)

How Can We Ensure Long-term Soil Erosion Control?

We will hope to reduce the farmer's soil erosion ultimately to an acceptable level. But the farmer's overriding goal of necessity must be to significantly increase crop production per hectare. He has to think first of family food supply and income. Erosion control and increased production must go hand in hand.

WATER RUNOFF: RAINSTORM WATER RUNOFF FROM LAND

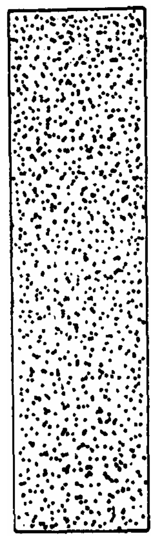
What Do We Mean by Water Runoff

Water runoff is the excess water which runs off the land during and immediately after a rainstorm. It is that percent of a specific storm's rainfall, that amount of rainwater, which did not soak into the soil. It is measured in millimeters and expressed as a percentage of the total rainfall for a given rainstorm or for a given period of time.

What Does It Do?

- Water runoff transports away hundreds of tons of soil particles torn free from the soil by rainfall splash. Some of these soil particles may stay on the farmer's field but the great majority leave the farm unless controlled.

- If farmers do not handle runoff water properly, its hydraulic force digs gullies in their farms. Over time, if left uncontrolled, together with "rainfall splash" it can--and does--turn farmers' fields into wasteland.



C D

Figure 2-11. Profiles of the soils on four different farms. What is acceptable erosion? Think in terms of farms represented by soil profiles like these. Profile A has very deep topsoil, B a fair amount, C only a thin layer of topsoil and D almost none.

Table 2-2. Water Runoff--Good or Bad?

Drawbacks of Wat6r Runoff	Possibilities of Water Runoff
Transports away soil particles and plant nutrients. As runoff increases, erosion increases.	
Scours the soil, creates gullies from its hydraulic force	With proper control, can be channeled into ditches and ponds, provide irrigation water, and keep much of the soil sediment on the farm
Can cause floods when combined with runoff from other farmers fields	Can be channeled or stored for useful purposes
Can plug streams and reservoirs with silt	Can replenish streams, ponds, and reservoirs with clean, useable water if flow is controlled and run over grass sods which keep it clean
	Can be stored in ponds which make possible: • a constant water supply for the farm family and animals • irrigation water • fish culture* *The Peace Corps has in some cases successfully deployed fish culture projects using ponds charged with runoff water. This has been an economic incentive for farmers to construct and maintain waterways (controlled exit ditches), catchment ponds, and larger reservoirs.

- However, water runoff, if handled properly, can often be used beneficially. (See Table 2-2.)

FACTORS AFFECTING RUNOFF

All of the following influence the amount of water which will run off a field during a rainstorm:

1. The Intensity of Rainfall and Duration of Storms

The intensity of rainfall (how hard it rains) determines the rate of water downpour, and therefore the amount and rate of runoff. A light rain of 15 mm/hr might not cause runoff, whereas a heavy rain of 50 mm/hr definitely would.

2. The Infiltration Rate of the Soil

- The faster the soil soaks up the rainwater, the less water remains to run off the farmer’s field. When a rain begins, all water goes into the soil until the rain falls faster than the soil can absorb it. Then it begins to run downhill.

- The infiltration rate of different soils varies, but it is relatively high for many of the tropical soils if the soil surface is covered with grass or mulch. However, if the soil is bare, the runoff will probably be heavy.

- If the soil is ~ large raindrops pound the soil surface; destroy the soil structure; and partially seal the surface, plugging the soil air and water spaces. This reduces the infiltration rate. Water runoff and erosion increase.

- If the soil profile is already saturated, the incoming rainfall will all run off.

- Soil compaction also influences water infiltration.

- During a heavy rain, look at the runoff on a compacted surface such as a foot path, an unpaved dirt road or the area around a livestock water hole where animals have trampled the soil. Notice that the rain water immediately runs off all such compacted soil surfaces. This is because the soil structure is destroyed. The air-water passages are plugged.

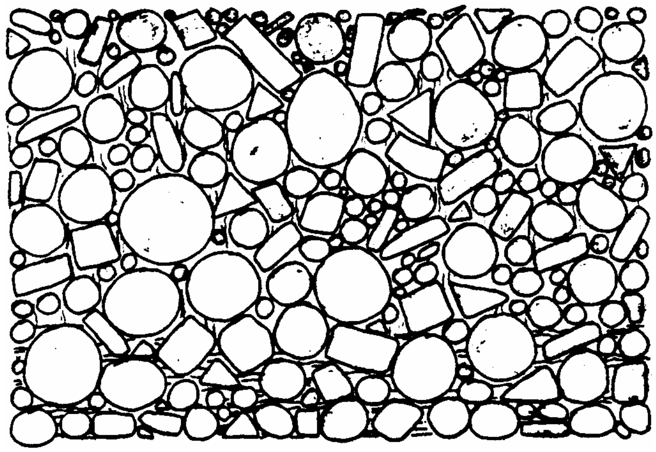


Figure 2-12. Compacted soil with poor structure and limited pore space. Little water can infiltrate.

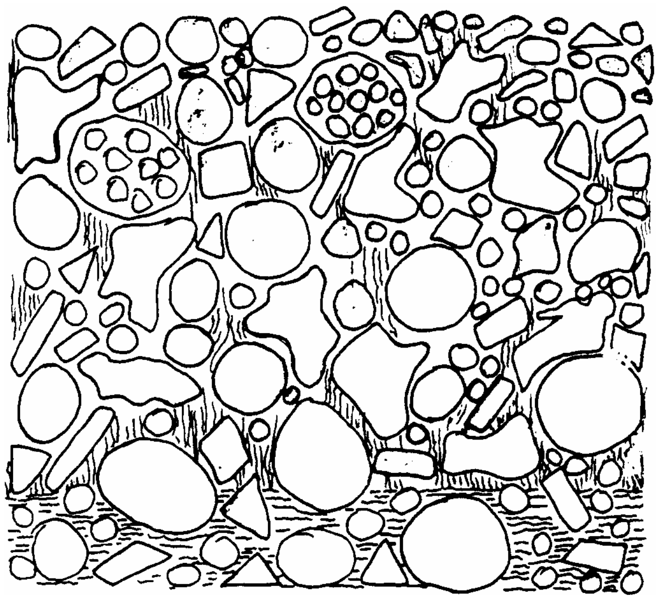


Figure 2-13. Soil with good structure. This soil has many pores and passageways for rainwater to enter and pass through to the subsoil.

- Compare sandy fields to clay loam fields during or immediately after a heavy rain. Notice how much more of the rainwater disappears into the sandy soil.

3. The Water Holding Capacity of the Soil: the Depth of Topsoil and Subsoil

Different soils and soil types vary greatly in their ability to retain water. Chapter 1 on soils gives you information on soil structure, the infiltration capacity of different soils, their water holding capacities, and some pointers on how to recognize them. Refer to Peace Corps Reprint # R0008, Soils, Crops. and Fertilizer Use by David Leonard, which is loaded with good, practical data.

4. The Slope of the Land

As you would expect, the higher the percent slope, the greater the runoff (other factors being equal). On a steeper slope the water does not have as much time to soak into the soil, so it runs off more quickly.

5. The Vegetation on the Land

- Infiltration rate into a given soil will increase if the land is covered with trees (forest with a good cover of leaf litter) or well managed pasture with a healthy grass sod, or if a plowed field has a thick grass mulch.

- With a dense protective vegetative cover, the rainwater percolates quickly into the soil and may not become runoff.

6. The Farmer's Conservation Practices

As with erosions the farmer's land and crop management methods will strongly affect the amount of water runoff.

a. Land management practices.

Poor land management practices encourage the flow of water into destructive patterns, i.e.: cultivating and leaving bare soil, plowing vertically down hills, failing to handle runoff, failing to deal with incipient gullies. Good land conservation practices stop or help slow the flow of water from the field.

b. Crop Cultural Practices

Good crop cultural practices help maintain high infiltration rates by keeping a mulch or live vegetative cover on the soil surface.

Figure 2-14. Erosion control using low rock barriers to slow the flow of water from the field. (Picture by author.)

Figure 2-15. Farmer using mulch. He has cleared the mulch from the small space in front of him so you can see his soil. This farmer has used much mulch, which has caught most of the large raindrops and eliminated erosion as a hazard. Because he has used mulch, compost and manure together with some commercial fertilizer, his crop yields have greatly increased--hence his big smile. (Picture courtesy of World Neighbors.)

They also maintain high fertility so that plants produce abundant soil cover and organic matter. The best case is well-managed minimum tillage.

Poor cultural practices leave the soil bare of vegetation so that the rainfall can pound and compact it. The worst case, of course, would be planting row crops up and down the slope of the hill.

What Should Be Done about Runoff Water?

Whatever the method of erosion control, surplus runoff water must be dealt with. The amount of rainfall, the infiltration rate and erodibility of the soil, and steepness of the slope determine whether or not the field needs contour drainage ditches and exit drainage ditches. Usually some drainage control ditches need to be installed. Provisions must also be made to handle the runoff from very large rainstorms which may occur only once in several years.

THE RAINFALL AND THE RAINFALL CALENDAR

Why Do You Need to Know about Rainfall in Your Area?

In order to help the farmer plan, you will need all the information about local rainfall which you can find.

- Cropping plans may help you to have the maximum vegetation growing and spreading its leaves, protecting the soil from raindrop splash ~ heavy rains come. The knowledge you learn from your rainfall calendar will help you set up the most desirable cropping plans. You might use the rainfall data to suggest how traditional planting and harvesting dates can be modified for better conservation. However, this is always a challenge, since so many other responsibilities in the farmers' lives can be affected.

- Other erosion control practices also depend upon weather knowledge and planning. For example: When is the best time of year to begin and when to complete terraces? When should you start contour drainage ditches--when have them finished? When should you plant live barriers for best germination and growth? Terraces and ditches should be finished well ahead of the rainy season; seeds need to be planted at the beginning of the first gentle rains.

How to Make and Use a Rainfall Calendar

1. If available in your host country, get data for national and area rainfall from the nearest weather station and from your host country's Bureau of Climatology or other appropriate agency. Get rainfall intensity data: how much rain falls during peak storms and how much total rainfall for each given month. You may be able to locate climate maps and/or tables somewhere. Consult government experts if they are available. Learn all you can about area rainfall and erosion from other PCV's, your PC Associate Director of Agriculture, etc.

2. Consult local farmers and village leaders. Learn what they know about rainfall in their local area; this may be the best information you are able to find. When do peak rains fall? How heavy are they (mm/ hr)? How long is the rainy season? The dry season?

3. Begin keeping your own rainfall record book. Later transfer all pertinent rainfall data to the calendar. (See the Appendix--the Tool Kit for instruction on measuring rainfall.)

- If data is available, determine the average rainfall that occurs each month of the year and the total amount. What seems to be the year to year variation?

- Look at the ~ the very dry or very wet months. Consider these and the total annual rainfall to understand the local cropping practices and to make plans for soil conservation activities.

- Determine the length of the dry season, and whether the area has one or two wet seasons. With two seasons, do farmers practice double cropping? What different crops are grown?

4. Memorize your bar graph calendar, and keep asking questions of farmers and village leaders. How long after the early rains (planting time) do the really heavy rainstorms begin? This is important to know. The longer the crop has been growing, the larger the plants will be, and the more they will cover the ground to protect from the raindrop splash of heavy rains.

5 If local rainfall data is not available, begin a long range rainfall data gathering project. Get other PCV's from different areas to work with you. Arrange to pass this project on to others when you leave. This is important information. (See the Appendix--Tool Kit.)

A SPECIAL WORD BEFORE YOU START CHAPTERS 3 AND 4

You are all set now to get out in the field with the farmer. Although many of the conservation methods in the following chapters will be strange to him, they will sell themselves--if they meet the small farmer's really desperate needs.

Small farmers often exist at a subsistence level. Frequently they and their families stay only one step ahead of starvation. They cannot afford any risk, even of labor, without something extra to show for it.

Motivating Small Farmers to Use Erosion Control Methods

For long-term success, increased crop yields must accompany erosion control methods. The farmer's crop yields should increase the first year, if possible. If yields haven't increased by the second year, you've lost him. On the other hand, if yields increase significantly, he will be eager to continue and will proudly demonstrate his successes to his neighbors.

The soil-protecting methods in this manual do increase crop yields under good planning and management.

Increasing soil fertility must go along with soil conservation. This is urgent! Be sure to consult the excellent book by David Leonard, Soils. Crops and Fertilizer Use (Peace Corps Reprint R0008). It is an invaluable guide to methods of increasing soil fertility and crop yields.

TWO APPROACHES TO REDUCING SOIL EROSION AND WATER RUNOFF

There are two approaches to controlling soil erosion. Both are important. Often the farmer in the tropics needs to combine them to get maximum protection. Farmers should aim for as near zero erosion as possible if the soil is shallow. Hillside tropical soils are likely to be just that.

Whatever approach you use, keep the farmer's interest focused on the value of the topsoil. Field research around the world has demonstrated that the deeper the topsoil, the higher the crop yield; the more topsoil lost to erosion, the more topsoil lost to erosion, the smaller the yield. Farmers who realize this relationship will usually be highly motivated to save their soil.

ONE APPROACH: <u>Changing Degree of</u> <u>Slope and Length of</u> <u>Slope: Changing the Physical Shape of</u> <u>the Land</u>

Changing the degree and the length of the slope do not in themselves prevent raindrop splash erosion. They <u>hold the rainfall water in one place</u> after the rain has hit the soil, or else they <u>slow the speed</u> of the runoff, thus minimizing erosion.

This approach treats the <u>symptoms</u> of the disorder by various physical changes to the land. If the farmer can keep the water from running off, or can slow down the speed of the runoff enough, much of it will soak into the soil. In addition, many of the soil particles held in suspension will have time to settle out and drop to the soil surface before they are removed from the farm.

A SECOND APPROACH: <u>Dissipating Raindrop Splash Energy</u>

With this approach, farmers <u>cover the soil</u> and screen it from the force of raindrop splash. Thus the soil is <u>protected from the force of large raindrops</u> and the raindrop energy which initiates erosion. When this is done, erosion usually does not take place.

This approach seeks to <u>prevent</u> the disorder, to keep erosion from occurring in the first place. The farmer keeps live or dead <u>vegetative cover</u> on the soil whenever possible. He can also try many <u>crop management techniques</u> which help do this.

Chapter 3 (and later chapters for special situations) will look at the ways of combating raindrop splash.

Chapter 4 will deal with ways of changing the slope (percent slope and length of slope) of the land. It will also discuss drainage ditches in detail.

<u>Is Water Runoff Control Necessary with Either Approach</u>?

Yes! Whatever the method of erosion control, <u>any surplus runoff</u> water must be dealt with. The amount of rainfall, the slope of the land and/or the infiltration rate of the soil determine whether or not the field needs contour drainage ditches and exit drainage ditches to handle excess runoff. Usually some system of ditches for drainage control is needed.

CHAPTER 3

COMBATING RAINFALL SPLASH EROSION WHILE INCREASING CROP YIELDS: KEEPING THE SOIL COVERED TO PREVENT EROSION

The Benefits of a Live or Dead Vegetative Cover on the Soil

- It forms a protection or screen over the soil, dissipating the force of raindrops.
- It decays with time, forming organic matter, improving soil structure, raising the rate of water infiltration and increasing soil fertility. It helps prevent depletion of the soil.
- It shades the soil, reducing soil temperature, and thus evaporation of soil moisture.
- It increases plant root growth because of lower soil temperature and better soil moisture during hot weather.
- It can produce a net result of increased yields and lessened erosion.

Does Soil Cover Really Prevent Erosion Significantly?

Even partial soil cover effectively protect the soil. Research studies show that when even 40% of the bare soil surface is covered uniformly, 90% of the potential erosion does not occur.

Certainly then, under field conditions, if adequate depth of field trash or mulch is distributed over 50% of the surface, more than ~ of the potential erosion will not occur. Some of the minimum tillage techniques can achieve near zero erosion. So can a complete thick mulch or a grass sod.

Good Ways to Protect the Soil with a Cover

- Mulch; field litter
- Minimum tillage
- Green manure cover crops
- Agroforestry
- Alley cropping

- Arranging crop planting dates, crop mixtures and sequences so the soil has a crop canopy (leaf cover) when the high intensity rains occur.

- Maintaining high soil fertility for quick and profuse leaf spread, and, later, more organic matter in the soil due to increased vegetative production.

FIELD LITTER

How to Use Field Litter to the Maximum

1. Do not burn the fields before planting.

2. Leave crop residues (stalks, leaves, clippings or trimmings) on the ground after harvest. Leave old plant root stubble in the soil to anchor it.

3. Be a mulch farmer. In some experiments, heavy straw mulches (rice straw, wheat straw, or dead grasses) have completely protected the soil, resulting in zero erosion and increased yields! (But remember the extra yields do not materialize unless the soil is very fertile, or made and kept that way. Use recommended amounts of manure, compost and commercial fertilizer.)

MULCH

Mulch: What Is It?

A mulch is composed of dead plant material: straw, harvest litter, grasses, leaves, manures, compost, used alone or in combination.

How to Make and Use Mulch

1. Leave the stalks and leaves on the field after harvest. Find additional mulch: strip leaves from trees growing nearby, bring rice straw from fields in the lowlands to use on sloping fields, get straw or harvest trash from neighbors.

   Caution: Do not use diseased plant residues in mulch.

2. Prepare the soil for planting, and do not burn the trash. Some of the stalks can be turned under and some left on the surface.

3. Properly fertilize & the soil--for more crop yield, more fast-growing leaves to cover the soil, and more organic material .for mulch next year.

Figure 3-1. Maize leaves intercepting raindrops. You can actually see the plant leaves break up large raindrops into harmless small ones which do not erode the soil.

These corn leaves are near enough to the soil surface to act as good protection. Corn which is not close together, however, will cover only part of the soil. (Picture courtesy of Soil and Water Conservation Society.)

4. Cover the soil: spread compost and available straw, leaves, etc. on the soil surface. Ideally the mulch should be spread about 10 cm thick.

5. Plant through the mulch, using a dibble stick, or if you use a hoe, make a very narrow trench or hole for the seed.

MINIMUM TILLAGE

What is Minimum Tillage?

Minimum tillage leaves a nearly undisturbed layer of vegetative cover on the soil at all times. When the farmer plants his crops, he breaks up the soil as little as possible. He leaves most of the soil intact and covered. The farmer tills only a very narrow seed bed, just the minimum space needed to place and mix fertilizer and compost with the soil, and to plant seeds or insert seedlings.

Methods of doing minimum tillage vary. The degree of slope of the land (whether steeply sloping or nearly level) and the needs of the farmer will determine what modifications are needed.

Why Use Minimum Tillage?

- Minimum tillage provides all the advantages of a good soil cover. In fact, it provides them so well that some farmers can achieve zero erosion.
- Under the right management it greatly reduces labor, as compared to conventional methods.
- It makes a cumulative, progressive improvement in the soil organic matter and soil fertility year by year.
- Minimum tillage can produce significant increases in crop production if fertility is adequate.

Is Minimum Tillage Feasible?

When research on this idea began in the United States in the 1960’s, some people called it “Carpet Farming” (planting crops through a sod or mulch carpet). Today, farmers in the United States grow many millions of hectares of crops using some type of minimum tillage.

Minimum tillage has now come to the small hillside farmers of Central America, Indonesia and other developing countries. I recently visited a large number of farmers in Honduras who are using minimum tillage on hillsides with great success. Most had been trained by Peace Corps volunteers or by World.

Corn—oats—meadow—rotate—Contour]

Corn—oats—meadow—rotate II

Corn—oats—rotate

Continuous corn

I I I I

0 50 100 150 200 250

Annual Soil Loss (tons/hectarWyear)

Figure 3-3. Effect of continuous maize on erosion of soil compared to grass sod and rotation treatments.

The beginning of minimum tillage research: Early soil conservation field research in the United States showed that a healthy grass sod had insignificant erosion, as the results for blue grass pasture indicate here. Field research also showed then, as it does today in the tropics, that growing maize by itself on a sloping field resulted in extreme erosion. However, different rotations and contour farming reduced erosion.

Many researchers began to envision some form of minimum tillage which would allow the soil to remain covered, as in the case of grass pastures, yet allow maize or other crops to grow on the field, protected by a biological carpet. Research on various approaches to minimum tillage began in the 1950’s and early 1960’s. Minimum tillage is used on many farms in the U. S. today. (Modified from D. D. Smith et. al.)

Figure 3-4. Minimum tillage in the United States. Here we see soybeans planted' in narrow rows in a wheat field immediately after wheat harvest. The field is not plowed. The soybeans are planted in very narrow seed beds, leaving wheat straw and stubble between rows. (Picture courtesy of Soil and Water Conservation Society)

Neighbors extension workers. The particular form of minimum tillage called "in row tillage" was developed by World Neighbors. This farming technique works well on hillsides. It is simple and can be carried out with tools which the farmers have always used. Thousands of small hillside farmers now use in-row tillage.

In-Row Tillage: A Form of Minimum Tillage

What Is In-Row Tillage?

- Using this method, the farmer digs narrow rows of soil going around the bill on the contour. The rows are 1 meter apart. Each year he cultivates only the same narrow strips, and plants his crops in them. He leaves space between the contoured rows untilled, covered with native grass, and unfertilized.

- The idea is to build up the organic matter, fertility and soil structure in the narrow cultivated planting rows as the years pass. The soil in them rapidly develops increased rooting depth, superior soil tilt and good organic matter content, becoming more and more fertile and productive.

- The uncultivated part left in native grass (the rest of the 1 meter space) protects the soil from raindrop splash with a good grass cover. At the same time, the matting of grassroots helps hold the soil in place on the hillside.

Note: This system works best where soil moisture is not limiting to plant growth.

How to Establish In-Row Tillage

Most of the following instructions are based on experience in the field by World Neighbors workers in Honduras and elsewhere. They have been field tested by many hundreds of small-scale tropical farmers under observation.

1. Since in-row tillage is contour farming, the farmers must learn how to construct and use an A-frame device so that their contour rows are level. See Appendix A, The Tool Kit, for instructions for making an A-frame.

2. As with most erosion control farming schemes, begin work at the ton of the slope. Otherwise, flood water coming from above may destroy your work.

3. During the dry season, construct an upper drainage contour ditch (diversion ditch) at the top of the field to protect the work from flood waters coming from neighbor's land above. It should have a 1% slope toward the exit drainage ditch.

4. Begin minimum tillage immediately below the ditch. Do not cultivate anything except the narrow planting row.

5. Dig other contour drainage ditches as needed, depending on the rainfall situation, soils and slopes. (See Chapter 4.)

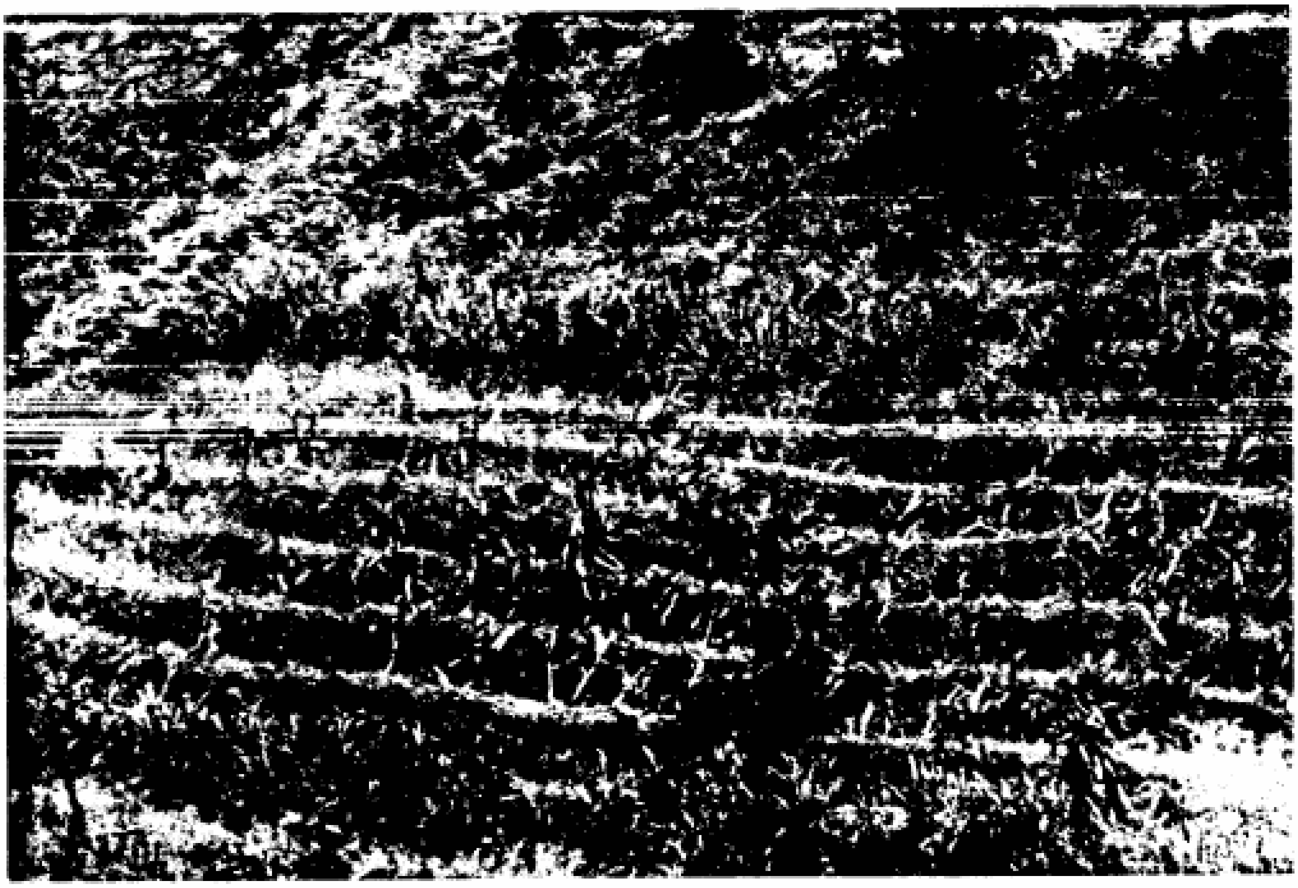


Figure 3-5. Minimum tillage (in-row tillage), Honduras. This picture taken in the dry season in Honduras shows last year’s corn stalk stubble standing in the in-row’ rows where they grew. Notice the excellent grass cover over the area. When the next crops are planted in the same row, only the very narrow band will be dug up (about 25 cm. wide) and compost, manure and commercial fertilizer mixed into the seed bed. The other 75 cm width space will not be disturbed. The narrow planting row is always the most inside part of the total 1 meter space. You can barely see a diversion drainage ditch just above the first row of corn. (Picture by author.)

6. Run the first few contour rows with the A-frame. Space the rows. 1<u>meter apart.</u> Hopefully, this field already has a native grass growing in it. Use a long knife to trim the grass back and partially clear the contour rows. Save the cut dead grass to be used as mulch later. Dig only the narrow strips, nothing else.

7. If a native grass is not already covering the area, the fanner will need to plant low-growing grasses in the spaces between the narrow rows. A <u>good grass cover is essential</u>.

8. Begin to dig the first row. Its width should take up only about 25 to 30% of the distance from the beginning of one planted row to the next planted row (a strip 25 to 30 cm wide out of each 1-meter spacing).

9. Suppose the farmer is working in a field with a 40% slope. He actually digs into the hillside, keeping the row vertical as he digs down. He takes great care not to lose any topsoil. He carefully keeps on the contour.

   The result is <u>a narrow row</u>, worked so that <u>the bed is level and about 25 cm deep as well as 25cm wide.</u> This uses only about 1/4 of the 1 meter wide space. The remaining 3/4 will stay in native grass.

10. Remove stones and plant roots, etc. so that a seed bed can be prepared.

11. Begin the seed bed. World Neighbors recommends using a “V’ (letter V) shaped hoe With this hoe, the farmer can make a “V” trench or furrow along the length of the contour row on the <u>inside (the uphill) part</u> of the cultivated planting bed. This helps concentrate the fertilizer and moisture in the row exactly where the plant roots can get maximum use of the fertilizer. It also keeps fertilizer from washing off the outside edge.

12. After finishing this first demonstration row across the hillside, dig a second contour row one meter below it. Continue in like manner down the hill, with rows about 1 meter apart. Be sure the rows are level, i.e., on contour.

13. Add extra contour drainage ditches as needed to take excess water away.

14. <u>Very important:</u> Stress to the farmer that the space <u>between</u> the <u>narrow seedbed rows</u> must <u>not be tilled</u>, so that the growing grass protects this soil with cover and prevents rain drop splash erosion.

15. Now apply plenty of fertilizer. Apply manure and/or compost and some commercial chemical fertilizer. Following a <u>good fertilizer recommendation</u> is a must! If commercial fertilizer is not available or feasible, use plenty of manure, compost, and leaves from legume trees if available.

    Spread the fertilizer in the bottom of the trench and <u>mix well with some topsoil.</u> <u>Do not fertilize anywhere else,</u> <u>only in the ‘V’ furrow</u>.

16. Cover the fertilizer with some more topsoil or compost.

17. The seed bed has now been prepared. The width of the tilled row is about 25 cm, and the depth of the tilled row is about 25 cm (about one and one-half hands).

18. Plant the seed. Cover the seed with topsoil. Then <u>add some dead grass</u> mulch on top of the row to

protect it from the rainstorms.

19. Use some mulch on the narrow row, but leave enough space for the plants to emerge.

20. After the rains begin and the grass begins to grow, prune the grass between the rows with a knife as needed to keep it from shading and competing too much with the row crop.

21. <u>The next growing season, use the same narrow rows</u>. Never destroy the grass strips between--only prune the height with a knife.

22. Each year, use plenty of <u>organic fertilizer</u> (manure, compost, etc.) and some <u>commercial fertilizer</u>. Leaves from legume trees (live barriers) containing much nitrogen fertilizer can be stripped from tree trimmings to be used in the trench row also.

23. Depending on the steepness of slopes, the farmer may choose to include a few <u>rock barrier walls</u> or <u>some legume tree live barriers</u> in the field, placing them above a drainage ditch in each case.

24. Use crop rotation if possible. For example, plant the row to beans one season and to corn the next. If the rainfall season permits, when the food crop has matured (but long before harvest), plant a second crop (hopefully a green manure crop) in the row with it. By the time the first food crop is ready for harvest, the second crop will have emerged and will be growing to provide soil cover and extra income. (See “green manure crops” later in this chapter.)

Figure 3-6. Close-up view of minimum tillage. This hillside farmer is preparing the seedbed (the narrow inner strip) with his right foot on the grass-covered walkway of one row and his left foot on another. The dark area beneath his right foot is the bank which borders the cultivated strip. (Picture by author.)

Figure 3-7. Minimum tillage--in-row tillage. The grass cover is dormant because the photo was taken in the dry season. This particular farmer has tripled his maize yields while protecting his farm from erosion. (Picture by author.)

Special Advanta2es of In-Row Minimum Tillage

- As with other forms of minimum tillage, in-row tillage increases crop yields, usually greatly.

- Organic fertilizer-manure-compost (and recommended chemical fertilizer) is concentrated in the rows. Therefore these bands of soil become extremely fertile--more so each year.

- The fertilizer is not spread widely. This saves fertilizer costs. It feeds crops, not weeds.

- The grass-covered area acts to prevent erosion. The rows (tilled and untilled) become micro terraces (grass covered).

- Farmer experience shows that minimum (in-row) tillage, once it is established, often requires only 1/2 the amount of labor as conventional tillage.

- The farmer can walk easily on the outer edge so he can do his field work on the contour (whether pruning back the grass, planting the seed or harvesting). By walking on the outer edge, the farmer does not compact the tilled row by foot traffic.

- Post harvest trash (leaves and stems of crops) is used instead of wasted. Some is chopped and worked into the seed bed. Some is used to cover the freshly planted narrow rows each year.

In-row tillage is truly minimum tillage, maximum yields and maximum soil protection from splash erosion.

Note: In addition to my own observations and field advice from Peace Corps and World Neighbors workers in Honduras, these instructions are based on World Neighbors publications: (1) World Neighbors in Action Newsletter In-Row Tillage (2) World Neighbors filmstrip (in English or Spanish) entitled In-row Tillage--Maximum Yield from Minimum Labor

COVER CROPS--ESPECIALLY GREEN MANURE COVER CROPS

What Is a ‘Cover Crop”?

A cover crop has special ground-covering characteristics--the crop spreads widely and quickly, and should have dense, large leaved foliage. It is planted to provide cover for the soil and also for food. It can sometimes be planted by itself to cover bare ground, or in the middle between rows of other crops, or as part of a crop rotation.

Figure 3-8. Hillside garden near the farm family home. A combination of in row tillage and a small step terrace with riser wall made of rocks. Notice the small bench terrace on the extreme upper left. (Picture by author.)

Often a cover crop is used as a companion crop. In other words, it grows well with a chosen row crop (such as maize), and is planted between the rows.

Planting row crops in combination with a cover crop works especially well in regions with adequate rainfall. It also is effective if the rainfall pattern allows double-cropping (i. e., growing and harvesting two crops one after the other during the year, as opposed to growing a single crop). Even planting two tall-growing food crops such as maize and cassava together has advantages. Not only is more food produced in the space but more leaves are spread over the soil to catch the raindrops and reduce erosion.

One example of a cover crop is a grass (or a grass and legume) sod which covers the soil in an orchard of fruit, palm oil or rubber trees. The grass carpet, composed of perennials, covers the soil. If the cover crop is a grass and legume mix, the low-growing legume will produce enough nitrogen for itself and the grass.

What Is a Green Manure” Cover Crop?

When the cover crop is a legume we call it a green manure cover crop. It has three special characteristics: (1) It acts as ~ to intercept rainfall since it grows rapidly and is very leafy. It is usually planted as a companion crop which covers the soil between rows of crops (2) It is a 1~~um~ which produces much nitrogen fertilizer and large tonnages of green organic material to become soil organic matter. (3) It also usually produces some family food or animal feed

What Makes Legumes Special?

The nodules on legume roots house millions of *Rhizobium* bacteria which take nitrogen from the air and make nitrogen fertilizer from it. ‘Nitrogen-fixing legumes can furnish enough nitrogen for their own needs and also return a lot to the soil. Under the right conditions an excellent legume can produce 20 to 30 T/Ha of green plant material for organic matter, and 150 to 200 Kg/Ha of nitrogen fertilizer per year.

Green Manure Cover Crops: A Boon to the Farmer

Green manure cover crops are wonderful multipurpose tools. You will want to recommend them if you can find one which works well under local conditions. It can prove to be worth many bags of fertilizer for each farmer.

- A green manure crop provides all the benefits of a good soil cover (controls erosion; increases the rate of water infiltration; lowers soil temperature, and thus reduces evaporation).

Figure 3-9. Velvet Beans--a good green manure cover crop. This fast-growing climbing bean spreads out quickly over the soil, giving excellent protection from intense rainstorms. It grows well with corn. When the corn is mature, Velvet Beans climb over the corn stalks and continue to grow for several weeks, yielding dry beans, green foliage, and extra nitrogen fertilizer. (Picture by author.)

- At the same time, it directly <u>improves soil fertility</u> at a rapid rate.

- When used with recommended water and soil conservation methods, many farmers get very <u>good food crop yields</u>, in many cases 3 to 4 times the former yield.

- The organic nitrogen fertilizer <u>crows at the site</u>. It does not require special transportation from store to field as commercial nitrogen fertilizers do. It does not need to be purchased.

- Green manure cover crops <u>produce abundant organic matter</u>. The soil organic matter increases in amount and depth in the fields, increasing rooting depth and soil fertility.

- Some farmers leave the green manure crop on the surface as a mulch.

- Green manure crops can often reduce the length of time that depleted land must lie fallow from a number of years to about two or a little more. Note: In ~~me cases, phosphate fertilizer or manure may be needed to establish the green manure crop on very poor soils.

- Some green manure crops <u>produce yields</u> themselves for <u>food. feed and extra income</u> from seeds or by-products.

- The <u>expense is small</u>. The farmer's only financial cost will be for seed the first year. He can save seed from the first cover crop to plant the following year.

- The <u>labor needed</u> including that for weed control, <u>is minimal</u>. Often the thick, spreading leaves of the cover crops shade out weeds so they can't grow, reducing labor costs.

- Green manure crops can shade the soil for as many as eleven months of the year (important in tropical climates).

<u>How to Choose a Good Green Manure Crop</u>

Look for as many as possible of the following characteristics:

- It should be a <u>fast-growing legume</u> which <u>grows well in a poor soil</u>, if possible without the addition of fertilizer.

- It should produce <u>large amounts of green foliage--20</u> to 30 tons each year. The foliage should be <u>low-growing</u> and should <u>spread out</u> to cover the soil.

- It should <u>manufacture large amounts of</u> <u>nitrogen</u> (100 to 200 Kg. per hectare per growing season).

- It <u>germinates readily</u> and is <u>easy to plant</u> with little soil preparation (can be dibbled into the soil or broadcast over it).

- It should do well with the food crop to be grown with it.

- It is <u>not highly susceptible</u> to plant diseases or insects.

- The grain crop grown in the same soil the following year should show a sizably larger yield.

- It may produce a crop which provides feed, food, or cash income.

- It should be drought resistant if it is to be planted late in the rainy season and will grow partly in the dry season.

- It should be shade tolerant if it is to be planted early and grown with tall-growing plants or those with wide-spreading branches.

- Seeds or plants of the chosen variety should be readily available in quantity. Hopefully, some good alternate varieties are also available, so that the farmer can plant more than one kind together.

- The combination grain crop-green manure cover crop together should control soil erosion, increase water infiltration and maximize grain yields (assuming contour ditching and other recommended conservation practices are followed).

  Note: You may not be able to find a legume with all of these advantages. The choice will depend on the seed supply and the farmer's priorities and needs.

How to Locate Suitable Species of Green Manure Cover Crops

1. Begin by looking at Table 3-2, a list of suitable green manure cover crops. (Check the Appendix for sources of seed.)

2. Discuss these with successful farmers in the area, and with the local government specialists, Private Voluntary Organizations, your APCD, and senior PCVs.

3. Look for a successful legume plant growing locally. You may find a good local bean already being used for food.

4. If you still need help or a source for seed, see the names and addresses in Appendix C.

Table 3-1. A List of Green Manure Cover

Stizolobium (Velvet bean) Mucuna pruriens	Main...Use Cover crop and green manure Same	Drought Resistance
		medium, prefer distributed rains Same
Lablab prurien (Lablab bean) Dolichos lablab (Lablab bean)	Cover crop and Green manure Same	Highly resistant; grows during dry season
Vigna unguiculara (cowpea)	Cover crop, Green manure	Highly resistant; some varieties produce fast.
Cajanos Cajan	Leaves can be used as green manure.	Highly resistant.
Vigna aconitifolia (moth bean)	Food and hay; cover crop	Extremely so; forms mat on soil surface
Canavalia ensiformis Cjackbean)	Cover crop and green manure	Highly resistant
Canavalia gladiata (sword bean)	Excellent green manure cover; for age	Yes
Phaseolus lunatus (tropical lima bean)	Food-- also excellent green manure cover crop in hot humid lowlands. Not for low pH soils.	More research needed; once established, resistant to drought
*Compiled from World	Neighbors information and	Tronical Levumes: the Resources

Human Consumutiori	Fodder Value	Comment
As refried beans, in tortillas, and as coffee substitute.	Cows, goats, pigs and rabbits eat it well	
Seeds can be eaten green (like garden peas) or dry (like dry beans)	Animals prefer it over other species	
Green pods and dry seeds	Eaten by some animals	
Dry seeds	Animals eat leaves and tender parts	
Yes--bean is excellent food. Dry seeds.	Good hay	Commercial crop in dry areas of India. Shades soil. Grows as mat on soil surface. Plant as second crop or with other food crop. Needs considerable moisture to establish. Once established, is deep-rooted and drought resistant.
Tender pods; white dry seeds	Cattle eat it but prefer other species. Is preferred where dry season is a problem	Grows at 14C to 27C. Rainfall 4200 to 700 mm. Prefers full sunlight but tolerates shade. Altitude: sea level to 1800 M Soil: pH 4.3 to 6.8. Yields: Green weight 30 to 50 T/Ha.
Young leaves and green pods, but mature beans boil and can be eaten if cooking water changed 2 or 3 times.	Same as Jack bean (See above)	As with Jack bean, grows under wide range of conditions. Soil pH 4.3 to 6.8. Does best in sunshine, tolerates shade, does well in lowland infertile soils. Tolerates water logging, salinity, and some frost. Altitude from sea level to 1800 meters.
Dry white beans OK. Dry colored beans need very special cooking, changing water once or twice. Toxic if bitter taste. Young pods and leaves OK.	Probably good, since leaves and pods are eaten by humans	Well adapted to lowland usually tropics, especially highly leached infertile soils. Very high yields in lowland tropical rain forest. CIAT in Colombia is growing it with maize. Yield: 1 to 2 tons beans 5 tons corn. Seed pods non-shattering. Altitude: Sea level to 2400 M. Prefers pH 6 to 7

<u>for the Future (National Academy of Sciences). no. 1-108</u>.

How to Plant and Grow Green Manure Cover Crops

The technique is simple: the farmer plants a green manure cover crop between rows of crops such as maize or sorghum. He will follow the planting, growing and harvesting practices recommended for each crop.

Important: Green manure crops are legumes; the seed must be inoculated with *Rhizobia* if the plant or similar plants have not been grown in the field recently. See directions in The Tool Kit.

Crop Combinations and Planting Times.

- Growing certain crops together calls for special crop traits. Crops grown in combination should be mutually compatible and beneficial. For instance, a green manure crop grown under partially shaded conditions should not require full sun.

- An outstanding example of a successful combination is the Velvet Bean grown as a green manure cover crop in combination with corn. Workers for Peace Corps and for World Neighbors in Honduras and some other parts of Latin America give enthusiastic reports on the Velvet Bean. It is well adapted to the region, fast-growing, high yielding in nitrogen, abundant in foliage. The farmer can leave the foliage in place to become mulch and compost.

  At the next planting date the farmer cuts back the dead foliage, and plants corn, which he dibbles through the dead bean leaf-stalk mulch with a dibble stick or hand planter. Under this system, corn yields increase rapidly during the second year. Many farmers who are using the Velvet Bean cover crop system now produce 2 1/2 to 3 tons per hectare of maize grain without buying any nitrogen fertilizer. By also adding commercial fertilizer they usually produce much more.

Do Green Manure Crops Reduce the Land Area Available for Food Crops?

- If the green manure cover crop is planted properly, the land area is usually not reduced. Planting crops between row crops does not take additional space. (This would not be true with the typical dense planting of corn often found in the United States.) Such row crops as maize and sorghum grow above low-spreading cover crops with no loss of space.

- Certain green manure cover crops can grow under or around fruit, nut, or coffee trees, to the benefit of the trees.

- If a fast-growing legume competes with a corn or grain crop too early, the farmer can prune the growing bean tops lightly.

- Where farmers ordinarily leave land to lie fallow, or shift to other land, planting green manure cover crops will greatly shorten the time to return the land to productivity.

- Even if some minimal land space is lost initially due to intercropping, green manure cropping increases fertility, which in turn soon increases crop yields. The row crop yield should not usually drop even the first year unless soil moisture is limiting. Yields should increase substantially the second and third years. Furthermore, the green manure crops themselves often provide additional food or feed.

- The farmer can sometimes delay the planting some cover crops a bit so that they continue to grow during the dry season when the land is ordinarily idle.

Good Ways to Utilize the Green Manure Cover Crop

- Some farmers often plow this growth under before the next planting time. Although this exposes the soil somewhat to rainfall splash, it speeds up the breakdown of the material into organic matter.

- Many other farmers cut down the dead stems and leaves before food crop planting time, leaving them on the surface without tilling the soil. This makes an excellent protective carpet. They then plant seeds or seedling through the carpet. This is an efficient minimum tillage technique.

COMPOST

What Is Compost?

Compost is a mixture of green and or dry plant materials, manure and some topsoil, miscellaneous organic materials such as vegetable peelings, even a little commercial fertilizer (if available), to which some water is added. Soil microbes convert this within one to four months into a very good organic fertilizer, one which the farmer can produce right in his field or at his own homestead.

How to Make Compost

1. The farmer needs a source of plant material, manure, topsoil and water, a knife, a spade, and a bucket. If he wants to make the compost using a wooden frame, he will need wood and nails to make a wooden frame about 25 to 30 cm high to enclose an area of 1 to 2 square meters. This frame is the mold or form in which the compost is compacted. As the stack of compost gets higher he will move the frame higher.

2. The stack should be located in the sunlight and near the garden or field where it will be used. Some farmers locate it near the animals which produce the manure.

3. Gather and stockpile the following materials: crop leaves and stalks, other dry leaves, green leaves from trees and shrubs, straw, grass, legume residues, kitchen peelings. You will need about 1500 pounds of plant materials to make a cubic meter of finished compost. Collect about 500 to 700 pounds of manure for each cubic meter of composted materials. Be sure there is plenty of water and some topsoil you can use.

4. Make the frame: measure and then nail (or otherwise fasten) the boards together. Move it and the stockpiled materials to the chosen location (in the sun, near water (if possible) and near where the compost will be used).

5. Chop the plant materials into relatively small pieces (about 5 to 8 cm long) so that they will decompose quickly. Also, if you loosen up the ground before starting the pile, the drainage will be better.

6. Pile 25 to 35 cm of plant material in a layer on the ground inside the frame. Take out anything which will not decompose, such as rocks, glass bits, plastic. Compact the mixture by walking on it time after time.

7. Add water evenly over the plant material layer. You will need 20 to 30 liters of water for green plant material, but more for dry plant material, about 40 to 50 liters. The layer should be thoroughly damn but not dinning. Too much water will drown the bacteria, and too little will slow down decomposition. The layer should feel well moistened, like a cloth you have wrung out.

8. Cover the first layer with a layer of manure 6 cm to 8 cm thick.

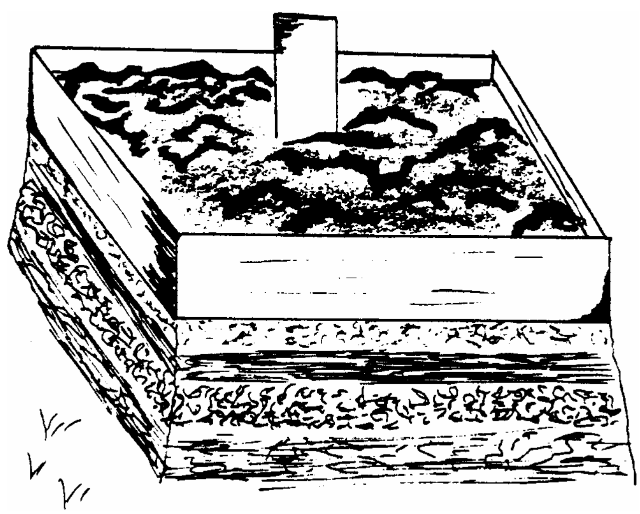
9. Water evenly with another 12 liters of water per square meter, more for dry manure.

10. Insert 12 to 18 cm diameter poles upright in the pile, one in each square meter (more or less). Place the narrower end of the pole at the bottom so that it will come out more easily. In 4 or 5 days, you will pull the poles out. The long holes left vertical in the compost pile become air vents for oxygen and CO_2 to exchange, thus improving aeration.

11. Continue adding alternative layers as described above--a layer of plant material and water, then one of manure and water, and then repeat. Raise the frame as the stack grows taller. The stack should reach a height of 1 - 1 1/2 or more meters. If the stack is too high some layers may fall off the pile. With each layer, insert the posts, then remove them after 4 or 5 days.

12. Top off the stack with about 3 cm of good topsoil.

Build a frame one meter square. Make and compact the first layer in it.



Slide the frame upward as needed to add and compact new layers of compost.

Figure 3-11. Two sketches of compost being made in a frame one meter square.

13. Cover the compost pile with straw, plastic, etc. to protect it.

14. Do not disturb the pile for about 30 days. During this time, much heat will be generated in the stack. Therefore, after 25 to 30 days thoroughly mix the stack, and add more water if it feels dry. Reassemble and repack it; reinsert the poles, again removing them after 3 or 4 days.

15. Thirty days after this mixing, mix the pile again and reassemble as in Step 13. This will be about 50 to 60 days from the beginning.

16. About 3 or 4 weeks after the final mixing (90 days from the beginning) the compost is a rich organic matter-humus complex. It has become a good home-made fertilizer ready to use.

17. Place the compost in the field near where you will work it into the planting bed or the narrow tilled row. Mix thoroughly with the soil in the row.

Other Types of Compost Piles

1. Make compost in a conical stack on the ground, like a small haystack.

2. Make it in a rectangular or round nit in the ground. The below-ground compost pile may be preferable to one above ground in areas where water is scarce or where the humidity is low and temperatures are high.

3. Make compost in a trench or ditch on the contour in the field. This compost would not be turned or mixed, but takes much longer to be ready to use, about 5 to 6 months. Soil is then mixed in and the crop planted into the same trench. I visited a successful small farmer in Honduras who planted bananas this way.

GOOD CROP GROWING PRACTICES: A SUMMARY

1. Develop High Soil Fertility And Keen the Soil Covered. A fertile soil is a less erosive soil. Good farm practices keep more soil.

- High soil fertility results not only in higher yields but in faster plant growth which covers the soil more completely and quickly. Lush, profuse, healthy plant growth makes a thicker cover than sparse, sickly growth.

- Plants grow larger and develop larger leaves sooner. They produce more green matter in tops, stems and roots to form organic matter and mulch. This in turn can improve soil fertility and infiltration rate.

- Plants develop much larger and deeper root systems which search out more nutrients and moisture. This makes them drought resistant.

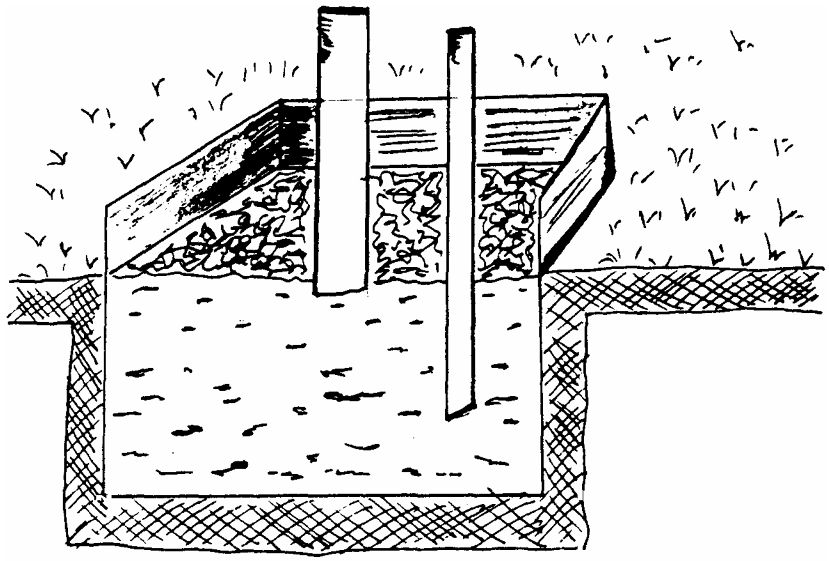


Figure 3-12. Vertical cross-section of a below-ground pit. This rectangular underground pit works well in arid regions where water is scarce and the evaporation rate is high.

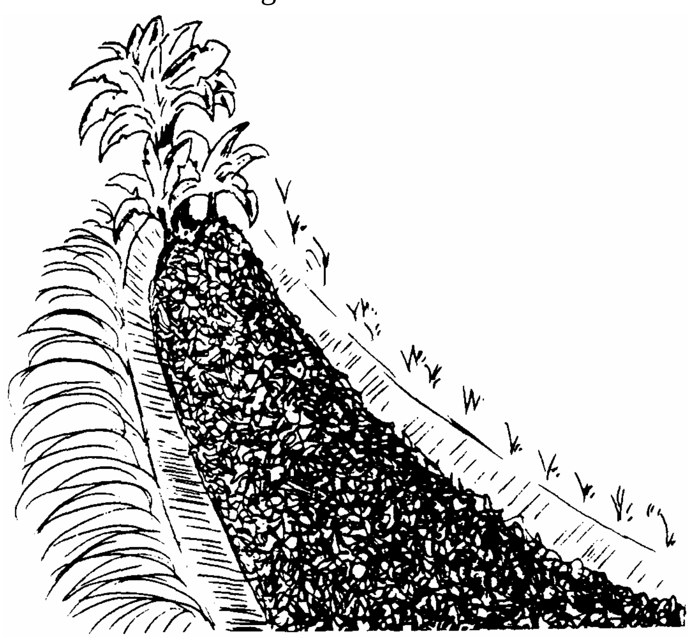


Figure 3-13. A small ditch or trench compost. This makes good soil fertility and moisture conditions for growing bananas in the field or garden. The compost may or may not be turned. If left undisturbed, it takes one or two extra months to finish curing. Then the farmer adds more soil to the compost before planting the bananas in the trench.

- Crops can be planted more densely. The farmer can plant many more plants per hectare, thus better covering the soil and increasing yields.

How to Increase Fertility

- If soil testing labs are available use the tests and follow recommendations.
- Use all available manures and composts possible.
- Grow green manure cover crops that are adapted and produce 100 - 200 Kg N/Ha and 20 - 30 tons/Ha of green material.
- Use crop residues as mulch or turn them under.
- Use recommended amounts of commercial fertilizer.
- Use an appropriate soil and water conservation program so that erosion is no more than 11 tons/Ha/Yr.

2. Use Intercropping

We have already looked at intercropping using green manure cover crops. Here we look at intercropping in which the farmer chooses crops primarily for food or income. By good planning, protection to the soil can also result. Even if the farmer does not use green manure crops, he can use food crops in ways that cover the soil as much as possible. Intercropping with well chosen combinations can help do this. Even a partial cover greatly reduces soil erosion.

Important: Where possible, intercropping with a green manure crops is always best.

- Plant together different food crops of different heights and growing habits. If plants are harvested at different times in the growing season, the crops may provide longer partial soil cover than if the crops are harvested at the same date.
- Grow combinations of food crops together in which:
- the leaves of the crop combinations overlap to form a low umbrella over the soil surface.
- the crops sprout up and leaf out quickly.
- the two crops are compatible. The farmers and you may put your heads together and think of better combinations for their particular location, rainfall, and elevation, as well marketing potentials for various crops.

3. Make a Rainfall Calendar and Apply It.

With the help of farmers, and PCV friends, do your best to fit this to local recommended planting and harvesting dates for different crops. Learn the best planting dates so that maximum growth for cover occurs before the peak rainfall storm intensity comes. Combine your rainfall calendar and your crop management calendar. Farmers will often be eager to help you plan. (Refer back to Chapter 1 for directions.)

Table 3-2. A Comparison of Composting and Green Manure Cover Cropping

Compost	Green Manure Cover Crop
Merely decomposes organic matter a farmer already has on the farm	can add over 30 tons of additional organic matter per hectare to a farmer's system. Since organic matter is often in short supply on small farms or is already being recycled, this is important.
at best, will return to a farmer's field about 98% of the nitrogen started out with.	will add 100 to 200 or more Kg/Ha/Yr of nitrogen to the system.
takes a tremendous amount of work as anyone who has made compost can attest to. In fact, in most Third World countries, it is difficult to make enough for basic grain crops. It will often do well in a vegetable garden, but it is difficult to make enough compost for good yields of field crops like corn and millet.	takes some labor to plant (using a dibble stick), but nowhere the amount of labor of a compost heap In some cases, where the cover crop is intercropped among traditional crops (like corn, sorghum, or millet), it covers the ground so well that one or two weeding operations can be eliminated, thereby reducing the net increase in labor to nothing.
cannot be used as a food, source, either for animals or humans.	can be a valuable food source for both human and animal consumption
cannot be produced in enough quantity to sell any. The farmer will need all he can make for his own garden, plus some for his field crops.	Often can produce enough seed so that the farmer can sell some for cash
usually is placed around the hill or in the row, and worked into the soil. It usually does not form a carpet over the soil surface to protect it from raindrop splash erosion	once established, forms a leafy cover over the surface which catches the large raindrops before they hit the soil. They make an excellent protection. They also increase rainwater infiltration into the soil.

Expanded from World Neighbors in Action Newsletter Vol. 19, Number 2E.

CHAPTER 4

CHANGING THE LANDSCAPE TO CONSERVE WATER AND SOIL

As you recall from the soil erosion equation, the steepness of slope and the length of slope help determine the amount of soil erosion. The farmer can make actual physical changes to the land to modify these two factors. Technologies which lessen the percent and the length of slope can control the rate of runoff flow and save much, sometimes all, of the water and soil.

The Key Consent of This Approach:

The slower that runoff water flows, the less soil it will transport. As the water flows more slowly, there is more time for more water to soak into the soil. Slow-flowing water also allows more particles of soil to settle out and be deposited on the farmer's own field, rather than in the bottom of some river. As runoff water flows more slowly, erosion diminishes.

What Physical Changes to Land Surface Help Conserve Water and Soil?

1. Farmers can construct diversion drainage ditches to divert excess water away from their fields (water coming from neighbor's fields above or from a higher elevation elsewhere on their own farm). These ditches should empty into a control drainage ditch which runs down the hill to exit at the bottom of the hill without erosion occurring. (See figure 4-1.)

2. They can also use contour ditches to catch the water and to hold it or release it slowly, trapping the runoff water and retaining the suspended sediment, thus decreasing erosion. In addition, contour ditches spaced at intervals across the field shorten the length of slope.

3. They can build contour barriers to restrict the rate of the water flow. Barriers reduce the length of slope. Eventually, as sediment accumulates along the upper side of the barrier, the percent of slope lessens also.

4. They can build ~ especially bench terraces, which change both steepness and length of the slope.

Important: In all cases, for any kind of ditches or terraces, a key principle must always be to build them so that the water does **not collect during heavy rainstorms and spill over the edges.** Water washing over the lip or edge of the terrace or contour ditch can quickly form gullies all the way to the bottom of the hillside. This can cause serious damage and loss of the system, which has been built at the cost of many days of back-breaking physical labor.

FARM DRAINAGE CONTROL DITCHES

The farmer should construct a proper, safe water disposal system. Otherwise, the field will become gullied. A good disposal system slows down the flow of the water and carries the excess away.

DIVERSION DRAINAGE DITCHES

The first step in controlling excess water on a field is to catch and divert runoff water from hills or fields above or from the side. Build a <u>diversion ditch at the top of</u> <u>the field</u> (and around the sides of the field if needed to keep other flood waters away from the field). The diversion ditch is a <u>drainage control ditch</u>,

- The diversion ditch must be wide enough and deep enough to handle even the heaviest storms without overflowing.
- The farmer digs the ditch on the contour across the uppermost part of a field. It should be at least 50 to 60 cm deep and 50 to 60 cm wide, with a 1% slope (grade) in the direction of the outlet.
- If more than expected water falls in the heaviest rainstorms, the ditch can be made wider and deeper to handle the surplus water in the next large storm.

Important: <u>Drainage control ditches should empty into an</u> "exit control drainage ditch".

SUPPLEMENTARY CONTOUR DRAINAGE DITCHES

Sometimes excess runoff water accumulates farther down the hillside. The farmer can dig <u>one or two auxiliary contour drainage ditches</u> at a gentle 1% slope to the exit control drainage ditch.

THE MAIN CONTROL DRAINAGE DITCH--THE EXIT DRAINAGE DITCH

The drainage water must all finally empty some place. Sometimes the farmer can find a natural place for the water to empty into, perhaps a small creek or natural gully, perhaps some grass-covered pasture land. If not, he will need to dig a protected <u>main control drainage ditch</u> which goes down the hillside, usually at the edge of the field.

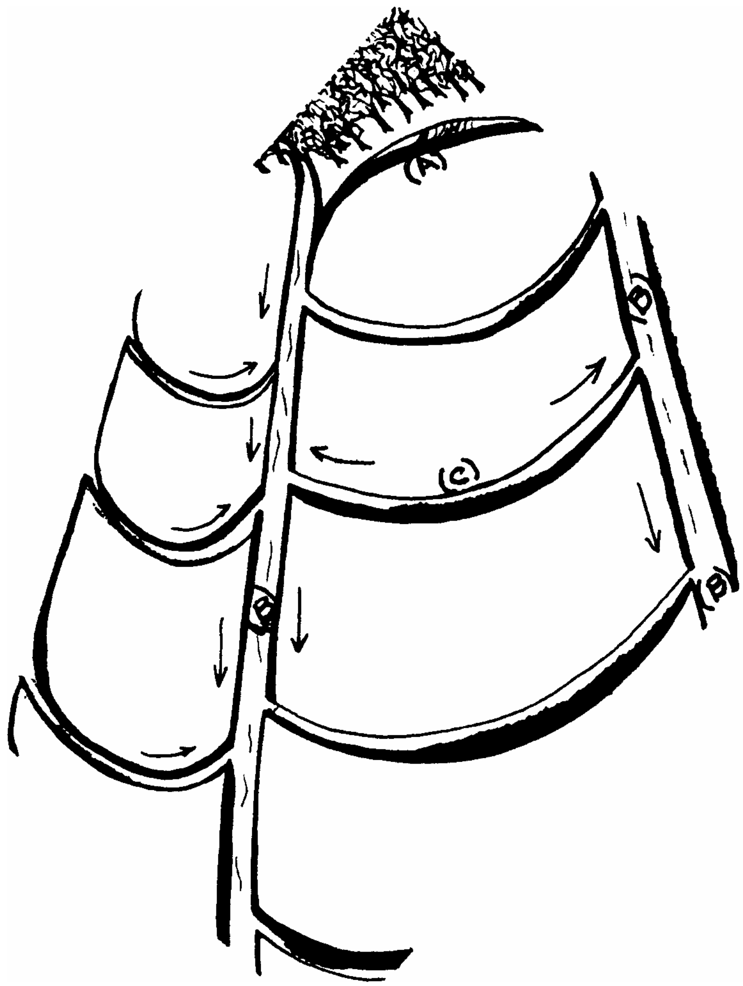


Figure 4-1. The small farm drainage control system with the diversion control ditch at the top (A) which empties into the exit control drainage ditches (B). The supplementary contour ditches (C) catch excess water in the field. They empty it also into the main control ditches (B), which carry all of the excess water away from the farm. (Modified from World Neighbors.)

- At the top of the hill, this ditch can be 50 to 60 cm deep and 50 to 60 cm wide. It should be deeper and wider as it goes down the hill, possibly 75 cm or even 1 meter deep and wide near the very bottom of the field (assuming the size of the field to be about a hectare). The ditch collects and handles a lot more water as it approaches the bottom of the field.

How to Control Drainage Ditch Flow

Water flowing down steep hillsides in a gully or ditch builds up a lot of cutting (hydraulic) force which can quickly deepen and widen the ditch, eroding good soil. The speed of running water in the exit drainage ditch must be controlled.

One excellent water-slowing technique is to build check dams within the drainage ditches themselves. Check dams are small barriers or dams to 'check" the water before it continues down the drainage ditch.

1. With all forms of check dams, take special care that they retard. but do not stop, the flow of the water. Stopping it altogether will cause flooding over the bank of the ditch.

2. Line the bottom and sides of the ditch with rocks. Rock-lined ditches are excellent. (See accompanying sketch.) The rocks must be large enough not to be moved by the force of the water. Observe the size of rocks used on roadside ditches or other farms.

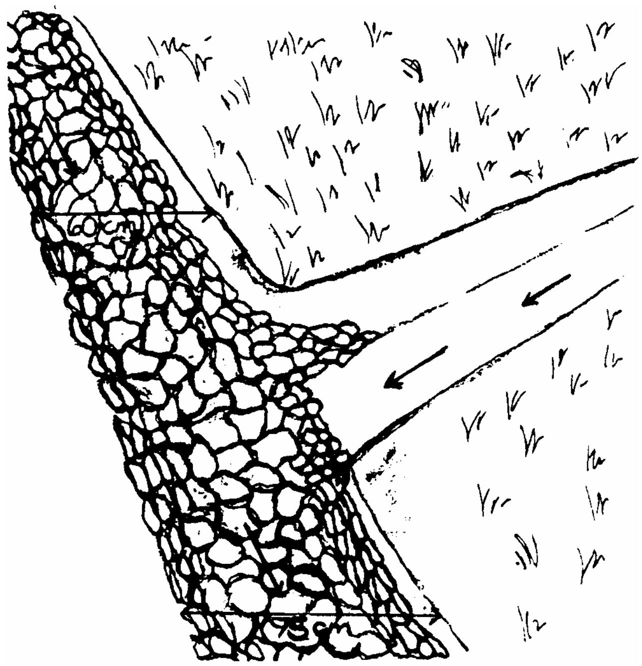
3. Make check dams with rocks or concrete. The top rim of the check dam should be lower than the ton of the ditch bank, so that at peak flood the water will not spill over the bank of the ditch to run wild.

4. When rocks are not available, build check dams from tree limbs and poles. Drive posts or tree limbs into the ground to hold the structure in place, and interweave small limbs, bamboo, vines, etc. through them. (See Figure 4-3.)

5. Stakes taken from a fast-growing legume tree which sprouts easily will grow to form an excellent 1jingsh~k.4~m. Prune the trees as needed.

6. Line the drainage ditch by planting strong, deep-rooted short grasses. This living lining for the bottom and side of the ditch works well if the hills are not too steep. Water flows over the short grass, flattening it down to overlap the grass immediately below it. This acts as a thatched grass roof over the soil to prevent erosion in the ditch.

7. Build the ditch so that the water inside it falls at intervals over steps (vertical drops) and lands in rock basins or log catchments which break the fall and prevent gouging of the soil. In a cross-section view, this looks like a series of small waterfalls separated by slightly sloping 1% stream beds, with each waterfall dropping vertically into a catchmnent basin. When the land is steep the distance between these mini-waterfalls should be short. (Fig. 4-4).



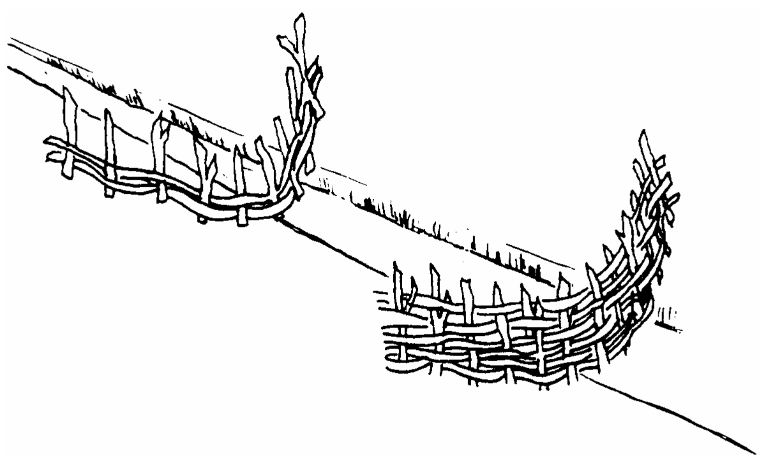


Figure 4-2. Rock-lined drainage control ditch with a small contour ditch feeding into it.

Figure 4-3. Check dams (one under construction) made from tree limbs and vines. This one is poorly designed. The dam wall should ~ rise above the ditch bank. It should be a little below the top of the banks. Otherwise water will flood over onto the adjacent land. (Idea for sketch from World Neighbors.)

- Building the vertical drops in the ditch changes the percent slope and also the length of slope of the ditch. The water will flow slowly over the 1% slope between the mini-waterfalls and catchment basins if they are properly spaced.

- Take two precautions with this system:

- Line the catchment basin floor well with protective cover (rocks, limbs, logs).

- Protect with stones or wood the lip and wall of the ditch over which the water will spill vertically.

Where Should the Drainage Water from the Field Go?

When the water in the exit control drainage ditch reaches the bottom of the farmer's field, it should discharge into a farm pond, or lead to a natural gulf or stream. If this is not feasible, the farmer should consult with neighbors and work out cooperative arrangements to share ditches. Be sure the drainage water does not flood a neighbor's property.

CONTOUR DITCHES FOR BARRIERS

The purpose of these ditches is more to serve as barriers and catchments for water and sediment than to divert runoff water. The farmer usually therefore constructs and locates them differently.

How to Construct Contour Ditches (Catchment Ditches)

1. For deep. nourished soils with good infiltration rates:

- The farmer can construct contour ditches with zero slope to act as a barrier to water runoff. The ditches can be built so they hold all the water and soil particles they catch. The water soaks into the soil; the soil particles stay in the ditch.

- A zero slope is feasible only if the soil is Deep enough and can soak up the water fast enough to hold and store all of the rainfall and soil sediment.

- Even though the ditches are level, they should open into an exit control drainage ditch. In heavy peak storms excess water will then run out of the end of the ditches to spill into side drainage ditches, rather than overrunning the banks of the contour ditches. Remember that small low check dams can be placed in the contour ditches if the water tends to run out of them prematurely into the exit control ditch.

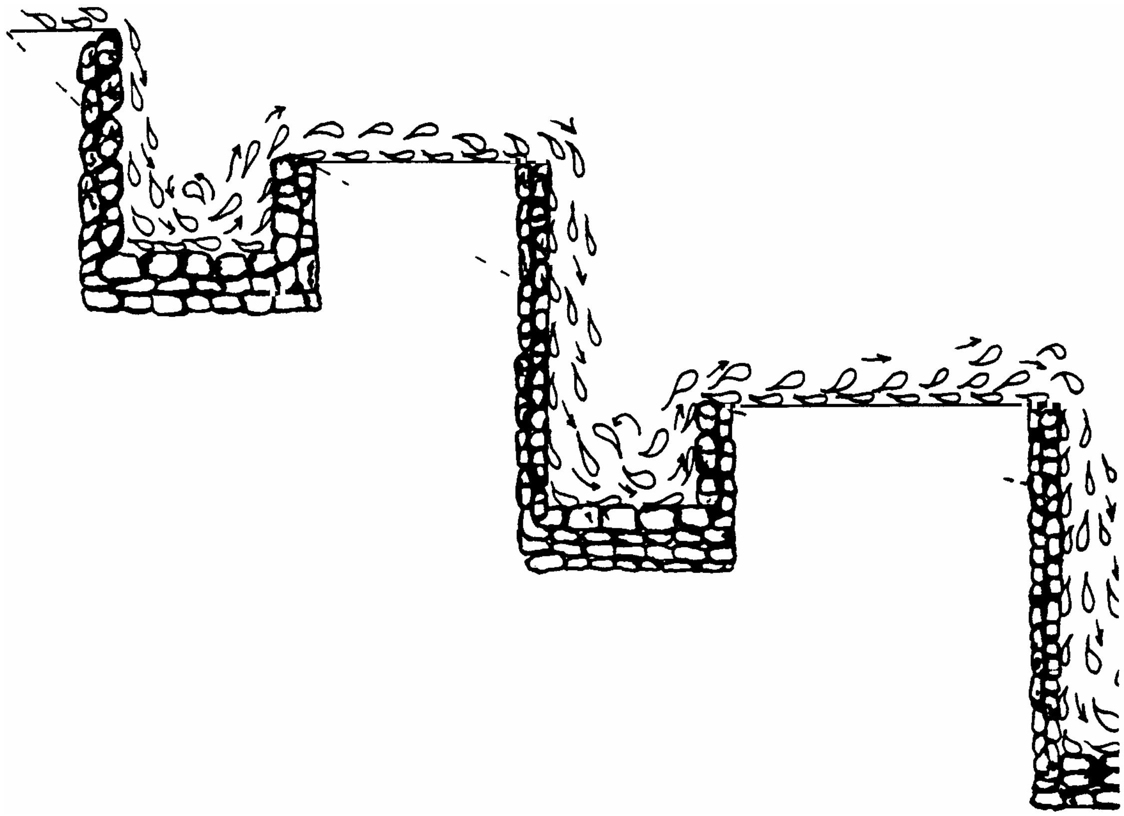


Figure 4-4. Vertical drop check dams made from rocks (vertical cross-section view). The distance between the structures becomes shorter the steeper the slope of the field. Between the drop check dams the water flows fairly slowly and does not erode the ditch sides. (Modified from Soil and Water Conservation Society.)

2. For shallow soils with limited storage capacity, or for heavy soils with low infiltration rate: even though its main purpose is to serve as a barrier, the contour ditch must have a 1% slope (grade) and must empty into an exit drainage control ditch. Otherwise excess accumulated water will spill over and run uncontrolled down the hill. The farmer with shallow soil may choose to use contour ditches as an interim measure while living barriers are being established. (See later in this chapter for a discussion of living barriers.)

3. On moderately sloping land, the farmer spaces the ditches 5 to 6 meters apart. On steeply sloping land he spaces them 3 to 4 meters apart. The steeper the land, the closer together the contour ditches are placed. They should be 40 to 50 cm deep and 50 cm wide. The depth and width remain the same.

4. When digging the ditch, the farmer piles the soil on the lower bank of the ditch to form a dike. This will help keep water in the ditch from spilling over during heavy rains.

5. On the other hand, if the farmer wishes to plant a grass barrier in addition to his ditch, he should throw the soil from the ditch on the upper bank to help form a dike, and should transplant grass slips onto that dike.

   Caution: Contour ditches must be kept clean. They should be cleaned out once or twice a year or more often if needed. Otherwise they will gradually fill in.

Advantages of Contour Ditches

For deep soil with a rapid infiltration rate, contour ditches are highly desirable because:

- They retain and conserve soil and water and effectively work to prevent erosion.
- Level contour ditches, when properly designed and spaced, catch and hold all runoff water and soil particles.
- Contour ditches are an excellent first step in a more complete erosion control system which the farmer can. develop over time.
- The concepts are simple and easy to understand and the ditches are relatively simple and quick to construct.

Figure 4-5. Contour ditches to catch and hold the water and sediment. These contour ditches are effective in conserving rainwater when the soil has a good infiltration rate. Note also the field trash and mulch left as protection on the slopes. (Picture courtesy of World Neighbors.)

Figure 4-6. Contour catchment ditches must be cleaned out so that they remain deep enough to function. If ditches overflow, this can be corrected by closer spacing of ditches and/or digging ditches deeper and wider. (Courtesy of World Neighbors.)

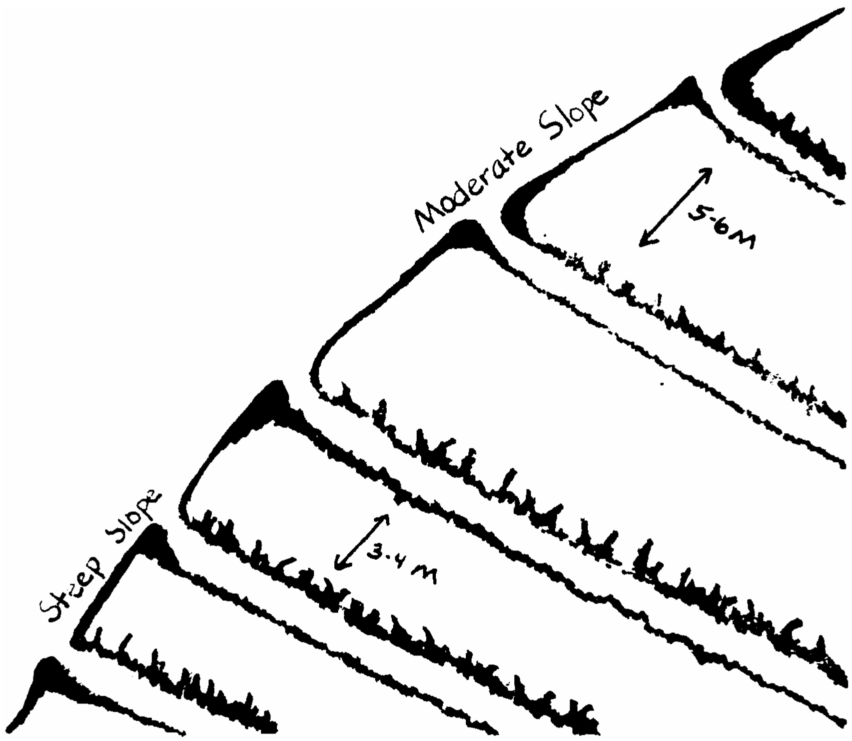


Figure 4-7. Spacing contour catchment ditches. In order to be effective, contour ditches must be closer together as the slope of the field increases, because the rainwater runs into them much faster on steep slopes than on moderate ones. (Sketch idea from World Neighbors.)

• They help increase crop yields if used together with adequate organic and commercial fertilizers.

- They can later be converted into living barriers.

Disadvantages of contour ditches

- They do not work efficiently on very shallow or heavy clay soils except as slow drainage ditches.

- They must be kept clean or they will fill with silt and cease to function.

- Banks must be maintained from time to time to keep them vertical.

Note: Much of the above information on ditches was obtained in the field by visits with technicians and small farmers who were trained by World Neighbors and Peace Corps.

CONTOUR BARRIERS

Contour barriers are live or dead materials placed on contour lines in a field to check the fast flow of water down the hillside. They very effectively stop, or slow and spread, the runoff water so that most of the soil particles are deposited there.

Since slower flow allows more soil particles to settle out, sediment from the runoff water will accumulate on the up-hill side of the contour barriers. Silt, organic matter and clay sediment will gradually build up at their base. Gradually a bench terrace with a relatively flat surface of better soil will form--an important long-term benefit.

Dead barriers are made from inert objects such as rocks, logs, and limbs. Farmers even pile up soil in earthen mounds. Live barriers are made from living plants grown to form an obstruction.

Important: Whether dead or live, the barriers should be placed on contour lines.

DEAD BARRIERS

Dead Barriers of Logs. Limbs. Bamboo Poles. Other Poles

Most dead barriers are constructed from rocks or earthen mounds. However, when a forest is cleared, farmers often use logs and limbs. In humid climates most logs decay rapidly. When this happens, the farmer can dig a contour ditch above the decaying logs, throwing soil on top of the logs, planting grass or legume trees to convert the space into a living barrier.

Figure 4-8. Erosion control--dead barriers made of tree logs and limbs. When the forest was cleared for growing fruit trees and food crops, the logs, limbs, and trash were piled in rows perpendicular to the flow of water down the hill. This has been only partially successful; some erosion is occurring. A low-growing cover crop should be planted and some drainage ditches installed. (Picture by author.)

Earth Banks for Barriers

Farmers often pile mounds of earth to form dikes or banks along a contour line. These work well in many places. Farmers can form them into many shapes, widths, and heights, depending on the need. Caution: Depending on many factors, earth mounds in your area may vary in design--based on many considerations such as whether to keep a true contour in order to hold the water or have a slight slope to run the water slowly toward a planned outlet.)

Ways to Use Earth Banks:

- to form raised contour dikes or banks which catch and hold all the water (with a planned emergency overflow outlet into a controlled drainage ditch to handle heavy, long duration rainfall).

- to form raised banks to channel or elude runoff water slowly to a control exit drainage ditch or other protected outlet such as a grass sod waterway.

One such type, called "fanya jou", is common in Africa. The African word 'fanya jou" means " to throw up or throw back". In this method, the farmer digs a contour ditch and throws the soil above the ditch, then plants grass on this soil. Each year as the ditch is cleaned out, the farmer throws the silt from the ditch back above onto the top of the grass mound. Year after year he repeats the procedure and maintains the grass cover. Eventually, when enough soil has been thrown upon the mound, and enough eroded soil from above has been deposited, a bench-like floor forms. The farmer can easily finish it into a regular bench terrace.

Rock walls

Where rocks are available, rock walls are common and can make excellent barriers. Usually rock walls are loosely constructed, with spaces for water to seep very slowly through. However, some farmers fit rocks tightly together into solid walls, sometimes using cement to hold the rocks together. Solid rock walls are much more common in the more arid areas. With low rainfall they often can catch and hold on the field most or all of the rainwater.

Advantages of Rock Walls

- Removing the rocks from the field improves the land.

- Rocks are sturdy. Rock walls are relatively permanent.

- Crops can be grown up against both sides of either loose or solid rock walls. In fact, next to the wall on the up-hill side is a choice spot to grow vegetables. The soil is especially moist and fertile in that location, where the water deposits sediment and nutrients most frequently. Farmers often grow pineapple in this location. Vine crops grown near the wall can be trained to grow over and along it.

Figure 4-9. Contour grass-covered earthen banks. Contour rows and contour tillage on moderate slopes where soils have good infiltration rates are effective conservation practices. Note the raised banks, which serve as emergency protection in case of excessive floods. (Picture courtesy of Soil and Water Conservation Society.)

Figure 4-10. In northern Tunisia, this land has been farmed in a sustainable way for thousands of years. You can see a mixture of bench terraces and contour ridges (grass-covered earthen barriers which have been well-maintained). Close growing grain (barley/wheat) in rotation with close-growing clovers (legumes) has helped make the system sustainable and profitable. (Author's picture.)

Solid Rock Walls

Special Advantages of Solid Rock Walls

- They retain all the water and the soil particles.

- The buildup of deposited soil after storms will be much faster than with less solid barriers. Less time will be required to form a bench terrace.

- Solid rock walls, once in place, are quite permanent and easy to maintain. They should not need much attention for some time. They are less vulnerable to damage from animals.

Special Disadvantages of Solid Rock Walls

- The solid stone wall needs more accurate engineering than the loose stone wall. If it is to hold all the rainfall, careful calculations and design must ensure that the wall is strong enough and tall enough to withstand heavy rainstorms. Spillways must be designed for excess water from unusually heavy rains.

- Building solid rock walls calls for supervision by a mason or skilled craftsman. The rocks require careful fitting together.

- Solid rock walls are more expensive and slower to build than loosely fitted walls and require semi-skilled labor.

- The designer of the wall must know the soil depth and infiltration rate of the soil as well as peak amounts of rainfall.

- For more information on building solid rock walls, consult with local craftsmen if available.

Special Advantages of Loosely Constructed Stone Barriers

- Loose stone walls are relatively inexpensive to build if plentiful rocks are in the field.

- They do not require the careful engineering and precise construction of solid rock walls. Yet they work well.

- With time they will still form a terrace if rocks are fitted as closely as possible.

- These walls are easy to maintain if livestock are kept out.

- As with solid rock walls, stones removed from the field leave more room in the soil for plants to grow.

Disadvantages or Special Considerations

- Many farmers who would like to put up rock barriers do not have enough rocks. In these cases they might use a combination of rocks and earth covered with grass, or rocks stacked along the contour line plus a live barrier of legume trees planted next to their downhill side.

- Loose rock walls are susceptible to damage from grazing animals or playing children. The rocks, being loose. Cattle or goats wandering unsupervised in a field can destroy the effectiveness of the wall. If rocks are missing from a spot in the wall, water can rush through and begin to cut a gully below. Fencing or vigilance is important.

How to Construct a Loose Rock Barrier.

1. Lay out the topmost contour line; clear a pathway on it.

2. Make a contour (level) bed 50 to 60 cm wide and about 10 cm deep, following along the entire contour.
3. Choose rocks which fit together as well as possible. Separate larger rocks and smaller ones into two piles.
4. Place the larger rocks on the outside edges of the wall. Use the smaller stones to fill in the center space.

Figure 4-11. A loose rock wall barrier--a very effective contour barrier. (Picture by author.)
Figure 4-12. Removing rocks from the field for contour barriers makes the land more suitable for farming. (Picture by author.)

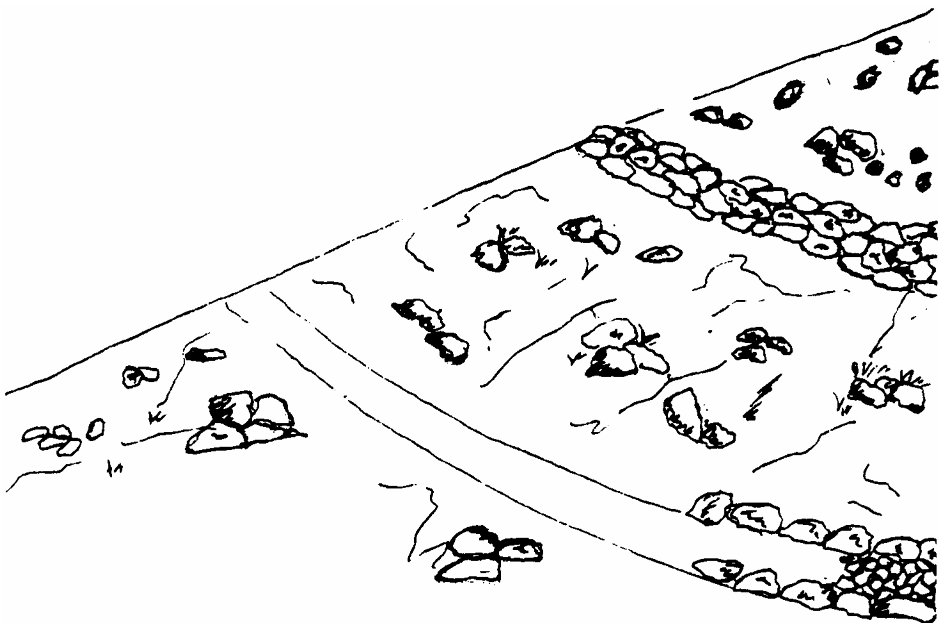


Figure 4-13. Building a loose rock barrier on the contour. Scrape a strip about 10 cm deep and 60 cm wide on the contour line. Fit large rocks together on the outside edges; use smaller rocks in the middle of the wall barrier. (Idea from World Neighbors.)

5. Continue until the wall reaches about 1 meter in height.

6. At a later date, the farmer might plant a row of legume trees such as *Gliricidia* on the lower side to reinforce the wall. Trim back to 1 or 1.5 meters when they are 18 months old. Keep them trimmed back from time to time as needed to keep root and shade competition with food crops to a minimum during the growing season. (See Contour Farming With Living Barriers by World Neighbors for additional details).

Low Row Ridges and Row Beds Used on the Contour as Mini-Barriers

When used on very moderate slopes row ridges and row beds can be effective in slowing runoff water. They work well where farmers want to plant certain crops in raised ridges or beds. Farmers may like to pile up ridges on the contour to grow root crops (like yams). Or they may use raised ridges where soil drainage is poor, to allow plant roots to have more air space in the soil.

The raised barrier on the contour captures or slows the water from most rains if it is on very moderate slopes. If the soil is shallow or has a low infiltration rate excess water from the beds should flow into a drainage ditch.

Advantages of Growing crops on Low Contour Ridges or Raised Contour Beds

- In poorly drained soils, raised beds or contour ridges allow better air exchange in the rooting area. Plant roots find more air space in the soil because excess water drains more quickly from the raised part of the bed.
- Raised contour beds work extremely well when used for vegetables which are planted closely together and which need much hand labor.
- The farmer can walk between the rows of crops. Thus when cultivating, he does not compact the soil around the crops.
- The farmer will do less painful stooping when weeding or doing other crop maintenance on raised beds or ridges.
- Raised beds are a traditional farming method in West Africa. Wherever farmers already farm with raised beds they need only learn to put the beds on the contour to help conserve water and soil.

Disadvantages

- Small raised ridges or beds by themselves are not effective barriers on steel They should be used on very moderate slopes only.
- They require much labor to build and maintain. They must be restructured every planting season.
- The soil in raised beds will dry out more quickly than in regular beds, a problem to be watched with sandy soils or in low rainfall areas.

LIVE BARRIERS

Live barriers are <u>living obstructions perpendicular to the flow of</u> <u>water</u>.

Most farmers in the tropics can grow some type of live barrier to impede water runoff. In fact, many small tropical farmers are already using this technique with great success.

- Plants seeded or transplanted very closely together on contours across a field can form excellent barriers. They function very much like dead barriers, and they can be equally effective.
- The soil from cultivation and erosion which accumulates above the barrier year after year eventually becomes a bench terrace; the barrier of living plants then becomes the terrace wall or riser.
- Not only can live plants make <u>effective barriers</u>: many varieties also contain much <u>organic matter</u> and/or <u>organic nitrogen fertilizer.</u>

<u>Row to Establish Suitable Live Barriers</u>

- Choose the <u>best type of</u> <u>live barrier</u> for the particular slope, soil, and other farm conditions.
- Choose the plants <u>best suited to local conditions</u> and <u>the farmer's needs</u>. Establishing live barriers requires considerable labor, cost, and land. Farmers will want to choose the types of plants carefully.
- The plants should, of course, i.e. a species, preferably two or more, which form a dense, lasting, and durable barrier. If possible, they should provide a useful crop. They should grow well in that particular locale and in that particular farmer's soils. <u>Encourage the use of</u> <u>legumes</u>.

You will find two general types of live barriers grown on the contour: those made of green manure and those formed by <u>legume trees or legume shrubs</u> growing very closely together, with intertwined root systems and trunks. <u>Combining both</u> of these types makes the best and most effective living barriers for either steep or moderate slopes in the humid region. The farmer plants a <u>double row of</u> <u>trees</u> (especially leguminous trees) on the top of the dike of a contour ditch. He also plants on the sides of the dike to keep it from eroding.

<u>Legume Trees and Shrubs as Barriers</u>

Trees and shrubs make a <u>very strong barrier</u> which can even help support rock walls and earth mounds as well as act as very strong barriers by themselves. Many of them can <u>withstand severe</u> weather and recover to <u>quick re-growth</u>, and have a <u>deep root system which withstands drought</u>.

A number of legume trees and shrubs give all these benefits, plus tremendous special benefits in increasing soil fertility. These trees can play a dual role: (1) as a living barrier 2) as a vital source of organic nitrogen fertilizer and green manure.

The fields of most small tropical farmers have infertile soils which are usually very low in nitrogen and phosphorus. The hill farmer needs to use more legume trees in barriers because of their usefulness as green manure and extra organic nitrogen. Manure or commercial phosphate fertilizer may need to be added for healthy legume tree growth in some cases.

Advantages of Legume Trees and Shrubs:

- They produce enough nitrogen fertilizer for their own needs. Some types of legume trees can produce 100 Kg to 200 Kg or more of fertilizer nitrogen per hectare per year.

- The tree leaves, twigs and stems are rich in protein nitrogen. When trimmed from the trees, they can be worked into the soil as green manure fertilizer or left on the surface as a mulch and fertilizer. Also adding the leaves to compost can greatly improve its quality.

- The depth of the tree root system allows it to capture and bring to the surface other plant nutrients such as potassium, calcium, magnesium, etc. from the deeper rooting depth. The deep roots actually do some recycling of nutrients which are beyond .the rooting depth of field crops.

  Note: For recycling to be effective, the subsoil must have nutrients and a healthy environment for root growth.

- Since tree roots go much deeper into the soil than food or feed crops, they can use moisture from greater depths to survive. Many legume trees stay green and grow during the dry season, furnishing feed from leaves to cut and carry to livestock at a time when other fodder may be scarce.

- Some legume trees produce a high quality ‘cut and carry” feed for animals. Extra trees should be planted elsewhere for this special purpose if needed, to prevent the live barriers from being destroyed.

- Some easily sprouting varieties which can be planted as stakes will sprout and root, and can also be used as living fences or fence posts. *Gliricidia* is commonly used for this.

- The larger pruned limbs can be used for firewood or converted to charcoal to sell.

- Trees can produce pods and seeds for human food, animal feed, or sale. Seeds from a few mature trees can also provide seed stock for a small farm tree nursery.

Disadvantages of Legume Trees and Shrubs

- Animals must be kept away or they will destroy the barriers. Damage of young trees from grazing animals can be a limiting factor. Protection of trees is a main concern.

- Trees can be susceptible to diseases or insects.

How to Guard Against Diseases or Insects of Legume Trees

- Plant two or more species together in living barriers to guard against catastrophe. One species may survive and produce better than another. Then, if one species dies out, the others will still provide a barrier and a crop to produce nitrogen fertilizer and organic matter.

- Before planting, inquire carefully about insects, diseases, and drought.

- Investigate and test all new varieties before recommending them. Some excellent plants for living barriers are *Calliandra*, *Gliricidia*, *Flemingia*, and *Leucaena.* For information on these varieties and others see the tables at the end of the chapter.

Question: Is *Leucaena leucoceDhala* still recommended for planting?

Answer: For some time, Leucaena leucocephala has had rave reviews and has been extensively planted as the ideal barrier tree. However, in some areas, farmers are now reporting insect damage to their trees. *(Heteropsylla)* are causing very serious leaf damage and death of the tree in the Philippines, Indonesia, and other parts of Asia. For the present (1992), *Leucaena* is no longer recommended there. However, in its home environment in Western Mexico and Central America, the lice are not a problem at present--and it is a superior tree when adapted to its environment.

Scientists are now working on resistant strains of *Leucaena.* In time such strains should be available. Watch for them because *Leucaena* has been very special.

Again, urge farmers to plant two or more varieties in their tree barriers as protection against loss.

Figure 4-14. Trees pruned back to hedges as live barriers. These excellent barriers against erosion, if properly chosen, planted and cared for, also provide the farmer with extra dividends. The picture was taken in the dry season after the trees have been pruned. (Picture courtesy of World Neighbors.)

Figure 4-15. Most live barrier trees are multipurpose trees. The man on your right is standing in the bed of a narrow bench terrace and dropping legume tree leaves and twigs into a trench in the row to make compost. This single row will be planted to corn later. The man below him, standing on the next terrace down, has a bag of tree leaves which he has trimmed from small trees (see by his right leg). These legume trees have been planted against the terrace wall (riser) to protect and help support it. The slope of this field is about 70%.

These farmers are obtaining good yields and have a sustainable farming system. Fortunately, the soil depth here is enough for bench terraces. On lesser slopes, they are also doing some minimum tillage. (Picture by author.)

How to Construct Live barriers of Leguminous Trees.

Choose species of trees which will adapt to the climate and to the soil. A legume species should also be chosen for the amount of green manure and organic nitrogen it produces. Some species produce much more than others.

2. Begin selecting types to plant by consulting local farmers and your PCV specialist. Suitable legume trees may already be growing in the area.

   In the 1880's, many tropical plantation owners introduced certain varieties of legume trees into Asia, Africa, and Latin America to shade coffee trees and/or to provide stakes for spices such as black pepper. *Gliricidia*, a highly successful example, continues to be very popular with farmers. It can also grow into living fences or fence posts, and makes an excellent live legume barrier.

3. As an experiment, get several farmers to test different legurninous species in check row plots, especially on their poorest soil. This may take two years to get results but the farmers will learn even after you are back home.

4. Before the rainy season, construct a contour diversion drainage ditch near the top boundary of the field, sloped 1% toward an exit ditch. Begin regular contour ditches 3 to 5 meters below the diversion ditch. The distance apart will vary according to the steepness of the slope. The steeper the slope, the closer together they should be. The ditches should measure about 50 cm wide and 40 cm deep. The ditches or barriers should be spaced about every 1.5 meters in vertical elevation. (Fig. 4-6)

5. Pile the soil to form a dike or ridge along the lower or downhill edge of the contour ditch.

6. Early in the rainy season, plant the trees on the top of the ditch dike. Also plant or set out grasses on the sides of the dike.

7. Soaking most seeds for 12 hours before planting is a good idea. They will sprout more easily and come through the soil more quickly. Also, any bad seed will float to the top. Some seeds require hot water treatment or chemical treatment before planting. (See Tool Kit in the Appendix.)

8. Treat the seeds with some soil taken from the area where the leguminous trees are already growing. *(Rhizobium* bacteria growing in association with the plant roots of legumes make nitrogen.) Rub the seeds in some of this soil just before planting. This transfers to the seed the special bacteria which makes nitrogen. Check locally if this soil is not available to see where you can buy some of the bacteria mixture; or find an area where such trees are grown. You can also get help from the Nitrogen Fixing Tree Association in Hawaii, or other sources in the Appendix. The seed must be treated. If *Rhizobium* bacteria are not present. they cannot act to "fix" nitrogen.

9. Start planting at the beginning of the rainy season. Plant the tree seeds along the top of the dike which is on the down slope side of the contour ditch.

   Plant the seeds so that roots and trunks of the trees wedge against each other closely as they grow. In order to get tight wedging or interweaving, plant two or three seeds together in a group, with the seed groups spaced every 5 cm. Plant two parallel rows. In the second row with those in the first row, making a triangular shape with those in the first row. (Fig 4-17)

10. Protect the dike on which the trees grow by planting grass under the trees. In erosive soils, plant grass slips on the lower side of the trees at the same time that you plant the trees. If you wait until the next year as some farmers do, much soil can wash away from the roots of the tree seedlings in the interval.

    Plant grass slips on the side slopes of the dike, especially the lower side, in rows parallel to the tree rows. The grass will protect the sides of the dike from splash erosion. Again, close planting is desirable. The slips should be spaced 15 to 25 cm apart with 25 cm between the rows, and again you should use a zigzag pattern. Spacing will depend on the nature of the grasses used. The grass will begin to grow in a few weeks and give some protection the first season.

    Some people prefer to plant closely spaced pineapple on the lower side of the dike instead of grass. In any case, the sides of the dike, particularly the lower side, must be kept covered to avoid raindrop splash erosion.

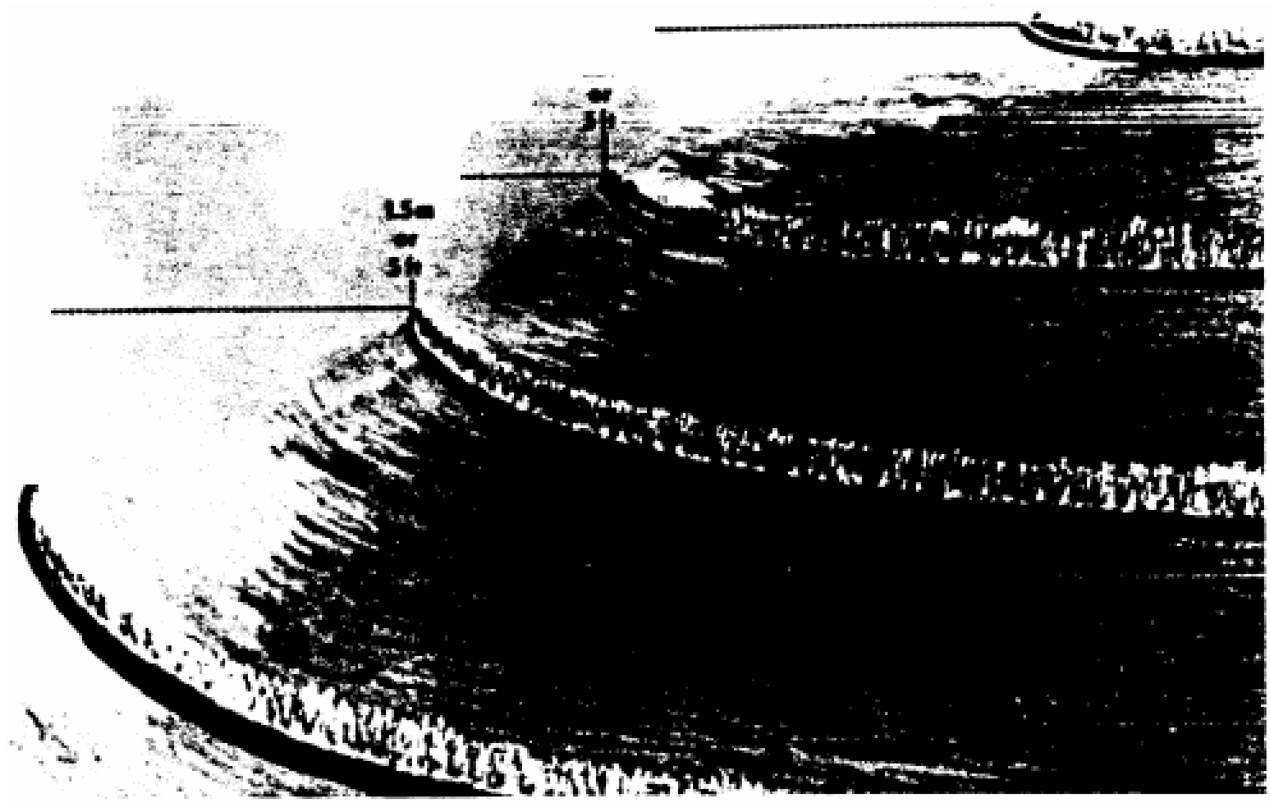


Figure 4-16. Distances for the planting of tree contour barriers. It is recommended that tree contour barriers be placed at every 1.5 meter difference in elevation as illustrated here. (Sketch courtesy of World Neighbors.)

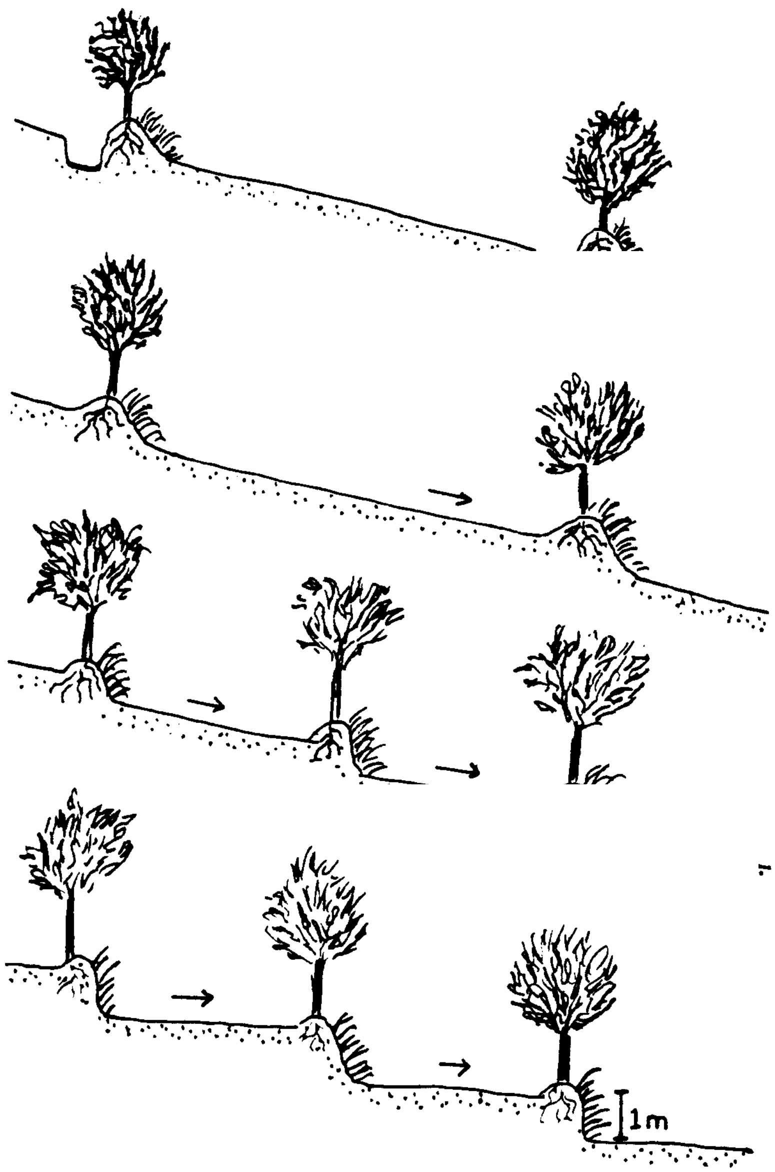


Figure 4-18. Cross-section view of legume tree live barriers. Notice the grass planted on lower side of dikes to protect from erosion. The tree seedlings are planted on top of a small dike which is protected by a drainage ditch as shown. When the trees are well established, the ditch is allowed to fill with soil which washes down. When the ditch is filled, the barrier stops most of the washing soil. Soon the slope of the field between the barriers begins to become flatter. Eventually a level bench terrace is formed. If the first barriers are spaced too far apart, another one can be planted between them, as shown here.

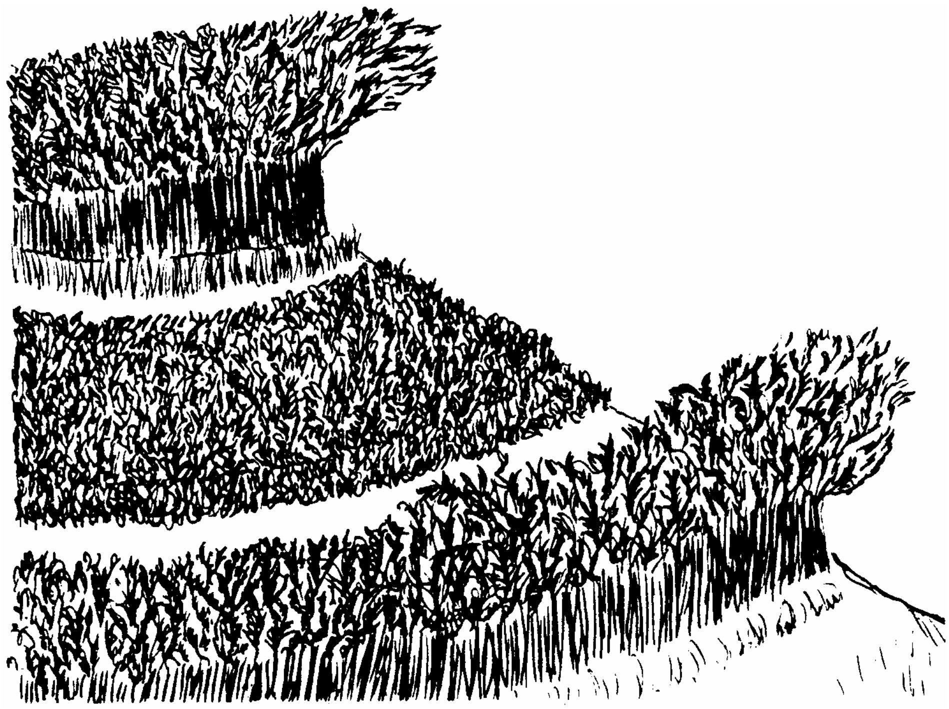


Figure 4-19. Inter-planted food crops growing between two rows of nitrogen-fixing legume trees. In part of the bottom row, the trees have been pruned back to about 1 meter height. The rest of the trees need pruning. Notice the grass planted at bottom of the trees to protect the lower edge from rainfall splash erosion around the tree trunks and roots.

11. At first, keep the contour ditch clear to channel the runoff water. After about two years, allow the ditch to fill. In time the soil sediment from runoff will accumulate on the up slope side of the trees, thus increasing the depth of soil on the bench top of the terrace. The land above the trees will become flatter and less prone to erode. It eventually will be a bench terrace.

12. Close planting is important. The farmer needs to grow a solid barrier, not only of the legume trees, but of the protective grass cover. Combining legume hedge rows and rows of grass on the dike gives a desirable plant combination which should last a long time, efficiently curb erosion, produce good yields, and enrich the soil.

How to Maintain Tree or Hedge Rows

1. Let the legume trees grow for 12 to 18 months after planting before you prune them back. The first year, only cut them back to about 1.5 meter height, since the tree is still establishing its tap root and deeper root system.

2. The second year and succeeding years, you can safely prune the trees to 1 meter height at food crop planting time. Trim the barrier as needed to prevent shade competition to the food crops. The cut grass, tree leaves and twigs can be used for mulch, green manure, or "cut and carry green feed. Hopefully the tree leaves can be left on the soil as a mulch and green manure fertilizer.

3. As much as possible, let the trees grow without trimming during the dry season so the roots continue to grow deep. Plant extra trees elsewhere if livestock feed is needed.

4. Protect both seedlings and mature shrubs and trees from grazing animals.

Grass Barriers

Because of their versatility and practicality, many grasses are useful as barriers. Farmers often use them in combination with other dead or live materials. On very steep slopes grass barriers should not be used by themselves, but in combination with legume trees as described above.

Unpalatable Grasses

- If animals graze in the field during the dry season, the barrier should be a grass which they will not eat or destroy. The farmer needs to plant a tough, deep-rooted, unpalatable grass. Palatability may be lessened by the taste, odor, or spines and thorns.: on the plant leaf or stem surface.

Figures 4-20 and 4-21. Barriers of unpalatable grass. These Vetiver grass barriers are doing a good job controlling soil erosion even though cows may be in the field during the dry season. They won’t eat this unpalatable grass. Vetiver grass is easily transplanted, deep-rooted, drought resistant when well established, unpalatable to rodents as well as to livestock. Some varieties are used in the production of perfume. (Pictures by author.)

- *Vetiver GrassVetiveria zizanjoides)* is good for such situations. It is widely used in India. Since it is unpalatable because of chemical content, animals won't graze it. Vetiver Grass makes an <u>efficient live barrier</u>. When well established and maintained, it holds back or slows the runoff very well. It is very <u>drought resistant, and</u> very deep rooted. Yet it does not spread into the field as a weed because it produces very few seeds and does not have stolons or rhizomes.

- <u>How to start a Vetiver Grass barrier</u>

a. Vetiver Grass grows in large clumps from a "spongy" root stock with clusters about 1/2 meter to 1 1/2 meters high. The bundles can be uprooted and torn apart into small rooted slips for planting.

b. At the beginning of the wet season plant the slips about 15 cm apart.

c. The barrier will need 2 to 3 seasons to become well established, but it is very effective. <u>Keen livestock away</u> until the grass is <u>well established</u> and deep-rooted.

d. Write the World Bank for their small publication, "Vetivar Grass. (See the Appendix for the address.)

<u>Palatable Grasses</u>.

- Many palatable grasses serve both as good barriers and animal feed if the farmer <u>confines the animals</u> and <u>carries the cut green feed</u> to them. Check around for good local varieties. With cut-and-carry feeding, the palatability and nutrient value of the grass is important.

- By confining the animals, the farmer can not only grow a barrier which he can use for feed; he can also save the valuable manure to use directly as fertilizer or in compost.

- Many varieties of grasses do well as both barrier and feed. (<u>Elephant Grass</u>) is often an excellent choice. In some cases sugar cane makes a useful temporary barrier. Often food crops such as pineapple combine very well with grass to form a barrier.

<u>Advantages of Grass Barriers</u>:

- Usually grass barriers are easy to establish. Grasses grow quickly and can be planted thickly.

- Grasses are often easy to obtain. Local grasses are usually available as slips, sprouts or joints to transplant.

- Certain grasses are low-growing and/or form a mat which make them suitable for covering mounds, terrace edges, ridges and slow-flowing drainage ditches or waterways. Study the native grasses in your area.

- <u>Where animals are confined</u>, grass species can be planted as live barriers which can provide animal feed to be cut and carried to the animals as green feed or dried as hay to be fed in the dry season. (Note: Grasses grow more abundantly when planted with a low-growing native legume.)

Disadvantages of Grass Barriers

- Grasses do not produce nitro2en. Unlike the legurninous trees they only pull nutrients from the soil, rather than add them.

- Grass barriers are not as sturdy as legume tree barriers. They are not as deep-rooted and do not make as strong barriers. They should not be used alone on steep slopes.

How to Establish Palatable Grasses as Live Barriers

1. As with legume tree barriers, establish drainage protection. Before the rainy season, dig a diversion ditch at the top of the slope, and a contour ditch about 3 to 5 meters below that. The contour ditch should be 50 cm or more wide and 50 cm or more deep. Deposit the dug soil on the upper side of the ditch to form a dike. Dig contour ditches as needed, depending upon the steepness of the slope.

2. Plant the grass slips at the top of the contour dike and down both sides. The slips should be about 15 to 25 cm apart in two parallel rows, using a zigzag (triangular) pattern. The rows should be about 15 cm apart. Repeat the two-row pattern as needed to cover the area completely. This will produce a barrier without gaps when the grass reaches its full height and spread. Note: Planting distance in the row may vary somewhat with the grass variety. (See Figure 4-22.)

3. Water as needed after planting.

4. Use only deep-rooted, drought tolerant species which are already growing in the region if possible.

5. Control foraging animals unless you are using an unpalatable grass.

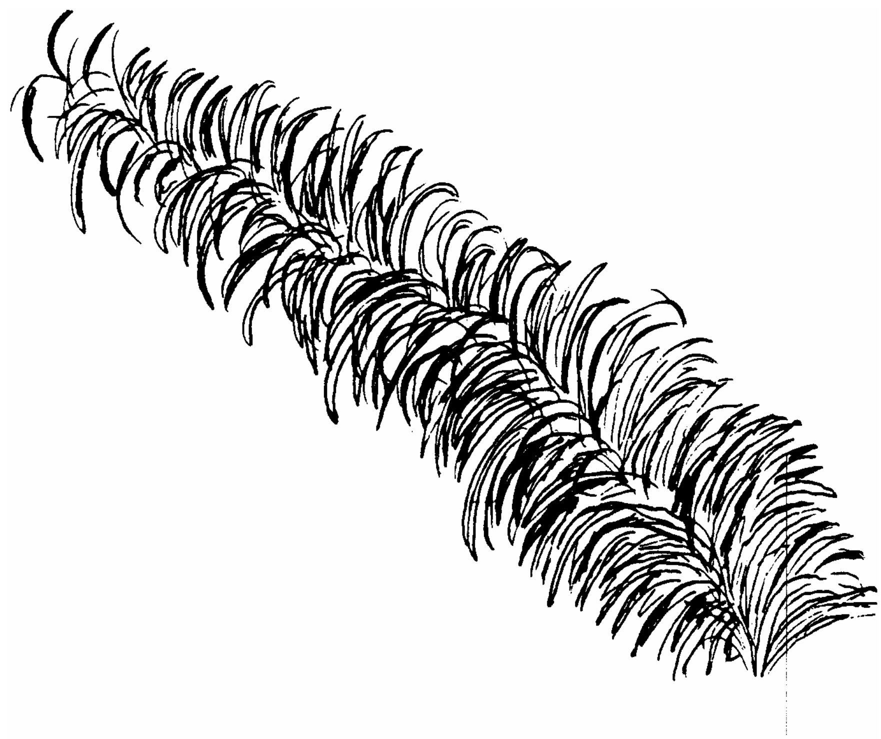


Figure 4-22 Planting grass barriers. Plant slips (stems) of grass in staggered rows on the upper side of the contour ditch. The rows should be about 25 cm apart and the slips spaced 15 to 25 cm apart in the row. (This may vary, depending upon the grass variety.) Be sure that the slips are close enough together to form an interwoven strong wall barrier. (Idea for sketch from World Neighbors.)

Figure 4-23. A very effective grass barrier which not only saves water and soil, but also provides much feed for farm animals. Note that the soil is completely covered by the grass barrier plus the field crop. (Picture courtesy of World Neighbors.)

Figure 4-24. This grass barrier has been started by transplanting slips (stems) of grass above the contour drainage ditch. (Picture courtesy of World Neighbors.)

CONTOUR BENCH TERRACES

We have convincing evidence that bench terraces can conserve water and soil. They stop the downhill movement of both soil and water; they also give the farmer a flat surface for growing crops even on steep slopes. They convert steep slopes into produce level land.

Bench terraces can last indefinitely. Farmers in ancient civilizations built them. Where they were properly designed, constructed, and maintained, many are still intact and productive today.

What Are Bench Terraces?

In bench terracing, the land is cut or reshaped into wide to narrow level steps or level table tops going down the hill like stair steps. If the land is very steep the tops will be narrow and look like benches. If the slope is not steep the tops will be much broader and might appear more like tables than benches. Each individual table top or step extends some distance around the hill on the contour. In profile, the tops look like stair steps going down the hill. They are continuous, with one bench or one tabletop up against the other, just like stair steps.

Types of Bench Terraces

- The standard bench terrace (continuous)
- The inward sloping bench terrace (continuous)
- The outward sloping bench terrace (continuous)
- The irrigation bench terrace (continuous)
- The intermittent bench terrace (discontinuous)
- The platform bench terrace (discontinuous individual)

CONTINUOUS BENCH TERRACES

Advantages of Continuous Bench Terraces:

- Continuous bench terraces are suitable for growing any crop if soil is deep enough.
- They can be used under a wide range of conditions.
- They are suitable for any hillside, from a very minimal to a very steep slope if the soil depth is adequate. They make intensive use of steep slopes possible and effective. The limiting factor is the need for deep enough soil.
- They retain the maximum amount of soil and water on the bench top and in the soil profile.
- They make possible the planting, cultivating, and harvesting of all field crops on a level

platform. Good crop growing practices are much easier to carry out.

- They give maximum growing conditions, and, with good management, lend themselves to high crop yields.

- With proper maintenance, they last a long time.

<u>Disadvantages of Continuous Bench Terraces</u>

- Continuous bench terraces are very ~ to build (labor intensive). Constructing continuous bench terraces on one hectare of land requires one man year or more of labor.

- They are usually practical only for high value crops because they are so expensive.

- Continuous bench terraces cannot be used on a very shallow soil.

- They must be well designed and consistently maintained. Inadequate soil cover on the risers (the upper wall or bank side of the terrace), plugged up drainage systems, damage from grazing livestock, and similar oversights can lead to the loss or serious damage of the system.

- They require fencing out livestock, and other protection from damage.

- In themselves, continuous bench terraces do not prevent raindrop splash, or the pounding of the soil surface into slurry, but since the terrace floor is level there is no water runoff, or else it is controlled runoff (assuming a designed system. <u>Caution</u>: if infiltration is slower than expected rainfall, the table top should be tilted inward and connected inward to a controlled exit drainage ditch.)

- For maximum crop production, the soil on continuous bench terraces will need a green manure crop, or compost. It will certainly need soil testing and recommended amounts of commercial fertilizers if available. Maximum production is important because of the expense of installation.

Figure 4-25. Narrow bench terraces in the background, with banana trees growing in part of the low drainage area. (Picture by author.)

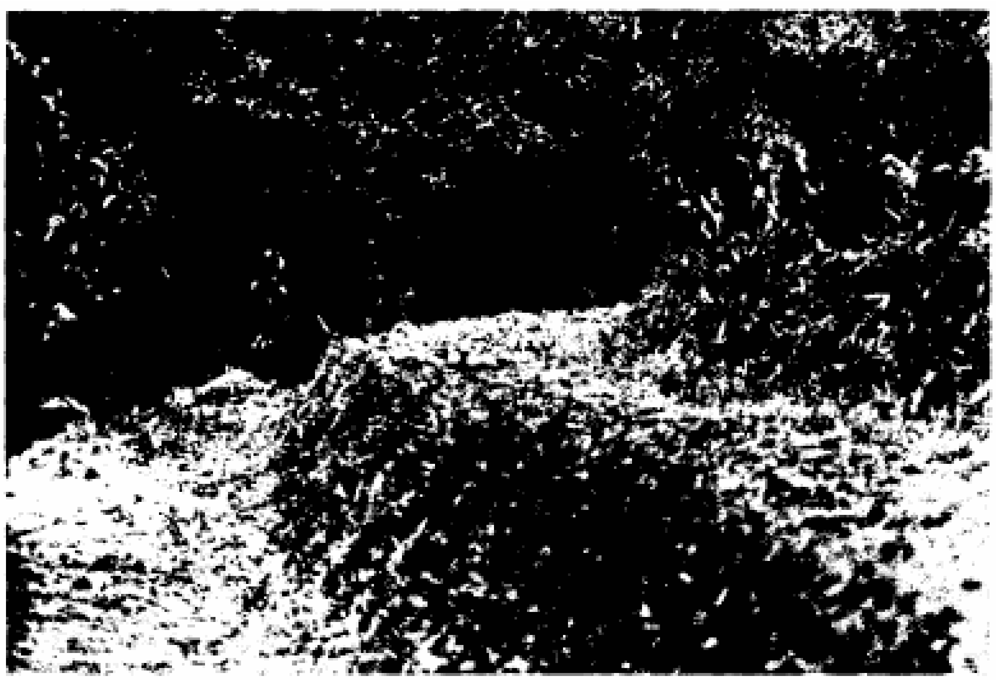


Figure 4-26. Close-up view of a narrow bench terrace with the risers (banks) well covered with grass to protect the risers from rainfall splash erosion. Food crops are grown on the flat bench top. (Pictures by author.)

The Continuous Standard Bench Terrace

The continuous standard bench terrace ideally has zero percent slope on the terrace itself (the bench top). The top is level as it extends around the hill on the contour. The terraces form a fairly unbroken pattern of steps down the hill. The bench surface may be relatively narrow or broad, depending on the slope of the field, the soil depth and the farmer's wishes. To protect the edge, the outside rim has a small raised lip about 10-15 cm or more high which is covered with grass. The wall of the terrace (riser) also should be protected with grass cover or stones.

The terraces should be sloped 1% along the contour toward the exit control drainage ditch to permit slight drainage. The table top can also be sloped inward slightly if there is danger of water spilling over the outside rim. Do not let water spill over the outside rim. This will dig a gully all the way down the hillside. If in doubt, use 5% inverse slope on the table top.

When and How to Use the Standard Bench Terrace

- Standard bench terraces should be used on any field, any slope as long as the soil is deep enough. The depth of the ~ down the vertical interval) should not be more than 2 ½ times the useable soil depth (the soil which will grow plants). Otherwise, you will expose rock or very poor soil when you cut down into the soil to build the terrace. Crops will not grow well there (if at all), leading to poor yields and erosion of the terrace.

  Example: If the useable soil depth is only 30cm, then the vertical drop of the bench terrace should only be 75cm.

- The standard continuous bench terrace can be used to grow any crop on deep fertile soils. However, since the terraces are expensive(labor intensive) to construct, farmers usually use them only for high value crops. To better understand how terraces are constructed, see Fig. 4 -36 to 4 -43.)

The Inward Sloping Bench Terrace

This terrace must defile the standard bench terrace by tilting the bench top surface inward, sloping it inward about 5 to 8%, allowing more water to be retained on the terrace top. I would recommend 8% inward slope if the soil is an easily eroded sandy/silty soil or if the soil has a low infiltration rate.

The Outward Sloping Bench Terrace

Here the terrace bench top slopes outward (downward toward the outside edge) about 1/2%. This brings about improved drainage from the soil. Farmers use this technique in parts of Asia where the soil is heavy and shallow, or where landslides are common.

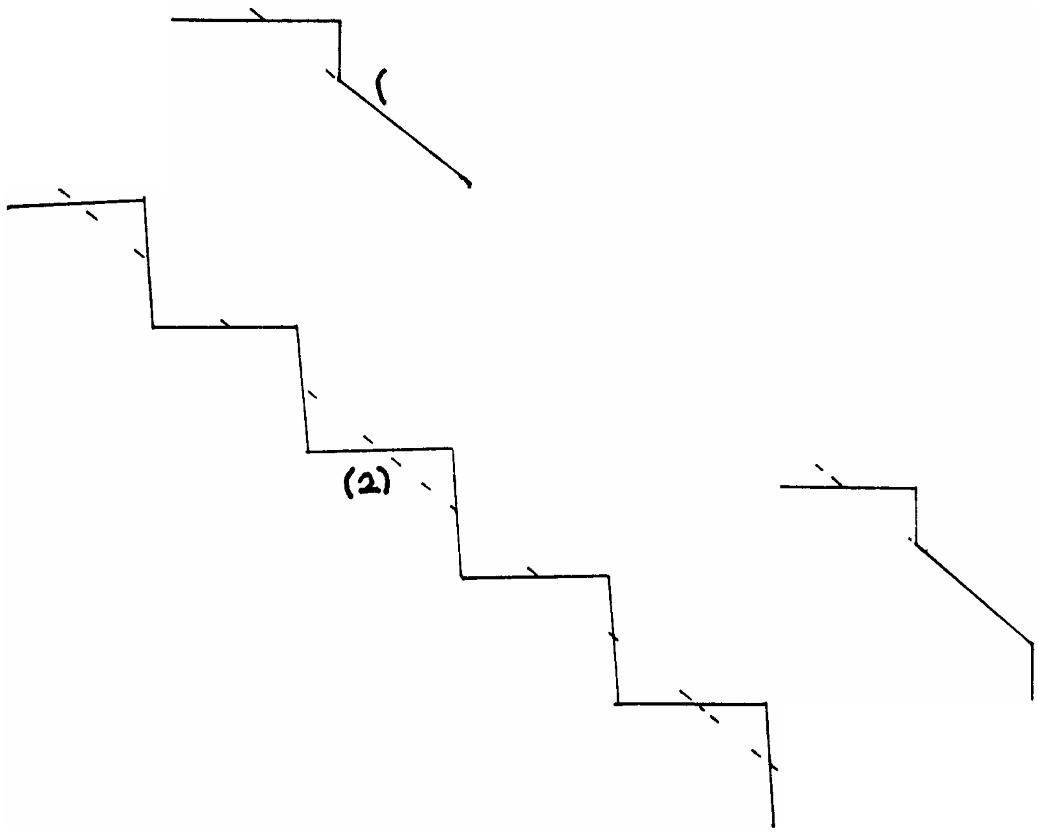


Figure 4-27. Sketch in profile of small bench terraces. Profile (1) on the right shows discontinuous terraces. The terraces have space between them which maintains the original natural slope of the hill. Profile (2) on the left shows continuous terraces. Each terrace is connected with another terrace. These are standard level bench terraces. (Sketch ideas from Soil and Water Conservation Society.)

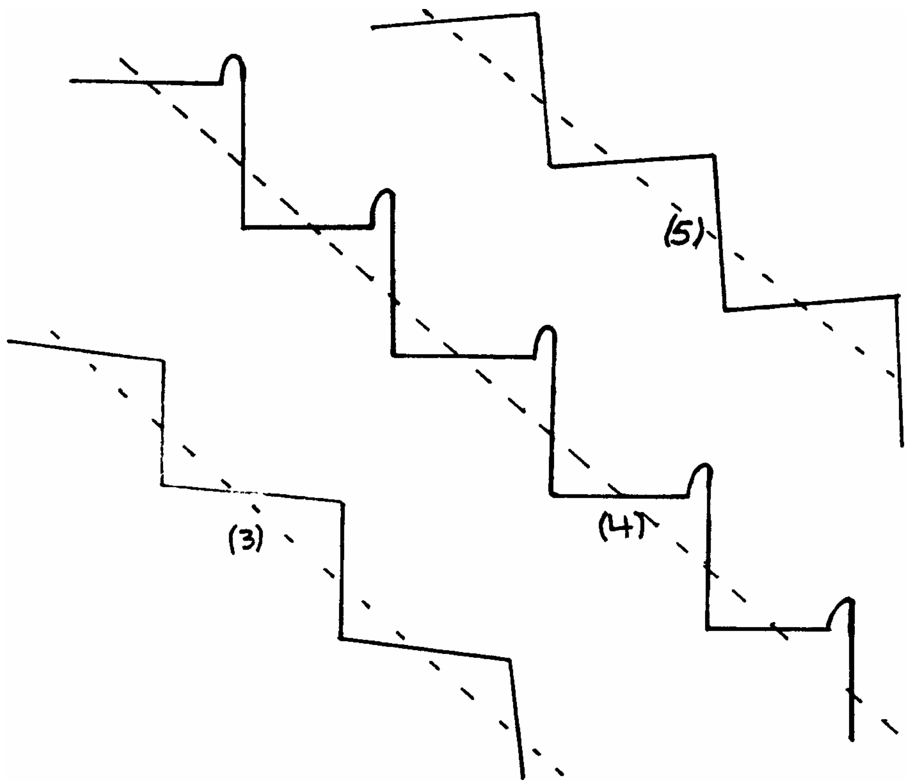


Figure 4-28. Sketches in profile of other small bench terraces. These bench terraces are, from left to right, (3) continuous out-sloping terrace (4) irrigation terrace (5) in-sloping or reverse sloping bench terrace. (Sketch ideas from Soil and Water Conservation Society.)

In the latter case, the farmers want to keep excessive water from entering the soil and making it too slick internally, leading to a landslide.

Since the outward tilt can encourage erosion of the lip of the terrace this system needs: (a) careful planting of grass along the ho and riser (b) special contour drainage and discharge ditches (c) very accurate construction with the supervision of an engineer.

The Irrigation Bench Terrace

These flat terraces have outer rims (walls) rising up to 30 cm to 40 cm, which permits the flat area to be flooded with adequate irrigation water. Low-growing grasses planted on the rims and side protect the outside rim (wall) from erosion. The farmer can apply irrigation water and can also control rainfall by interconnecting terraced plots and ditches. Rice paddies utilize this type of terrace.

Check with local, successful irrigation farmers for advice in constructing irrigation bench terraces if a specialist is not available In general, follow the directions for standard continuous bench terraces, but add sufficient height to the outside lip (edges) of the terrace to hold irrigation water and arrange for water level control.

DISCONTINUOUS (INTERMITTENT) BENCH TERRACES

Orchard Terraces

Intermittent or discontinuous narrow bench terraces (also called orchard terraces) have strips of protective vegetative cover between them. In this system, the farmer alternates narrow bench terraces with undisturbed sloping soil. (See picture.) There is a terrace, then an undisturbed sloping strip, then another terrace followed by another strip, and so on down the slope. The undisturbed expanses must be completely covered with .grass or other protective low-growing vegetation.

Intermittent bench terraces are ideal for tree and shrub crops like tea, coffee, and fruit trees. Therefore, farmers often use them in orchards in very hilly fields. They are sometimes called orchard terraces.

Figure 4-29. Inward sloping bench terraces. The hill itself slopes downward from your right to your left, and also somewhat downward away from you toward the trees. One terrace is still covered with corn stubble. Note that the riser is protected by grass. The other terrace is newly prepared for planting. Note that the land not only slopes to the left but also down the contour away from you toward the trees. To control flow on the slope away from you the farmer is planting in ridge beds to keep water in the terrace. These beds are perpendicular to the flow downward on the contour toward the trees, and they act as small check dams to that flow. The inward slope of the terrace (from left down to right) is not long enough to allow the ridges to act as erosion channels. The inverse slope is about
10%.

This farmer’s main problem is keeping an adequate cover of grass on the risers. These terraces, which were planted in corn the past season without a cover crop, should be planted to beans in rotation during the next season, or to a green manure cover crop between corn rows.

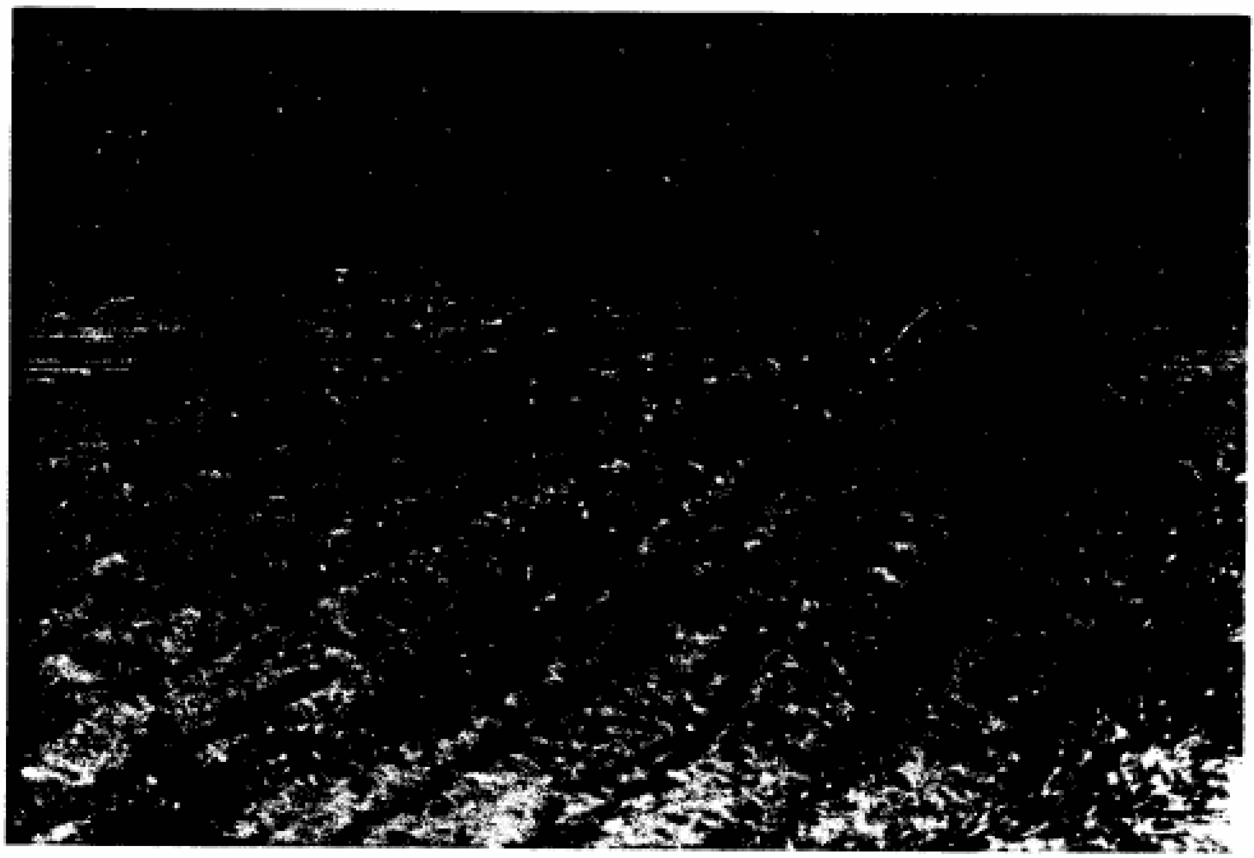


Figure 4-30. A close-up view of standard bench terraces on a moderately sloping hillside in Guatemala. Contour raised row beds have been prepared for planting as soon as the rainy season begins. Notice that the risers of the terrace wall are protected with grass. (Picture by author.)

Figure 4-31. Standard bench terraces with drainage ditches and low rock walls in the foreground on the near hillside. In the distance is a variety of bench terraces, with some irrigation bench terraces on the valley bottom. (Picture by author.)

Figure 4-32. Irrigated paddy rice terraces. In three of the plots on the right you can see bundles of rice seedlings placed for the laborers to transplant by hand the next day. In the paddies on the upper left are solid stands of rice plants which were transplanted earlier. (Picture by author.)

Advantages of Orchard Bench Terraces

- They require less labor than continuous bench terraces, (although they are still labor intensive to construct). Yet they still provide convenient and productive level platforms at intervals.

- They allow the growing of useful products on the sloping land between terraces. The farmer can plant perennial low-growing solid crops there (for forage, etc.).

Disadvantages of Orchard Bench Terraces

- The land between the terraces is vulnerable to erosion. Intermittent bench terraces require good vegetative cover on the intervening sloping land. A grass-legume combination is excellent.

- The terraces are quite vulnerable. They require maintenance. Workers must keep the back wall (the riser) covered well with grass as well as maintain a healthy vegetative cover on areas between the terraces. Drainage ditch must be kept clean. Otherwise, the system will fail.

- They require fencing or other protection from animals.

Individual Terraces (Bench Platform Terraces) with Contour Ditches

These are short lengths of individual terraces, each one having space for only one tree to grow. Oil palm plantations often use them. They can be used on very steep land --land too steep for conventional farming.

The platform bench terrace is quite vulnerable to erosion since it protrudes. (See picture.) The farmer should protect the whole area with standard contour drainage ditches spaced according to slope. Good ground cover should be planted over the whole area, including the protrusions mentioned. This could be low-growing grass or shrubs. Better still, use a low growing grass-legume combination that grows well together. It should require little attention, produce its own nitrogen, and be able to compete with weeds.

Advantages of Individual Platform Terraces

- Platform terraces provide level floors for growing individual trees.

- The terraces are excellent for large fruit or nut trees on steep slopes. They permit the planting of a desirable crop on land which might otherwise have limited value.

- With individual level platforms, the farmer can plant, fertilize, weed, prune, mulch, and harvest the trees much more easily.

- The flat surface helps retain soil moisture and control erosion.

- Grass-legume crops between platforms can provide animal feed as well as erosion protection.

Disadvantages of Individual Platform Terraces

- Platform terraces are not suitable for row crops, only for tree crops.

- The farmer must consistently keep drainage ditches cleaned and well maintained.

- The platforms are highly susceptible to erosion. Vegetative cover must protect the soil on the platforms themselves and on all areas between.

- They require protection from children and animals.

- The platforms require considerable labor to construct (though much less than continuous bench terraces).

HOW TO PLAN AND CONSTRUCT BENCH TERRACES

Precautions When Constructing Bench Terraces.

You will want to take special care in designing and building bench terraces. You may not know the exact infiltration rate for the soil or the particular soil type. You will be dealing with many unknowns. You may not have accurate rainfall data: the total annual rainfall; and the rainfall rates and amount to be expected in peak storms.

Visualize a level table top terrace with water on it. During a heavy rainstorm, water depth can increase quickly unless all of the water soaks into the soil. Water will soon spill over a completely level bench terrace when the downpour comes faster than the soil absorbs it.

- If you have any doubt about the bench terrace floor holding all the water in a peak rainstorm, do not use 0% slope. The risk is too great. Use a 5% inverse slope.

- Measurements should be accurate at each step. If not, the entire slope which has been cut and filled will be susceptible to quick serious erosion.

- If an A-frame is used as the leveling instrument, it is not as exact as a surveyor's instrument. As you use the "A-frame", keep in mind that it is probably accurate only to 1% plus or minus. Therefore, I recommend that you slope the terrace about 1% on the contour in the direction of the exit ditch. I suggest also that you slope the bench 2 to 5% inward (toward the uphill). Then, during rainstorms, excess water will not spill over the outer edge of the bench platform and destroy the terrace, but will soak in or move slowly around the contour to the control drainage ditch.

- When constructing bench terraces and calculating slope (the final slope you want), allow for settling of the bench floor. Remember that the outward half of the bench has the most loose soil. Even though you pack this dry soil by walking on it, it will settle further after rainwater has percolated through it. This will give a downward slope, causing the terrace table top to wash away badly. So if the inward slope desired is 0% or 1%, 3% or 5%, add ~ to the measurement of the slope of the bench top. The farmer may still need to make minor adjustments during the next dry season after the rains.

In most cases, you will want to build up the outer edge of the platform floor with a small ridge (20 cm wide and 15 cm high) covered with a grass. This grass should overlap with the grass growing on the riser (wall side of the terrace).

- As the soil is cut out for the terrace, be sure to set the topsoil aside and pile it together. After the terrace is formed, re-spread the topsoil over the same section. This is the richest part of the soil!

- Take extreme care to connect the dry soil thoroughly.

- Be sure to establish a solid stand of grass on the riser (the vertical bank). These sloping banks of earth must be covered with vegetation at all times. The farmer should check the plantings of grass at frequent intervals and plug in grass into the bare spots as part of a constant maintenance program.

- Accurately estimate the average % slope at different sites up and down the hill. It will vary!

- Carefully measure the useable soil depth on different slopes up and down the hillside and in different parts of the field.

  - Check the accuracy of the A-frame several times a day.

  - For more information on how to build bench terraces see Bulletin PC R062 by Crozier, pp. 24 - 35. Much of the above information is based on this excellent bulletin.

Figure 4-33. Using an A-Frame to determine contour lines. Be sure to calibrate this instrument several times each day. All measurements used in building bench terraces should be accurate. (Picture courtesy of World Neighbors.)

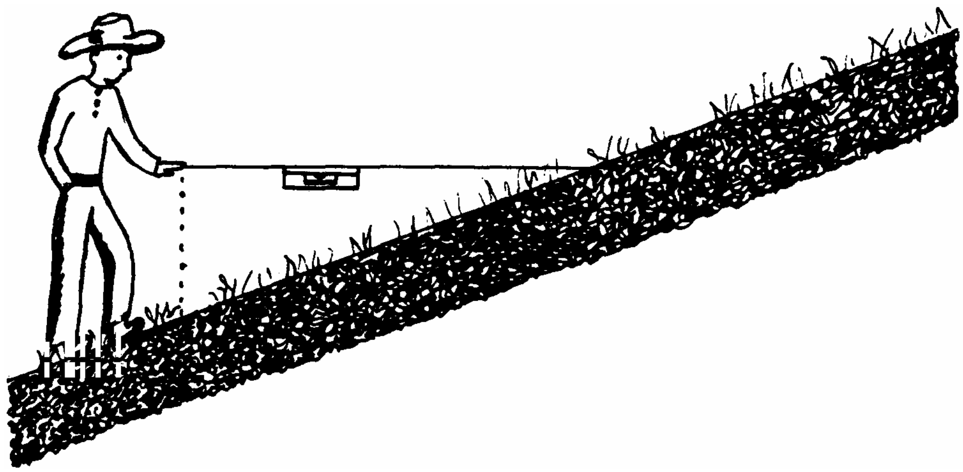


Figure 4-34. Using a carpenter's string field level. It is recommended that a string field level be used in determining slope measurements and also for checking grade lines and grade stakes at the terrace construction sites. These measurements control the inward and outward flow of water on the bench terrace floor. The A-Frame can be used to determine the original contour lines. (See Appendix A, The Tool Kit.)

Continuous Bench Terraces—Planning and Construction

1. Preliminary Planning. Before undertaking such an ambitious and labor intensive project, take some preliminary steps:

- Be sure the farmers understand the whole labor-intensive process--all the many days of hard work, the cutting, digging, and filling involved.

- Consider possible questions, needs, and problems with the farmers. Take them to visit farmers who are using bench terraces successfully. Visit any technicians who are working with them. Your group may have to travel a long distance to do all of this, but you will be glad you took them.

- A vital step-- dig a number of pits in the field to determine the depth of useable soil. Be sure it is adequate: the vertical height of the terrace bank can be no more than 2 1/2 times the depth of the good soil. Dig test holes up and down the slope to check the depth.

- Determine what crops the farmer can grow which will justify an expensive terrace.

- • Investigate existing or potential markets for at least part of the crops. Is there a good market for particular crops? Vegetables or other high cash value crops?

- Can the farmer find other crops which have better cash value and more demand?

  •• How can the farmer increase the crop yields?

2. Steps in Building Continuous Bench Terraces

a. For building terraces with hand labor, you will need heavy-duty hoes for digging, raking, smoothing, and even for lifting. You will find a few shovels and a mattock very useful. Assemble many stakes, some strong string, a small string level and a clipboard to hold papers and notes.

b. As slopes get steeper, the bench tops will become narrower (built closer together). With increasing steepness, an increasing amount of land space is lost for crop production unless the farmer uses the grass on the risers as a field crop (perhaps as cut-and-carry feed for animals).

See the table at the end of this chanter for recommended terrace widths for different soil depths and slopes.

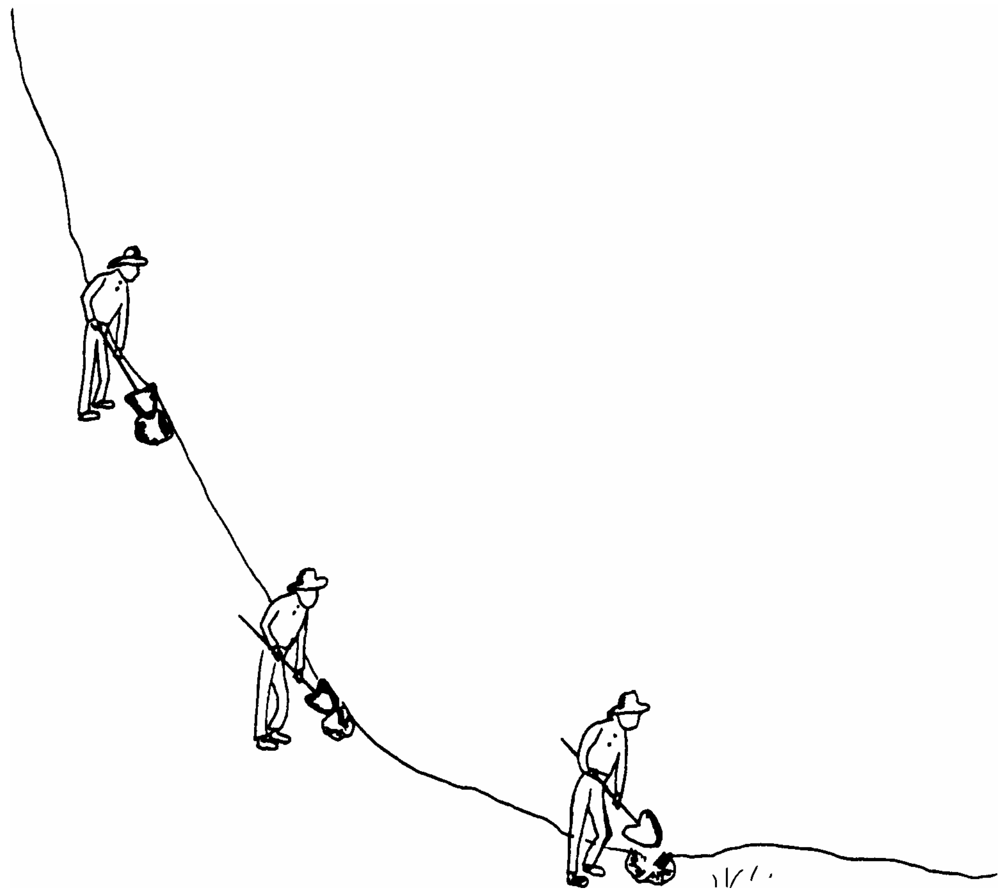
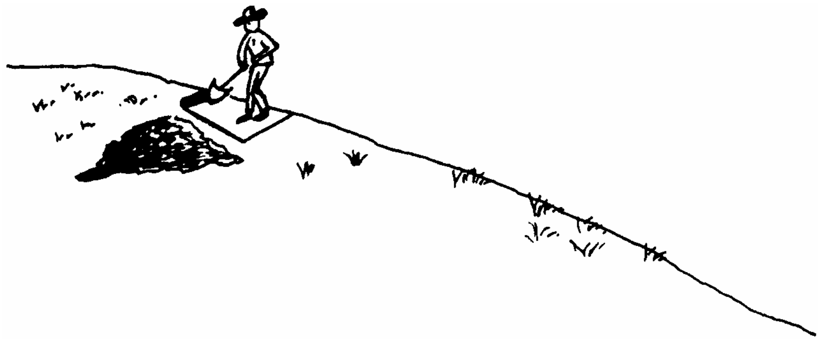


Figure 4-35. Checking useable soil depth before building terraces--a vital first step. Dig a hole or pit to the bedrock to determine soil quality and depth. Measure the useable soil depth all along the slope. The hole at the top (A) has shallow topsoil and subsoil. The hole midway down the slope (B) has slightly more useable soil. The hole on the bottom (C) has much more useable soil. Measure these depths carefully. Remember that the terrace walls (risers) cannot be higher than 2 112 times the useable soil depth.



Bench Terrace Construction Illustrated (Six Steps)

Figure 4-37. Step 1. After the hilltop diversion ditch is finished, begin the topmost segment nearest the drainage side of the field. Remove the topsoil from a 2 meter segment and pile it to one side, to be spread back on top of the segment after the subsoil has been shaped as a bench terrace. (Sketch idea from PC R062.)

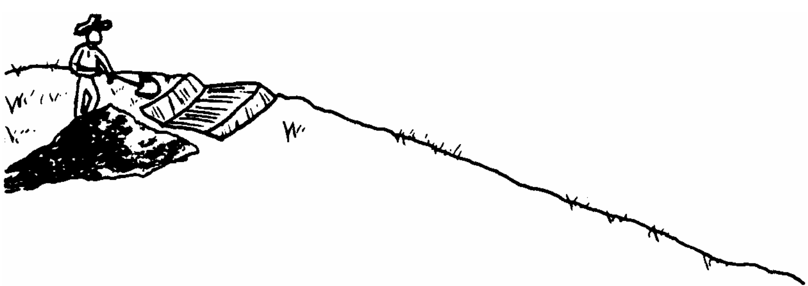


Figure 4-38. Step 2. Form a well-compacted segment of terrace, making sure it is measured correctly to grade. (Sketch idea from PC R062.)

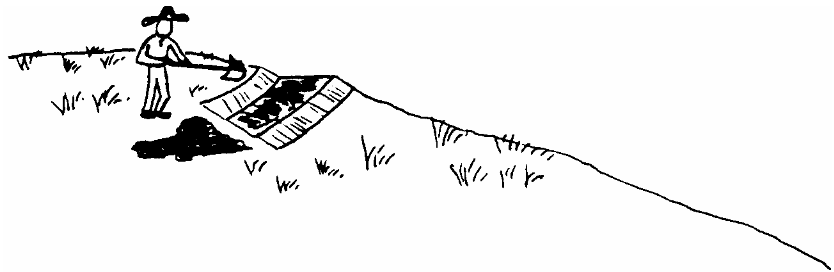


Figure 4-39. Step 3. Distribute the topsoil back over the same 2 meter section and pack it down well. Then clear another 2 meter section of topsoil and form it the same way as a terrace section. (Sketch idea from PC R062.)

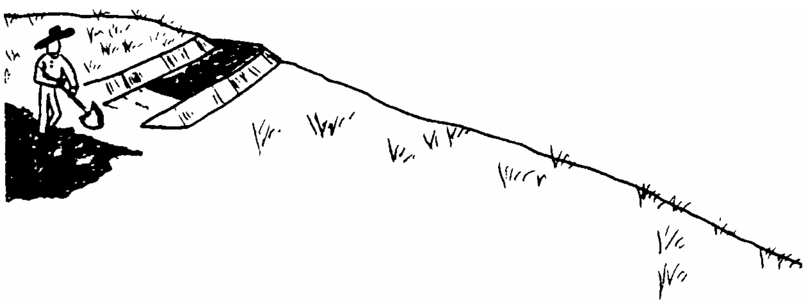


Figure 4-40. Step 4. Continue work with the top terrace, going in 2 meter segments sideways on around the hill. After the full length of the top terrace is completed, begin the next lower bench terrace in the same manner as the first. (Sketch idea from PC R062.)

Figure 4-4 1. Step 5. Continue work on down the hillside. Work always begins on the drainage side of the field. Each terrace should have 1% toward the drainage side. Check with local technicians. (Sketch idea from PC R062)

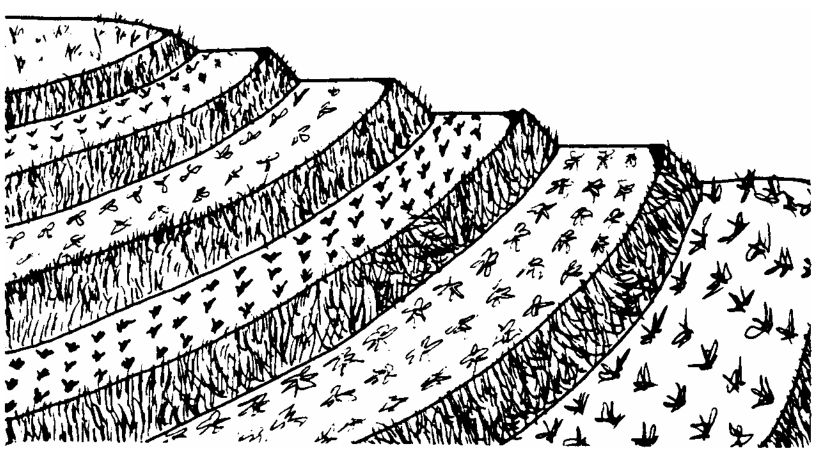


Figure 4-42. Step 6. Plant slips of grass on the terrace banks (risers). If possible, also use some straw or leaf mulch on the risers. Also mulch the outside half of the terrace floor where most of the fill has been made. This will help reduce erosion of this newly disturbed soil. (Sketch idea from PC R062.)

Figure 4-43. Constructing a continuous bench terrace. Notice the level string stretched along the top edge of the upper bank (riser) and also the stake in front of the nearest worker. These are grade indicators which give indications of vertical as well as horizontal directions. This lets the workers know how deep to dig and how high to fill in the soil on the down slope side of the terrace. Stakes also indicate where the outside and the inside lines of the terrace are--i.e., where the edge of the riser and the outside edge of the terrace floor will be. (Picture courtesy of Soil and Water Conservation Society of America)

c. Check your vertical distances I tbi.fi~1d after previous measurements and calculations have been made. Double check all calculations, slopes, soil depths, etc.

d. Construct all bench terraces in the dry season. Allow enough time to complete the projected terraces before the heavy rains.

e. Begin at the top of slope of the field. (Note: some people begin bench terraces from the bottom, but you are much safer beginning at the top.) First construct a diversion drainage ditch on the contour across the field to intercept and control water flowing down from up above the field.

f. Begin terrace construction <u>immediately below</u> the ditch, as shown in the accompanying illustrations. Do the work in small ~ Save the topsoil to one side, to be redistributed when the cutting and filling on a section is complete.

g. While the freshly disturbed soil is still loose and bare, it will be extremely vulnerable to raindrop splash erosion. The young grass will not fully protect the risers (sloped banks) for awhile. Cover or partially cover these areas. Use old rice straw, corn stalks, leaves and twigs from the forest--any mulch you can find.

<u>Inverse Discontinuous Terraces--Planning and Construction</u>

1. <u>Preliminary planning</u>

Building discontinuous terraces requires less time and labor than continuous ones, but they are still labor intensive. Adapt the suggestions for planning continuous bench terraces.

2. <u>Precautions</u>

The ten precautions listed immediately above are also very important here. You will want to adapt and use all of them. You will want also to give special attention to the following:

a. It is urgent that the loose filled soil be well packed.

b. If grass slips are not available, and grass seed is planted, a mulch cover is a must. It should be applied especially to the fill section (the outside part of the terrace floor) and to the inside terrace wall (the riser).

c. See the table at the end of the chapter for distances between terraces and for widths of terraces.

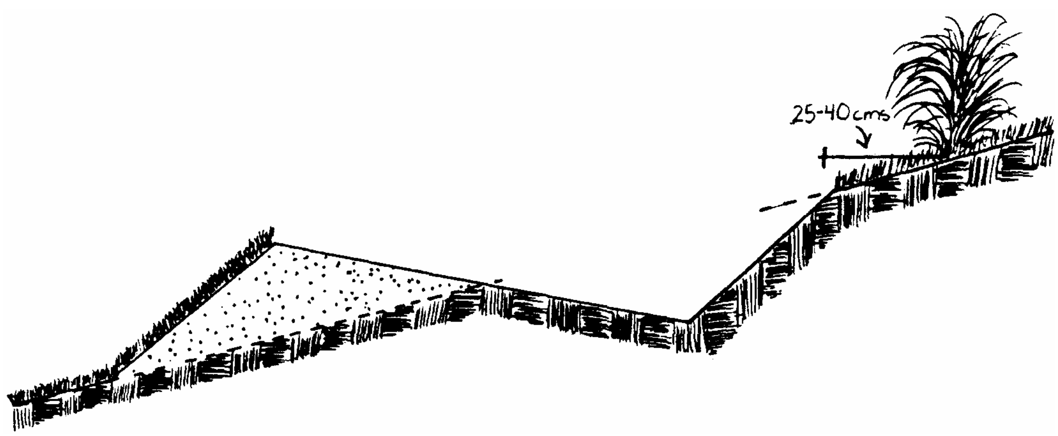


Figure 4-44. Vertical cross-section of a discontinuous (intermittent) narrow bench terrace. Construct inverse slope at about 15%. It will settle to about 10% after rains and foot traffic cause more compaction. (Drawing from PC R062)

Figure 4-45. Intermittent (discontinuous) terraces used for orchards. In the top drawing are individual platform terraces used for growing different kinds of trees on very steep slopes. Below it is a sketch of orchard terraces. It is urgent that all land between these types of terraces be covered with plant material, preferably a combination of grass and a low-growing legume (but not a climbing legume vine). These terraces must also be protected by drainage ditches. (Drawing from PC R062)

3. Steps in Constructing Inverse Discontinuous Terraces

a. Accumulate tools and supplies as for building continuous terraces. Begin at the top of the field with an appropriate contour diversion ditch. Add other drainage ditches including a controlled exit drainage ditch as needed.

b. Build discontinuous terraces on the contour with an inverse (inward) slope of 10%. Note that when the bench top is tilted this much inward, the inside cut (inside edge of the bench) forms a rather wide ‘V with the bank at the inmost edge. This then acts as a small drainage ditch to carry excess water away to the control drainage ditch.

c. The terrace will act as a conduit for unabsorbed surplus water, which will naturally follow the downward slope. Therefore, slope the terrace 1% along its entire contour, toward the direction of a drainage control ditch. (See Figure 4-44--vertical cross-section view.)

Individual (Platform) Terraces--Planning and Construction

1. Protect the terraces with standard contour diversion ditch at the top of the field and other contour drainage ditches as needed. (See Figure 4-45).

2. Plant one tree on each platform, and stagger the platforms over the hillside in an equilateral triangular or hexagonal pattern. This prevents the formation of straight rows down the hillside which make a path for runoff water. The distance between platforms will vary from 2 to 5 meters or more, according to the type of trees being planted. Get advice about this from local PCV AG specialists.

3. As the terrace is cut out, reserve the topsoil in a pile and return it to the top surface of the terrace. Compact the soil as shown.

4. After construction, be sure to cover the terraces with mulch. These terraces must be protected by mulch.

5. Also, plant low-growing vegetation to form a solid cover on both the ground level, sides. and top of the platforms and the slopes between. This is vital-the system erodes easily. Consider a legume-grass combination.

TABLE 4-1.
BENCH TERRACE CONSTRUCTION GUIDE*

Slope %	Useable Soil Depth (Meters)	Total Terrace Width (Meters)	Terrace Platform Width (Meters)
	0.3	2.5	2.0
20	0.4	3.3	2.6
	0.6	5.0	3.9
	0.3	1.7	1.2
30	0.4	2.3	1.6
	0.6	3.5	2.4
	0.3	1.3	0.8
40	0.4	1.8	1.1
	0.6	2.7	1.7
	0.3	1.1	0.60
50	0.4	1.5	0.80
	0.6	2.2	1.20

*Modified from P C R062

TABLE 4.2
GUIDE TO CONSTRUCTION OF DISCONTINUOUS NARROW TERRACES

Slope	Distance between Terraces (meters)	Total Terrace Width (meters)
5	18	2.2
10	14	2.3
15	13	2.4
20	12	2.5
30	12	2.7
40	12	3.0
50	12	35*

*GGW estimate. Modified from P.C. R062

Note: I have found Carl Crozier’s book for Peace Corps, Iflh1~idi..Earmjng (PC ICE R062) to be invaluable in preparing the above section--especially the engineering data and some of the sketches. Anyone planning to help farmers with planning and constructing terraces will want to study and use this excellent book.

CHAPTER 5

AGROFORESTRY: SUSTAINABLE FARMING SYSTEMS

The Need for Agroforestrv: an Overview

Deforestation of land in the Third World is a major cause of the appalling increase in drought, famine, and land degradation. Long-term development strategies increasingly stress tree planting as a prevention.

In 1985, several international agencies (including World Bank, World Resources Institute, UNDP, and others), met in a consortium which formulated plans to deal with the serious problem of deforestation in the Third World. They called for doubling spending on forestry.

One of their recommendations urged encouraging local participation in rural tree planting programs and natural forest management. Large-scale government reforestation or reform efforts must be supplemented by small-scale village and farm tree growing.

TWO DIFFERENT CONCEPTS OF TREE GROWING

1. Reforestation is the massive replanting of forests over a logged-off or cut area. This will always be important.

2. Social Forestry, also called Community Forestry, is the planting of trees as part of a plan to improve quality of living for a community. Farmers and villagers take part in planning, choosing and carrying out tree planting programs.

Tree Planting Projects which Failed: What Was Wrong?

1. In many of the earliest schemes trees were planted in huge government-managed tree plantations, often producing for large commercial enterprises. Harmful features often included:

   a. Large areas of land were often taken from villagers.

   b. Local farmers and villagers received little or no benefits. Outside owners garnered the financial returns.

   c. The cost was high in proportion to the amount of wood produced.

   d. Beneficial native trees were eliminated in order to grow special trees for large commercial enterprises.

2. In other efforts, <u>village-based woodlots</u> were established. Mistakes with these included:

a. Developers planted inappropriate species of trees.

b. Local people were not motivated or consulted in choosing sites and the kinds of trees to be grown.

c. Developers did not utilize and build on the villagers' existing knowledge.

d. The woodlots often did not meet the basic needs of the farming poor.

SOCIAL FORESTRY: FORESTRY TO HELP THE SMALL FARMER OR VILLAGER

Social Forestry trains villagers and helps them to create an environment abounding in trees; trees provide fruit, feed, fuel, and shade; and individual woodlots provide lumber or other products. Agroforestry, a form of Social Forestry, combines crop raising with tree raising. In addition to growing trees to rebuild soil fertility and conserve soil and water, farmers grow them to provide useful products or serve other purposes.

- Social/Agroforestry builds upon the farmers' traditional knowledge, expands and promotes it. Many Third World farmers have traditionally practiced a type of agroforestry. When they cleared fields for crops, they left in the fields the useful trees, like Acacia, Dawa-Dawa, and many others.

- If made a part of planning and development, villagers often become committed boosters.

- Agroforestry can usually use ways and concepts which individual families can understand and manage without much outside help.

- Small-scale assistance can produce significant results for the poor.

<u>Why is Deforestation Becoming a Serious World-Wide Concern</u>?

1. The world's people are stripping forests from the land at an alarming rate. During the 1980's, 11.3 million hectares of land in the tropics were deforested annually. Only 1.1 million hectares were replanted annually. In Africa, for every hectare planted, 29 hectares were cut.

2. Widespread deforestation devastates ecosystems, lands, water, and, ultimately, people.

- In West Africa, rates of water runoff from some bare cultivated soils have been twenty times greater than the runoff from forest lands. Deforestation is a factor causing increasing droughts.

- Many forest <u>soils deteriorate</u> under continuous farming without proper forest fallow (i.e., left in forest without cultivation for a long period). Crop yields drop drastically and the crops contain less nutrient value. Ultimately, the land becomes degraded, unfit for crops.

- The quality of life for the rural poor diminishes. Malnutrition grows. Fuel and wood products get scarce. People cut down or decimate the remaining trees and bushes for fuel. More time must be spent scrounging wood, often many kilometers away. Throughout the Third World, working-class people often spend more than 20 % of their meager incomes for wood or charcoal. Otherwise, they must use crop stalks or dung for fuel.

Why is Deforestation Increasing So Drastically?

As population numbers escalate, more people must cultivate an ever-enlarging amount of land to provide food. Much of the deforestation comes from the widespread increase of traditional methods of bush-fallow ("slash and burn") farming. Until now this has been a sustainable way of farming (i.e., a system in which the land could regenerate and keep its productivity).

Over 70% of the deforestation in Africa, at least 3.5 million hectares per year, is now from slash-and-burn farming. According to the FAO, shifting cultivation now causes about 70% of the forest clearing in Africa, about 50% in tropical Asia, and about 35% in tropical America.

What Is "Slash and Burn" or "Bush Fallow" Farming?

'Bush fallow **"** or "slash and burn' farming is a traditional kind of rotation farming with forests. A farmer clears a small plot (one hectare more or less) by cutting down most of the trees and tall brush. He burns most of the residues, an easy way to get rid of weeds and trees. After growing crops for 2 or 3 years, the farmer moves on and clears another place. The first farm plot rest fallow (i.e., without cultivation or cropping) for 10 to 20 years, returning to forest.

For thousands of years, tropical small farmers have practiced "slash and burn" farming. The "forest fallow" system kept the land in good condition indefinitely, even though some minimum erosion did occur. In those days the cleared land was not too steep. Forest trees and shrubs soon reestablished themselves when the land was left to lie fallow, gradually replenishing the organic matter and fertility of the soil.

Why Is "Bush Fallow" (Slash and Burn) Now Breaking Down?

Farmers still use traditional shifting cultivation systems in many areas of the world. Where land is plentiful, the system still works and is sustainable. However, intense population pressures are causing it to break down. As land gets scarce, farmers must clear steeper land, and must farm the same land for more than 3 years. Often they cannot move on to other land at all. Soon the soil on steeper slopes washes away and nutrients in the soil are depleted. After the soil is degraded, no longer useable, many families join the millions in city slums.

The breakdown occurs because many forest soils on steep slopes must have regeneration equivalent to forest fallow, or improved management which results in a sustainable system.

What Can We Offer as a Replacement?

For some years, agroforestry researchers and specialists have been devising and working out ways to incorporate trees into the farming system. They stress the urgent need for trees on small farms. Even degraded land will often sustain some types of badly needed trees.

What You Can Do as a Peace Corps Volunteer.

Many development experts believe that only the millions of small farmers and villagers themselves can solve large-scale deforestation. Their numbers are so overwhelming that only they can provide enough knowledge, labor and commitment for a problem of such scope. They are on site and trainable.

- In Kenya, for example, villagers have planted many more trees than have been planted on government plantations.
- In Rwanda, trees planted by rural people total about 200,00 hectares, more area than the remaining natural forests and state and communal plantings combined.
- As a Peace Corps volunteer you can be a tree-planting booster!
- You can educate farmers about the income value and replenishment potential of trees. You can build awareness with audio-visuals, meetings and workshops. You can encourage and motivate small farmers to plant trees (see later).
- You may also be able to establish a farm tree nursery or a village nursery, perhaps a tree growing club.
- At the end of this chapter you will find a description of a very successful, expanding agroforestry project in Ghana. It is full of practical ideas which worked for one group of volunteers.

To summarize, successful reforesting depends on: (1) getting the belief and commitment of the people at the grassroots (2) coordinating the work of many local groups from small villages and farms.

AGROFORESTRY--WHAT IT IS AND WHAT IT DOES

What Is Agroforestry?

Agroforestry systems use trees as part of a farming program which includes growing other crops. It often also includes raising animals. In agroforestry systems, the farmer grows trees to prevent erosion and replenish the soil, and also to provide food, feed, firewood and income.

Benefits of Trees in Agroforestry Systems

1. Trees as Replenishes of the Land

- Reforestation can utilize some degraded lands and restore them to usefulness.
- Tree litter (leaves and twigs) left on the soil surface prevents raindrop splash erosion. The protective cover also conserves soil moisture by reducing evaporation.
- Added organic matter from decomposing forest litter (tree limbs, twigs, leaves, mulch) improves

soil fertility, structure and permeability to rainwater; it diminishes rainfall runoff.

- Many legume trees (and a few other kinds) produce nitrogen fertilizer, which rapidly increases the soil's productive potential. (See Chapter 3.) Nitrogen-fixing trees can often reduce fallow time needed for depleted land from ten or more years to a very few years.

- The deep and wide-spreading root systems of trees interweave throughout the soil, and work the soil to great depths.

- Very long tree roots penetrate the soil more deeply than field crops and bring up plant nutrients from the subsoil which recycle when leaves and twigs return to the soil.

- Trees and tree mulch shade the soil and protect it from hot tropical sun, keeping the soil from baking. This creates a better macroclimate and microclimate. The cooler soil temperature also encourages more root growth and helps conserve organic matter.

2. Trees as Crops and Income for the Small Farmer

- More than 2/3 of people in the Third World use wood for fuel for heating and cooking. Trees on the farm provide a handy source of fuel wood from pruning limbs, branches and twigs, season after season; they help prevent denuding of forests.

- Trees can provide stakes, poles, lumber, fibers for weaving, and wood for crafts, furniture manufacturing.

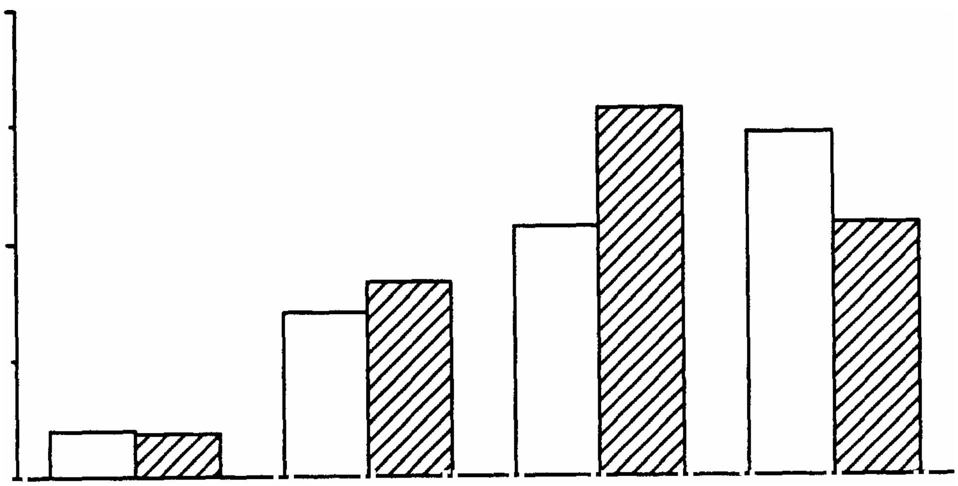
- Many species make valuable forage, either for grazing, or for cut-and-carry. Certain kinds can provide fodder during the dry season or during droughts when other animal feed is extremely scarce.

- Pods, seeds, fruit, and nuts from trees provide food which can greatly improve the family's diet and income. Certain kinds provide cooking oil; some even make fermented drinks.

- Some species provide nectar for honeybees, leading to beekeeping as an enterprise.

- Legume trees can provide nitrogen and mulch for improved crop yields and at the same time produce other tree products

- As with soil conservation techniques per se, motivating farmers to plant trees has proved to be extremely difficult unless the trees address one of the farmers' short-term needs--and since trees are long-term commodities this has been challenging. Finding short-term pay-back strategies seems to be a key element in successful community forestry projects. Peace Corps successes have included coupling beekeeping. fruit production. cut & carry forage production, and in some cases wood-lot development to provide incentives for tree planting and care taking. Live fences is another example of a motivation to which farmers have been able to relate. In arid regions trees for wind breaks have sometimes proven successful motivators.



Species Of Legume tree

Figure 5-2. Some legume trees when planted in rows 4 meters apart not only produce nitrogen but also recycle other plant nutrients. For example, the deep root system of *Glincidia sepium* withdraws heavily from the soil--more than 200 Kg of potassium, 50 Kg of calcium, 15 Kg of magnesium, and 10 Kg of phosphorus per hectare per year. Much of these plant nutrients are returned to the soil as the tree leaves drop, or as they are harvested and spread over the soil surface as mulch. Leaves of legume trees could also improve the quality of compost. (Modified from B. R. Kang et. al., International Institute of Tropical Agriculture, 1986.)

Systems of Tree Planting for the Small Farmer

1. Native trees and vegetation. Where available, these supply the main fuel and some food source for many rural subsistence families.

2. Planting around homes, in crop land, pasture or fields. Trees are located at random in grazing land to give shade for animals and fodder browse during dry periods.

3. Inter-planting of trees and crops

- Trees as live barriers combined with green manure crops to control erosion and improve soil fertility.

- Alley cropping (see later section of this chapter). Also known as ‘hedgerow intercropping”, “alley farming” and various other names.

- Multi-tiered planting: crops of several different heights growing together. They often include leguminous trees, shrubs, and cover crops.

4. Trees grown in stands for lumber, firewood, poles, fruit, animal feed or other needs

- Community woodlots. Also trees on the village commons or on designated state lands. To ensure success, careful management is necessary: Participants must understand individual responsibilities and especially how benefits are distributed.

- Farm woodlots

- Farm fodder feed banks. Farmers often concentrate trees for cut-and-carry fodder in stands or blocks to ensure easy harvesting and location near the penned animals. Small blocks thickly planted with trees also can be more easily fenced to keep out foraging animals.

5. Trees along fence lines, farm boundaries, roads, and stream banks; around homes or compounds; on terrace risers; in ditches.

- closely grown hedges to keep out animals, provide privacy, etc.

- windbreaks

- nurse or shade trees for other crops

- support trees for vine crops to climb on. Some crops which require support are black pepper, passion fruit, yams, and vanilla. *Gliricidia, Leucaena, and Sesbania* trees make excellent stakes if the branches are cut off and the trunks are kept cut to the proper height.

Figure 5-3. *Gliricidia sepium* growing on a farm boundary as living fence posts. These trees were originally stuck deeply in the ground as stakes which later branched and leafed out. Periodically these trees are trimmed back, the leaves fed to livestock, and the limbs used as firewood. *Gliricidia* also makes an excellent green barrier when planted close together, as instructed in Chapter 4 for growing live tree barriers. (Picture courtesy of the Nitrogen Fixing Tree Association.)

HOW TO ESTABLISH AGROFORESTRY IN YOUR AREA

Requirements for Success with Agroforestry

Successful agroforestry projects are not easy to establish. Many have failed in the past. Farmer commitment, the main requirement of success, depends upon:

1. consulting the farmers and using their knowledge
2. making farmers and villagers part of the planning and action
3. respecting traditional customs and lore
4. using some species which the farmer likes (usually a multipurpose tree)
5. meeting the farmer's perceived needs
6. increasing total yields or income
7. protecting trees from damage
8. clear understanding of obligations and benefits by participants in cooperative programs.

How to Get Started

1. Know your Area. Determine the kinds, extent and productivity of trees already growing, and varieties which are doing well. Investigate weather, soil types, elevations, special problems, special needs.

2. Consult with foresters, your APCD-Agriculture, your APCD-Forestry and others. Find out recommended varieties and sources of seeds, cuttings, or seedlings. Study local lists of recommended species used by researchers. Look at the list of trees in this chapter. Introduce new varieties cautiously.

3. Check for local sources of seed and seedlings. Also look for other sources.

4. Visit local farmers. Learn how long each farm has been under continuous cultivation, problems with erosion or diminishing crop yields. Determine the farmer's tree needs and preferences. How far must people go for firewood and fodder? What fruits are used in the family diet? Involve the farmer.

5. Visit local village and coon leaders. Ascertain needs, marketing problems and possibilities, ideas and preferences. Get their inputs. They will have very practical experience.

6. Arrange group meetings. Hold open discussions. Be sure to include women farmers and the wives of farmers. Examine together such concerns as:

    a. Need for more animal feed during the dry season or at any other time, for more firewood in the home or locally, for other wood products, for more fruit trees.

    b. Other needs for trees

c. Marketing possibilities for tree products: for trees already known in the area; for trees not being grown at present in the area; consider crafts or other activities based on tree products which could develop

d. Favorite or appealing types of trees--multipurpose trees, etc

e. The possibility of growing more trees on the village commons or in communal plots

f. Growing legume trees as live barriers if erosion is a problem

g. Growing multipurpose trees as windbreaks if wind is eroding soil or damaging crops (Chapter 7)

h. Group concerns about tree planting

i. The limiting factors to growing trees.

7. Take interested farmers and village leaders along with a forester or extension worker to visit successful farmers or village tree-growing demonstrations.

8. Hold small meetings, workshops and audio-visual presentations to raise general awareness, create hope and enthusiasm, and set tentative goals. (World Neighbors has excellent visual materials). Again, examine together what factors limit growing more trees

9. Involve youth groups: scouts, school classes, 4-H programs where available, other youth groups. They can raise a few seedlings for the market or possibly help with village projects or their own goals.

10. Introduce idea of alley cropping if rainfall is adequate (1800 mm or more), and if the desired multi-purpose legume trees do well in your location.

11. Encourage the establishment of individual farmer small nurseries and community nurseries. Discuss the formation of a village tree growing club. Look at marketing possibilities for tree seedlings.

12. Plan with individuals who want to plant trees

a. Help decide on tree varieties for each farmers particular needs.

- Encourage farmers to name first the trees they would like to plant and where.

- Consider the growth rate of various trees, whether fast or slow. How soon does the farmer need income from them?

- Consider the advantages, disadvantages, and special growing requirements of different varieties; palatable versus unpalatable varieties for livestock.

b. Consider the advisability of growing a mixture of varieties to minimize risk of loss from disease and insects.

c. Investigate the farmer's particular farm (excessive erosion, poor yields, fruit trees, food needs, etc.)

d. Incorporate ways to increase income or food yields and minimize risk. The farmer must avoid too much risk and must have a pay off in the short run. How could trees help?

e. Plan labor needs. If tree planting time conflicts with crop planting time, careful scheduling or neighbor cooperation should be included in the planning.

f. Plan follow-up care of young trees: keeping the young trees weed free and protected from drought.

g. Determine how to protect trees from grass fires (i.e., by constructing fire lanes, other methods).

h. Develop ways to protect trees from animals. (See later in this chapter.)

Desirable Types of Trees

1. Legume trees.

As noted throughout this manual, legumes adaptable to the region, in whatever size or shape (adaptable low-growing ground cover, shrubs or trees), are premium choices for soils low in nitrogen.

2. Multipurpose trees.

Ordinarily, the farmer needs trees which have several multiple (multipurpose trees). For example, a nitrogen-fixing tree might furnish fodder, firewood, nitrogen fertilizer, green manure and poles; its pods or seeds might provide food for the family. Field workers report that farmers will plant multipurpose trees when they do not want to plant trees specifically for firewood or for improving the soil.

3. Fruit Trees for the Family Compound

Many desirable fruit trees thrive in the tropics, and have great value for the health of the family. Citrus trees are of course noted for Vitamin C, but others like the avocado and the banana are highly nutritious. Do not forget the mango, the guava, the coconut, the papaya, and nut trees such as cashew.

Family nutrition often suffers when lands are diverted from family food crops to crops for market. Fruit trees can help fill the gap.

Growing peaches in Bolivia has been a successful program where the fruit is dried whole and sold to make a popular beverage.

Some Desirable Fruit Trees

The following are a few fruit trees or shrubs with the time from planting to harvest:

- Bananas--about 11 to 14 months
- Papaya grown from seed--6 to 9 months
- Citrus--(lemon, orange, grapefruit, tangerine)--about 7 years, but then they produce for many years with good care.
- Mango--begins to produce in 3 or 4 years, and produces for many years.
- Guava--grafted trees begin to produce in 5 to 6 years, and produce for many years.

Plant fruit trees, shrubs, or vines in well drained soil with lots of compost. Each year add leaves, manure and other mulch to the soil under and around fruit trees.

For more information see World Neighbors Filmstrip ~Grow Fruit for Family Use or World Neighbors in Action Newsletter Let's Grow Our Own Fruit. Many of the ideas above are based on information from World Neighbors.

Some Answers to Farmers Concerns about Growing Trees

1. Certain farmers may object that trees take too long before harvest time
   a. Many varieties grow quickly. Farmers can plant fast growing trees (like bananas and papaya) while slower growing kinds are coming along. The need here is to locate and plant some desirable fast growing varieties. Nutritious fruit is worth some wait.
   b. Other crops can grow along with the trees to provide food and income. (See chapter 6--the SALT program).
2. Farmers may object to shading of crops by trees.
   a. Many multi-purpose trees can be cut back or their branches pruned to eliminate shade competition during the food crop-growing season. The trees can then grow freely during the dry season, providing fodder when little else will grow.
   b. Rows of trees may be spaced more widely if needed.
3. Some farmers worry about trees taking up land area which could be put to crops.
   a. The trees occupy little space when they are small or when the farmer keeps them pruned.
   b. Even if a little crop area is lost, many multipurpose tree products when combined with crop yields add to the total income.

4. Some farmers may have failed with trees, due to animal damage, neglect of plants in other ways, (weeds, drought when young, grass fires, etc).

a. Proper management is extremely important, especially care of very young plants. This is a vital consideration.

b. Discussion of ways to protect plants and perhaps plans for cooperative action will be important.

HOW TO GROW TREES

1. Select the kinds of trees to be planted and decide where to plant them.

2. Locate seed, seedlings and/or cuttings to plant, if possible from healthy, well-known trees in the area. Encourage the farmer to test-demonstrate an area with new recommended varieties of multipurpose legume trees.

3. Make a seedbed for growing seedlings.

a. Making a seedbed: A properly prepared seed bed is essential for healthy, fast-growing seedlings.

(1) Make a slightly raised bed 6 to 10 cm above the surface to give good drainage. Be sure it is protected from any runoff water from above.

(2) Make the bed no more than 1 meter wide so that it can be tended from both sides without walking on the bed.

(3) Make the soil mixture from good topsoil plus some organic matter (well decomposed manure or compost). Work the soil well until it is composed of fine particles and is smooth in texture.

b. Planting the seed

(1) Plant seed in very shallow trenches made with a small stick or with your finger. The rows should be 4 cm apart. (Note that some kinds of seeds need to be pre-soaked--others may need special treatment. See instructions in The Tool Kit.)

(2) Cover lightly with oi1 and then with mulch.

(3) Water gently with some kind of sprinkling can which puts out very fine drops. Be sure the bed is slowly soaked well. Keep the bed moist.

c. Caring for the seed bed after planting.

(1) Water the bed daily with the sprinkler can. Keep the sprinkler can held low; apply the water gently.

(2) Shade the soil from hot sun and protect it from raindrop splash. Depending on the climate, build a frame roof covered with grass or straw, about 1 meter in height

above the seedbed, and the same width. This protects the tender seedlings from large raindrops and from full sunshine.

(3) Keep the bed free of weeds.

(4) When the seeds have sprouted, remove part of the grass mulch-enough for the seedlings to emerge. Some mulch remaining helps shade the soil and avoid too much raindrop splash.

(5) Thin the plants when the seedlings have grown their first two leaves. Leave plants in the bed for every 4 cm apart in each row. If desired, transplant those seedlings which you remove into another bed or into containers to grow.

d. Planting directly into containers. Some people prefer to plant directly into containers. Still others plant in beds and then move the seedlings to containers as they grow.

(1) Mix soil for containers much as above, plus some sand if possible (one part sand, one part old manure or compost, and one part good topsoil).

(2) Use small plastic bags to hold the potting soil, or small paper cartons, wooden boxes, tin cans, plastic jars, or containers woven from palm leaves or other local materials. Poke small holes in the bottom to facilitate drainage and prevent root rot.

(3) Place containers under partial shade. Water gently daily or as needed.

e. Transplanting seedlings. Seedlings will be ready to transplant into the field when they are 1 year to 18 months old, or sooner, depending on rate of growth.

(1) Always begin transplanting at the early part of the rainy season.

(2) Handle the seedlings carefully. Do not let them dry out. Be careful not to expose the roots to wind or sunshine. If possible, keep a ball of wet soil around the roots. If the seedlings grew in a container, remove the soil intact when wet and plant the entire clump of soil and roots.

(3) Plant the seedling into the ground at the same depth it was planted in the seed bed or container. Keep the plant in an up right while planting so the tap root stays vertical, is not bent, and will grow deep. If seedlings are planted too shallow some of the roots will be exposed.

f. Protecting transplanted seedlings. Transplanted seedlings are vulnerable to animals, weed competition, fire heavy rains, and drought. Make plans for their protection. These plants are very fragile!

(1) In case of drought a few weeks or months after planting, carry water to the forest demonstration and irrigate each tree until the drought is broken. Watch for wilting.

(2) Place some mulch around each tree. It will help control weeds and conserve soil moisture.

Figure 5-4. Protecting young seedlings in the field. If straw mulch is not available, some very young, fast-growing seedlings can be protected from heavy rains and full sunshine by placing other types of protection over them. Here, farmers are placing banana leaves in an inverted “V” over these very young seedlings. (Picture by author.)

(3) <u>Fence the forestry plot</u> to keep farm livestock away or the trees may be destroyed; or else fence or tether livestock. <u>Do not allow animals near</u>. Damage from farm animals is a major constraint to growing trees.

(4) <u>Make needed fences from local materials</u>. Usually low-cost or no-cost local materials such as bamboo, cornstalks, or tree limbs will make a suitable fence to keep out small animals. Sink the limbs or stalks into the ground and tamp them firmly. Use vines, raffia, other native fibers or string to weave around and through the stalks at 2 or 3 heights to form a fence similar to our picket fences.

(5) If this is impossible, devise some solution to keep animals out. Some farmers have used thorn bushes or cacti barriers as fencing. A project in India dug deep ditches surrounding plots to keep cattle out. Farmers acting together might hire guards or post family members.

(6) Be faithful in keeping the tree plot free of weeds, to reduce weed competition for moisture, nutrients and sunshine.

(7) Keep an open fire lane, clear of any dry burnable materials, around the plot.

g. <u>Harvesting</u> tree products. When to harvest depends on the tree variety; use to be made of the wood, branches, leaves, fruits, seeds; the age and growth of the tree; the market demand; and such factors as whether the tree is intended to grow tall or is to be kept small and bushy.

<u>Examples:</u>

(1) Quick-growing trees like the legume *Gliricidia* can be harvested back to 1 meter height for firewood at 1 and 1/2 to 3 years of age; at 2 to 3 years for poles. They can be harvested again as needed at any time for green manure, firewood or animal feed.

(2) Eucalyptus can be cut for posts or poles at 5 or 6 years. Smaller limbs can be cut earlier for firewood or to make charcoal.

(3) Trees can be allowed to grow large for lumber or for paper or chemical production.

(4) Firewood can be harvested as tree prunings.

(5) Certain multipurpose trees provide animal fodder at many stages of their growth.

(6) Seeds, pods, fruits, and nuts for human consumption usually grow on the trees until mature or ripe.

(7) Legume trees can be pruned as needed for mulch or green manure.

Figure 5-5. Multi-purpose nitrogen-fixing tree poles ready to be taken to market. (Photograph courtesy of Nitrogen-Fixing Tree Association.)

Figure 5-6. Construction with poles (instead of finished lumber) is common in tropical countries, especially in rural areas. (Picture by author.)

Why Have a Community Agroforestry Seedling Nursery?

Why have a nursery? Why not plant trees directly in the field from seed or cuttings?

- A nursery may not be needed for certain trees. *Gliricidia*, for example, will grow from green stakes driven into the ground in the early rainy season. Fast-growing trees with large seeds will grow from direct seeding. *Leucaena leucocephala*, though slow to grow the first few months, can be planted directly into the maize row at the time maize is planted. Weeding the corn also weeds the *Leucaena*, which establishes itself well while the corn grows.

- Most young tree seedlings, however, are very fragil and do much better when started in a nursery. A nursery also can protect them from hot sun, rain, drought, animals, and other damage. In the nursery, seedlings can be grown and kept watered through the dry season, so as to be ready to set out during the early rainy season.

- A nursery also makes possible a reserve bank of seedlings or small trees for farmers starting agroforestry, or for backup supply in case of shortages.

How to Establish the Community Seedling Nursery

1. Determine the purpose and the size of the nursery. How many seedlings will be needed? What kinds?. When will different varieties be needed? At what age will the trees be ready to transplant?

2. Select the people to help. You will need very reliable help.

3. Locate sources for healthy seeds or seedlings.

4. Choose the site. It should be a level area if possible. The nursery needs to be convenient, accessible and near available water. Ideally, part of the site should have partial shade from low-growing trees.

    a. Dig a contour drainage ditch around the upper sides to carry away any water from above. Be sure the site is well drained and will not have small ponds of water standing during the rainy season.

    b. Build a strong fence around the area to prevent damage from animals or children. Keep both out of the area.

5. Build a grass-thatched or other type roof over one or more areas, to keep seedlings out of direct sunlight and heavy rain. Make the shelter sturdy enough to stand up under winds from heavy storms.

6. Build another shelter which remains dry for storing seed, fertilizer and supplies. Provide a third dry shelter tall enough for people to stand and work during rainy spells.

7. Supplies:

• A plentiful pile of rich topsoil

• Old manure and/or good compost also piled and ready

• A pile of sand to be added to help form a potting mixture

• A sled or wheelbarrow to carry pots, soil, etc. If necessary, you or the farmer can build one.

• A source of pots or other plant containers. You may find plastic film tubing which tears off in short sections to become small sacks. Use whatever containers you can make or find. Some farmers use small woven baskets, sections of large hollow bamboo limbs cut to proper length (18 - 20 cm), depending on the size of the plant to be grown. Some types may require much larger containers. Whatever you use, be sure small holes can be punched into the bottom to allow drainage of the surplus water.

- Tools: You will need knives, (cutlasses or machetes), shovels, hoes, spades, mattocks, sprinkler cans, and buckets.

- If possible make a frame of wood--poles or lumber--which is about 3 or 4 cm thick and 6 to 8 cm wide. The frame should be about 45 cm x 45 cm or larger. It should be covered with coarse galvanized screen of about 1.5 cm square mesh. This will be used to screen out large clods and rocks when mixing soil for the small pots.

8. Test the soil at the soil lab if available for pH, phosphorus and potassium. Follow the lab's recommendations. If not available use the best topsoil available with abundance of compost and manure.

9. Purchase the needed fertilizer and ground limestone (if required) to make a very fertile soil.

10. Mix a large batch of potting soil. Use one part topsoil, one part sand and one part manure or compost.

11. You may wish to plant most of your seedlings <u>in small seed beds</u>. (See previous section of this chapter for instructions.)

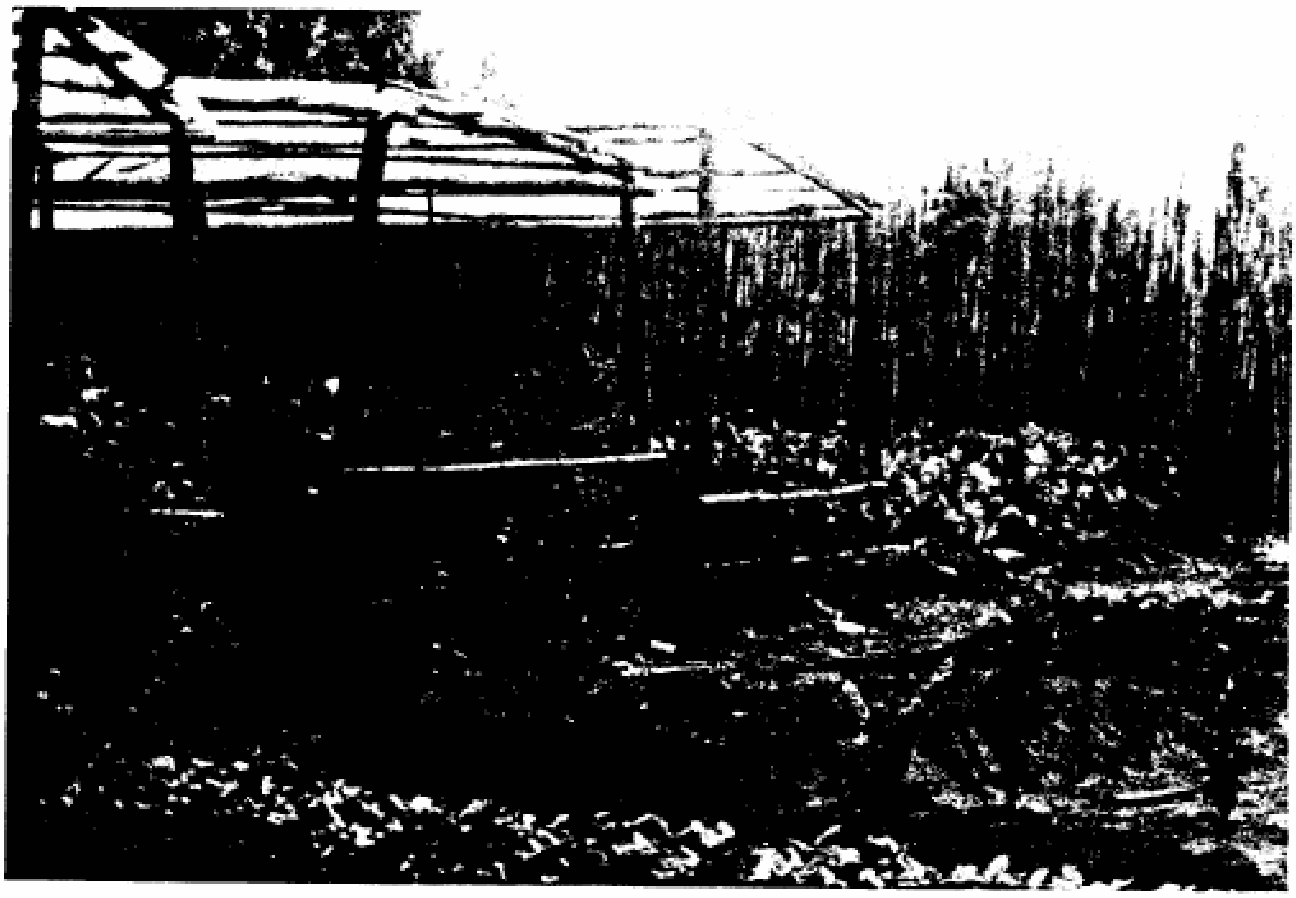


Figure 5-7. A village tree nursery. Notice the fence made mostly of cornstalks, and the framing for the shelter made of poles. (Picture by author.)

Figure 5-8. Trees in pots in a nursery, ready to be transplanted in the field. (Picture by author.)

12. You may wish to construct small trays or boxes with about 15 - 20 cm depth to use for planting seeds. You can put these boxes or crates on a raised table to avoid stoop labor. They allow plants to be moved quickly and easily when weather or other needs dictate.

Fill the boxes or trays with good potting soil. Plant seeds as you would in other seed beds. Transplant seedlings later as necessary to small or large pots, to wider row beds in the nursery, or directly to the field.

13. Build up a supply of mulch materials. Grain straw (wheat, barley, rice) is an excellent mulch. If not available, use dry leaves or other material to form a protective porous mat.

14. Seeds of some forest tree species need hot water or chemical scarification before planting. (See the Tool Kit.) Legume tree seeds will also need treatment with *Rhizobia* bacteria. If there are no *Rhizobia*, they cannot fix nitrogen! You can treat the tree seeds with *Rhizobia* by rubbing them gently with soil from underneath similar trees. If treated soil is not available, see Appendix for source of *Rhizobia* bacteria.

15. Plants in pots or small containers need frequent attention. They dry out quickly.

16. Some time before transplanting, begin to harden the plants. Gradually remove them from nursery conditions to field conditions so that they can survive in full sunlight.

17. See above under How to Grow Trees for instructions on transplanting seedlings.

18. Before beginning to construct and set up your nursery, be sure to check with any Peace Corps specialists who might help you.

19. Visit the national Forestry Division or School of Forestry for ideas and help. Perhaps also you can locate a village or state nursery to visit.

For more information on planting tree crops, see: (1) Planting Tree Crops from the World Neighbors Practical Guide to Dryland Farming (Many of above ideas came from this) (2) Sustainable Agroforest Land Technology (SALT 3).

Figure 5-9. The farmer is filling small plastic bags with greenhouse potting soil mixture. Behind him, you can see some filled bags. (Picture by author.)

Figure 5-10. Plastic bags filled with greenhouse potting soil mixture. (Picture by author.)

Figure 5-11. Seedlings which were planted in a small shallow box. In the background, notice very small seedlings in pots. (Picture by author.)

ALLEY CROPPING

Slash and burn farming, which requires short farming periods (2 to 3 years) and long fallow periods (10 to 20 years rest period), ties un a lot of land in fallow. Many tropical regions no longer have the land to spare.

Agriculture researchers and developers have tried to increase food production by transferring improved methods of farming into the tropics. The Green Revolution with its improved crop varieties, mechanization, large applications of commercial fertilizer and other chemicals, was highly successful for the larger tropical farms in the lowlands. However, much of the Green Revolution technology was not appropriate to meet the needs of the small subsistence upland farmers.

We must find a solution for the very poor small tropical farmers, the men and women struggling to survive. These farmers have little ready cash and no credit to buy much fertilizer, chemicals or special equipment. They have little education, and little background in mechanics. They use hand tools and depend on hand labor, sometimes oxen or water buffalo. They like and understand the methods of their ancestors; they distrust risky and strange ways. Some modifications and improvements of the old slash and burn system are needed.

Alley cropping solves the dilemma for some small farmers. It is not an outside system; it originated in Nigeria and builds upon traditional concepts of forest fallow. Farmers are used to letting land lie fallow. They already farm with intercropping, multiple and mixed cropping. For certain farmers and farming conditions, alley cropping can work well. More about this later.

What Is Alley Cropping?

In Chapter 4, we discussed using tree hedges in live barriers as a good way to control erosion. Careful contouring and very thick populations of trees are used to form these live barriers. We discussed their many advantages where fast-growing legume trees can be used. This can be considered one special form of alley cropping.

Alley cropping combines trees for forest fallow with continuous crop production in an intercropping system. It adds continuous use of forest fallow to continuous crop production.

In alley cropping, farmers grow *trees* in systematic rows or hedgerows, with food crops growing in the strips of land between the hedgerows. (See picture and sketch.) Some schemes include animal production. The rows of trees provide the benefits of forest fallow even though food crops are growing along with them. Ordinarily, the farmer uses special leguminous tree varieties to add their nitrogen fertilizer to the soil.

- As an essential part of the system, the trees are planted at intervals when food crops are planted or growing, in order to prevent shade competition with the arable crops.

- Sometimes, if the farmer does not plant food crops in the land strips, he allows the mature trees to grow without pruning, in order to provide a shade over the soil to control weeds. He can combine the system with periods of short or long fallow as he wishes.

- Often in such cases the farmer allows livestock to feed on the lower leaves during a fallow period. Caution: Be sure that the trees are at least 3 years old before animals graze, or the young trees will be destroyed.

- Where erosion is a problem, the trees should be planted very thickly. The rows should be on the contour to promote soil and water conservation. (See Live Barriers in Chapter 4.)

Special Advantages of Alley Cropping

- Under good conditions it provides a sustainable system which allows the farmer to grow crops year after year on the same land without degrading the soil. The rows of trees help keep soil organic matter and soil fertility relatively high.

- It limits the land which must lie fallow in trees to narrow rows, saving 80% of the farm land for crop production. It is a land-efficient system of forest fallow. Caution: for this system to work, the subsoil must be relatively fertile and deep. The tree roots must find nutrients to recycle.

- It applies appropriate technology . In other words, it builds upon systems the farmer knows, uses only tools he already uses and requires minimum outlay of capital.

- It adapts to many types of crops, crop uses and cropping patterns.

- It is highly useful and adaptable to systems of erosion control as live barriers.

- It can provide useful fodder and forest products in addition to the farmer's yields of food crops, if sufficient trees are planted.

- Under ideal conditions, it can increase crop yields.

- It can sometimes shade out many weeds if the farmer lets trees grow un-pruned during the dry season. The trees can form a canopy over the strips where food crops were harvested, discouraging weed growth.

Disadvantages and Special Requirements of Alley Cropping

- Where the farmer is planning alley cropping for soil building, and does not need a live barrier for soil conservation, there may be other, better alternative farming systems.

- The farmer should be sure of his land tenure. He or she should have a very long lease on the land, or own it. Trees are a long-term investment.

- The subsoil should be relatively fertile and deep enough for tree roots to have depth and grow vigorously.

- Most successful alley cropping to date has been done in humid and sub-humid regions. At present, alley cropping for arid and semi-arid regions should be approached cautiously and with an eye on future research results.

How to Establish Alley Cropping

The following instructions are for level land. Steeper slopes call for careful contouring of tree rows and much thicker planting in the tree rows. (See Chapter 4.) The farmer should use the following as guidelines, and adapt them to the particular situation.

1. Familiarize yourself with methods of establishing and managing live barriers of nitrogen-fixing trees (in Chapter 4). Also review the instructions for planting and growing trees given earlier in this chapter. Be sure the trees you plant are healthy, well adapted, and grow vigorously. Test all new species and varieties before expanding a demonstration.

2. On level land, erosion should not be a problem. Even though you will still plant 2 or 3 trees together in a cluster, space the clusters of seeds 10 cm to 30 cm or more apart in the row. If you have any doubt about erosion, run contour lines, treat the project as if you are establishing live barriers, and use the thicker population recommended for them.

3. Spacing between the hedgerows:

    a. This varies according to the need. Many researchers and farmers prefer about 4 meter spacings. On newly-cleared soil, 4 meter spacing is usually ideal.

We should remember, however, that the purpose of alley cropping is to enhance the chemical, physical, and biological condition of the soil and produce satisfactory sustainable crop yields. If the soil is in poor condition, the farmer may need to space the tree rows as closely as 2 meters--that is, if the soil moisture is adequate.

b. If the farmer wants to stake climbing vines (yams, for example), he might plant a middle hedge of trees between the regular 4 meter rows. He would space the trees in the center row farther apart and cut them back. The trunk, trimmed of branches, serves as the stake.

c. If the farmer plans to grow trees for lumber, he will want them to grow larger, and therefore will want much wider strips between tree rows and wider spacing in the rows.

4. Adapt your alley cropping plans to the availability of soil moisture on reasonably deep and fertile subsoil.

    a. Most alley cropping research and farmer experience has been in the humid and sub-humid zones where rainfall is 1800 mm to 2500 mm or more per year. In semi-arid regions crop yields may suffer from competition for soil moisture from trees. Where rainfall is less, use a wider spacing than 4 meters. Often the need for fodder in the dry season and for firewood may still make alley cropping desirable.

    b. Watch the outside row of the crop between rains. If leaves in the outside rows of crops are curling or wilting quicker than leaves in the inside rows (signs of moisture stress), then moisture is inadequate. One solution is to prune the tree roots. Cut down to a depth of 25 or 30 cm on both sides of the hedgerow about midway between crop and tree rows. Slice straight down with a straight edged spade, a hoe, knife, or cutlass. Do not dig. Slice down vertically through the soil.

5. Consider using the following recommended species. (Hopefully you may also find a locally-grown nitrogen-fixing tree which has proved itself.)

a. *Leucaena leucocephala.* (Remember cautions about insect problem) In non-acid or mildly acid soils it grows and produces exceptionally well, but it does not thrive in extremely acid soils.

b. *Flemingia congesta.* This legume is replacing *Leucaena* in the SALT Programs in the Philippines, where it is reported to be doing very well.

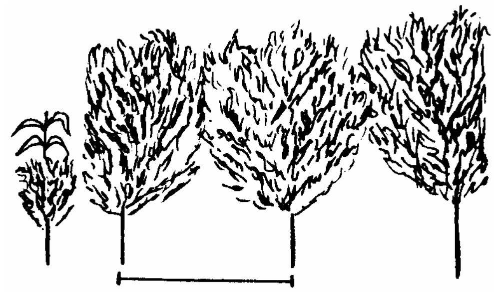
c. *Gliricidia sepium.* Another outstanding tree. It is second to *Leucaena* in production of foliage and nitrogen fertilizer per hectare. It is an excellent livestock feed.

d. For fodder trees, see the two lists following this chapter.

e. For more acid soils, you can experiment with:

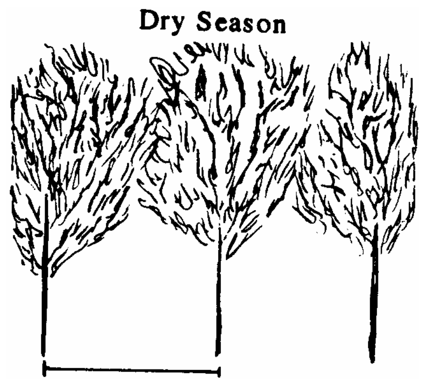
(1) *Inga edulis* (sp). Some workers consider this a promising tree for some acid conditions.

Figure 5-12. One form of alley cropping. Here, two rows of pigeon peas are growing, with bananas between. Rows of maize had also formerly been growing between the bananas and the pigeon peas. The maize has been harvested; note the cornstalks on the ground. Pigeon peas are a food crop, but also a legume shrub. (Picture by author.)



SECOND YEAR

Second Maize Crop

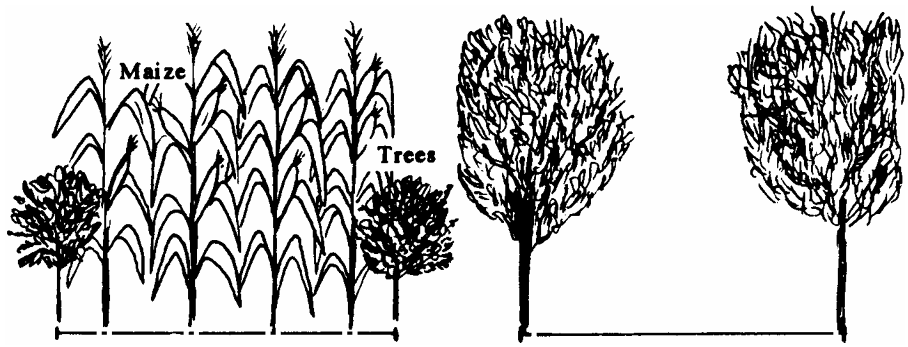


Maize

Figure 5-13. Establishing multipurpose nitrogen-fixing trees with maize. Diagram of the first two years' growth of *Leucaena leucocephala*, with rows of trees spaced 2 meters apart. Trees were planted at the same time the maize was planted, in the same rows as some of the maize, and with maize also growing by itself between. (Ideas for sketch from Kang, Wilson, and Lawson, IITA.)

FIRST YEAR
Establishment of Trees

Dry Season



4m SECOND YEAR

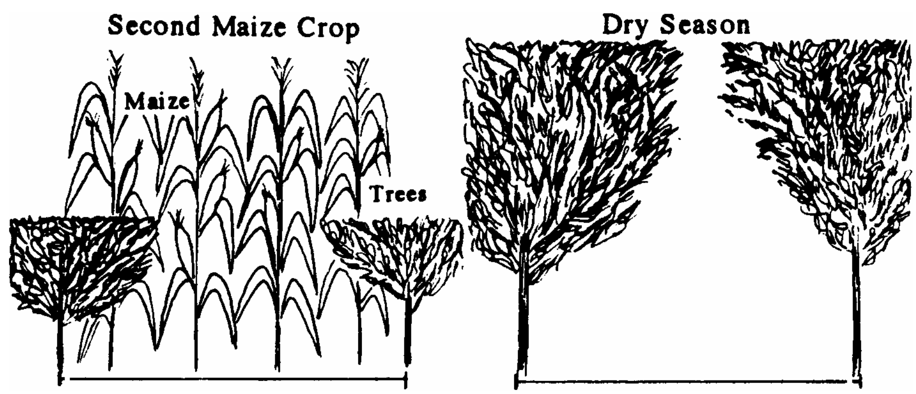


Figure 5-14. Multipurpose nitrogen-fixing trees with maize, with rows spaced 4 meters apart. The planting pattern was otherwise the same as in Figure 5-13. For most situations, the wider, 4 meter spacing between rows seems to be preferred by researchers and farmers using alley cropping. (Ideas for drawing from Kang, Wilson, and Lawson, IITA.)

(2) *Cassia siamea.* used with success in some studies by IITA in Nigeria

(3) *Acioa berterii*

(4) Look for native legume trees on site.

(5) Contact the Nitrogen Fixing Tree Association for latest information about possible varieties for acid soil.

<u>Desirable Characteristics for Trees to Be Used in Alley Cropping</u>

<u>Note:</u> Most trees will not have all of these advantages; the choice depends upon the farmer's priorities.

- Well adapted to the climate and soil
- Easy to establish
- Quick growing
- Profuse in foliage. Produces high tonnage of plant material (dry matter)
- Capable of producing 100 to 200 or more kilograms of nitrogen per hectare per year
- Possessing a deep-rooting system. Able to recycle reasonable amounts of plant nutrients, especially calcium, magnesium, potassium, and phosphorus from soil depths below the food crop rooting zone
- Able to withstand lopping or pruning back to about 1 meter height at end of the dry season, and additional pruning during the food crop growing season
- Quickly regenerative after pruning. Coppices well
- Insect, disease, and drought resistant
- Multipurpose
- Easily eradicated; has little potential for becoming a weed
- Non-toxic and palatable if tree trimmings are to be used as feed.

Field Research Observations on Alley Cropping

1. Nigeria. Agriculturists at the International Institute of Tropical Agriculture in Nigeria developed alley cropping in the 1970's. Since then they have worked extensively with it under humid and sub-humid conditions. With Alfisols and related soils, they found the following:

- *Leucaena leucocephala* and *Gliricidia sepium* were found to be the most promising woody species for alley farming.

- The best way to establish them was planting in a food crop row with the crop. This protects the small seedling as it begins to grow, and keeps it weed-free. (Example: seeded in the row between stalks of corn.)

- Once established (12 to 18 months) the trees can be cut back to hedgerow height and kept pruned to keep the trees from competing with the food crops.

- The above two varieties had higher N - P - K yields and higher dry matter yields than did local legume trees tested.

- High food crop yields were consistently maintained when these tree prunings were returned to the soil. If the prunings are carried away from the field, food crop yields will fall.

- Alley cropping increased and sustained yields of maize, cassava, and upland rice at reasonable levels. Cowpea yields did not increase. (Note that the cowpea is a legume which makes nitrogen fertilizer for itself.)

- Chemical and physical soil conditions improved with alley cropping. Soils contained more organic matter, held more available nutrients, and had higher moisture-holding capacity. The added mulch decreased soil erosion, lowered soil temperature, and helped control weeds.

- *L. leucocephala* proved especially effective in reducing erosion. (Other researchers and tropical farmers around the world confirm the value of planting legume trees on the contour as live barriers.)

- *Acioa berterii, Cassia siamea* and *Fleminga congesta* seem to be suitable for alley cropping on acid soils. However, more research on this is needed.

- Alley cropping systems developed at Nigeria by IITA:

a. The *Leucaena / Gliricidia* - maize - cowpea system. (The maize and cowpeas are rotated.)
b. The *Leucaena* - maize - yam system. (Here also the two food crops are rotated.)

c. *Leucaena / Gliricidia* in systems of livestock production for small ruminant animals.

2. Other Observations about Alley Cropping

- Alley cropping works best on soils which have not yet been heavily depleted and degraded. It has, however, produced good results on very poor, nitrogen-deficient sandy soil which had a relatively fertile subsoil.

- Alley cropping studies on very infertile, highly acid soils have not done well. We must await more research results for soils with these conditions.

- Some work in arid and semi-arid regions shows that competition for moisture from the hedgerows adversely affects crop yields there. Much wider hedgerow spacings may solve part of the problem. In some cases, economic gain from tree and crop yields more than compensated for lower crop yields. Here again, we must be cautious until more research has been done.

  Farmers in arid regions where fodder shortage becomes critical in the dry season can use trees for fodder when less deeply-rooted plants do not grow. Some form of alley cropping may therefore be suitable in that situation.

- As noted elsewhere, *Leucaena*, the star performer of the legume trees, has become vulnerable to a bad leaf insect in Indonesia and the Philippines. The insect has not yet jeopardized *Leucaena* in other tropical areas. However, farmers should consider diversifying, i.e., mixing it with other varieties to minimize risk.

- *Leucaena* used alone as fodder can cause mimosine toxicity. Farmers can solve this by mixing *Leucaena* with grass or *Gliricidia* in proportions of one to one.

Summary: At this time, some scientists recommend alley cropping in the humid and subhumid zones on soils which are near neutral or moderately acid, and have fairly fertile sub soils. Future research must still investigate alley cropping adaptations in other climate/soil conditions, and must compare these adaptations with other possible farming systems. High quality research for the tropics continues and will hopefully provide answers to many of the important questions that remain.

A CASE STUDY: A SUCCESSFUL AGROFORESTRY PROJECT IN GHANA

The project is located in a densely-populated rural region in northern Ghana. In Garu, land is scarce and denuded. The Kusasai farmer usually has 1 to 2 hectares of land around his mud compound which he cultivates on a permanent basis. Trees are now so scarce that villagers use millet stalks as fuel for cooking, a costly and short-lived source.

Program background:

Beginning in 1983 World Neighbors supported the efforts of John and Denice Kleindouwel, who have worked under the sponsorship of the local Catholic Church, to encourage planting of trees in the area. The program has had a budget of $9,000 per year, but in only a three-year period established itself as a model.

Methodology

Over a three-year period a network of volunteer tree promoters and tree-growing committees was developed in over forty villages in the Garu area. They learned how to establish village tree nurseries to grow and sell tree seedlings, took responsibility for promoting tree planting, and trained the people buying tree seedlings how to plant and protect them.

Summary of Methods Used

1. Awareness-raising

- The purposes are: to motivate villagers to take action; to build on existing knowledge of the importance of trees to their livelihood and to the environment; to start a dialogue about handling problems caused by lack of trees.
- Village leaders and interested people are contacted.
- A series of awareness-raising sessions uses GRAAP, flannel graphs, filmstrips and problem-posing techniques.
- Awareness training is used in a continuous process.

Determining the Villagers' Felt Needs: the Dialogue Continues

- Villagers look at their priorities with regard to trees, examining their resources, their time, and local constraints.
- They discuss and analyze solutions.
- They decide on a plan of action.

3. Recruiting Volunteer Tree Promoters

- In each interested village, contact persons (one or more) are chosen. They are usually influential persons in that village (school teachers, prayer leaders, etc.) who have shown enthusiasm for tree planting.
- The contact person takes responsibility for promoting tree planting, makes a list of interested people, organizes the sale and distribution of tree seedlings.
- A Village Tree Committee is formed after acceptance grows in a particular village. It will be composed of several farmers who have gained practical experience in tree planting and protection. The Committee helps with awareness, and usually starts local tree nurseries in their own home compounds.
- Contact persons and the Tree Committee have continuing responsibility for training villagers

(who have ordered trees) in proper planting and protection of seedling trees. They are also responsible for continuing to build awareness.

4. Training of Trainers

- Once a year, usually just before planting season, all contact persons are invited to participate in a training workshop. They learn techniques of planting trees, establishing and maintaining nurseries, and protecting trees from animals and fires. They share experiences and practical problems.

5. Establishing Local Responsibility and Self-Reliance

The aim of the program is to establish tree growing as an activity that will become sustaining with a minimum of outside support and assistance. Ways of doing this are:

- creating the Village Tree Committees. Hopefully, as tree growing moves into an increasing number of villages, the Tree Committees can form an association which will take responsibility for getting its own seeds and sacks.

- establishing the village-based tree nurseries. Thus the program will not be completely dependent on the central tree nursery run by the project leaders.

6. Identifying the Limiting Factors

The next consideration is handling constraints to increasing the number of trees the farmer can plant. In Garu, the most limiting factor is the 1ack of easy, inexpensive ways to protect trees against grazing animals in the dry season. This problem makes planting trees in the fields a difficult problem.

7. Testing and Evaluating New Technologies

With the cooperation of farmers, new protection methods are tested. Examples include building millet stalk cages, using mud walls and broken pots, identifying animal-resistant species of trees, planting thorny hedges and using animal dung as a repellent.

- Over 35,000 tree seedlings have been produced, distributed and planted.

- Training in planting and protection techniques has achieved a survival rate of 50%. (World Bank uses 30% survival rate as expected average for most projects.)

- Forty villages have taken up tree growing.

- There are 22 village-based nurseries run by Tree Committee members, each nursery having between 20 and 200 seedlings. One village has over 5 nurseries.

- Forty contact people have been trained to train their neighbors.

- Over 120 Village Tree Committee members in 30 communities are promoting tree growing.

- Various approaches to tree growing adopted by villagers are:

- Fruit trees such as mango, cashew, lemon, grapefruit, tangerine, orange, papaya and guava. They account for about 50% of the total number of trees planted around compounds.

- Firewood and roofing pole trees--the next most popular category. Some are planted around the house, while other farmers have attempted to make small plots of 20 to 50 *Leucaena* seedlings.

- Roadside tree planting of animal-resistant species such as *Acacia aureculiformis*, teak and eucalyptus has been done in 4 villages.

- People have taken action to protect the natural tree cover in selected areas by prohibiting cutting down of trees.
(The above used by permission of World Neighbors.)

Table 5-1. Native African Tree species, Nitrogen Fixing, of Economic Importance, Sources of Animal Feed

Acacia albida Del.	
Acacia senegal (L.)	
Acacia tortilis (Forsk.) Hayne	
Albizia gummifera (Gmel.) C.A.Smith	Browse ,firewood,tannin
Albizia lebbek (L.) Benth.	Browse, firewood, charcoal
Baphia nitida Lodd.	Fodder, firewood
	Browse, charcoal
Cordeauxia edulis Hemsl.	Fodder, firewood, furniture
Entada abyssinica Steud. ex A. Rich	Browse, firewood, living fences, dye
Erythrina abyssinica Lam	Browse, nuts, dye
Flemingia macrophylla (Willd.)	Browse, fruit
Parkia filicoidea Welw.	Browse, green manure, fruit
(syn .P. Africana (R. Br.)	Browse
Sesbania sesban (L.) Merr. *Xeroderris*	Browse, firewood, edible seeds, dye
stuhlmannii	Fodder, green manure Browse, timber
(Taub.) Mend. and Sousa	

***** Modified from "Nitrogen-Fixing Trees for Fodder and Browse in Africa" by J. L. Brewbaker in Alley Farming in the Humid and Subhumid Tropics, 1986, p.59.

Table 5-2 Tropical Fodder Trees and Shrubs that Fix Nitrogen

The following format is used to list and describe the shrub and tree species in this Appendix.

Genus and species; "common names" (family: subfamily of first species in genus)

1. Centre of origin; distribution; uses
2. Description; botany; ecology.
3. Forage value (***excellent; **good; *fair to poor); use as forage; digestibility; problems.

Acacia albida Del; "Winterthorn", "K ad" (Leguminosae: Mimosoideae)

1. Africa; widespread, now to India, Israel; fodder, ornamental, shade, green manure.
2. Tree to 20 m = *Acacia leucophloea;* leafless in rainy season, bipinnate, thorny; drought tolerant to 300 mm. frost sensitive.
3. *; pods eaten, also foliage (dry season); fast growth if watered (10 m in *7* years).

Acacia aneura; F. Muell. ex Benth; "Mulga"

1. Australia; widespread; hard wood, fuel wood, ornamental, variably browsed by stock.
2. Shrub or tree to 12 m; phyllodes; slow growth, high drought tolerance (to 200 mm), frost tolerant, frost sensitive.
3. ****;** some varieties good stock fodder, the "most important fodder tree in Australia" (Everist 1969), widely browsed; low foliage DMD (39%), little success in Africa.

Acacia angustissima Miller

1. Central America.
2. Shrub to 5 m; not thorny; rapid growth.
3. Fodder in Indonesia.

Acacia bidwillii Benth.; "Corkwood-Wattle"

1. Australia.
2. Tree to 7 **in.,** related to *A. calcigera ;* bipmnnate; mesic.
3. Good fodder.

Acaia coriacea ; (DC.) "Wirewood", "Desert Oak", "Dogwood"

1. North Australia, 1.5 m ha; introduced in Africa.
2. Shrub to 7 m; phyllodes; slow growth, high tolerance of drought and fire.
3. Leaves and pods eaten but of poor palatability, best when dry; low leaf yield.

Acacia currasavica

1. America; forage.
2. Shrub to 5 m; thornless, bipinnate; cold tolerant.
3. Leaf DMD = 64% (stems 28%).

Acacia estrophiolata F. Muell.; “Ironwood”

1. Australia only.
2. Tree to 15 m; phyllodes; slow growth, long life, drought tolerant.
3. Foliage eaten avidly; grows too tall.

Acacia excelsa Benth.; “Ironwood” “Ironwood Wattle”

1. Northwest Australia; fuel wood, fodder.
2. Tree to 10 m; fair drought tolerance.
3. Eaten freely by sheep, but can cause impaction.

Acacia farnesiana (L.) Willd.; “Huisache” (Mexico), “Sweet Acacia”, “Mimosa Bush”, “Klu” (Hawaii)

1. Americas, now worldwide; ornamental, cultivated for perfume, tannin, dyes, gums.
2. Shrub 2 - 7 m; bipinnate, forms thickets, stipular spines (< 1 cm); frost tolerant, rapid growth, weedy, tolerant of heavy clay.
3. pods browsed when young; foliage DMD = 54%, contains cyanogenic glyco sides.

Acacia holosericea A. Cunn ex G. Don

1. North Australia; grows well in Africa; fuel wood, ornamental, hedges.
2. Shrub to 5 m; phyllodes; widely adaptable, tolerant of salinity, not tolerant to prolonged drought.
3. High fodder production, but not fed fresh, only as dried phyllodes.

Acacia homalophylla A. Cunn. ex Benth.; “Yarran”

1. Northwest Australia; fodder.
2. Tree to 8 m; phyllodes.
3. Leaves eaten readily, similar in value to *Acacia aneura*.

Acacia litakunensis Burch; “Umbrella thorn”

1. Southern Africa; fodder.
2. Tree to 10 m; thorny, bipin.nate; forms thickets.
3. Pods are a favored fodder.

Acacia neriifolia A. Cunn ex Benth.; **“** Silver Wattle”

1. Australia; windbreaks, emergency stock fodder.
2. Shrub to 8 m; phyllodes; drought and frost resistant.
3. Foliage browsed only in times of stress.

Acacia nilotica (L.) Willd. ex Del, “Babul (India), “Munga (Africa), “Prickly acacia” (Australia)

1. India and Africa; now widespread; firewood, charcoal, tannin and gum source, fodder.

2. Tree 6 - 12 m; very thorny, bipinnate; tropics, midlands, frost susceptible, drought tolerant, deciduous.

3. good leaf and pod fodder yields and quality; pods sweet, readily eaten, but can cause bloat; many insect pests.

Acacia nubica Benth.; “Last” (Sudan)

1. Northeast Africa; browse shrub.
2. Shrub to 5 m; thorny bipmnnate.
3. ~ important browse shrub in Africa.

Acacia pendula A. Cunn. ex G. Don; “Myall”

1. Australia; introduced to Israel; fodder, shade tree, timber, fuel wood.
2. Tree to 8 m; stately, phyllodes; subtropical, drought tolerant.
3. **“‘;** drought-stock fodder; foliage DMD = 47%.

Acacia polyacantha Willd.; “Khair, “Catechu Tree”

1. Africa, India; fodder, charcoal, black gum, dye.
2. Tree to 25 m, = *A. catechu* ; recurved spines, bipmnnate, weedy; midlands to 1,000 m, takes mild frost, low drought tolerance, coppices well, long life.
3. *; fair growth rate; good fodder DMD (6 1%); many insect and diseases, low tannin (1.5%).

Acacia saligna (Lindl.) H. Wendl.; “Coolan,” “willow”

1. West Australia (now widespread); common in Southern and North Africa; ornamental, fodder, fuel, erosion control, dune stabilization.
2. Tree to 8 m = *S. Cyanophylla* ; phyllodes; rapid growth, tolerant of drought, fire, salt, and wind.
3. Little browsed; may be toxic to cattle, high tannin in leaves and saponins in pods.

Acacia senegal (L.) Willd.; “Gum-arabic Tree, “Hashab”

I. Africa to India; firewood, charcoal, gum arabic, fodder.
2. Tree to 10 m, but often shrubby; deciduous, thorny bipmnnate; dry tropics to 200 mm rainfall.
3. Not important as feed, but pods and foliage used by goats and camels.

Acacia seyal Del.; “Thirsty Thorn”, “Dushe (Nigeria)

1. North Africa; wood, gums, and tannins, important feed (pods, leaves, bark).
2. Slender tree to 12 m; bipinnate, long thorns, semi-arid tropics.
3. ***;** bark is a valued feed, up to 10% protein; leaves and pods also fed in Africa.

Acacia sieberiana DC.

1. West Africa; gum, fodder, honey, furniture wood.
2. Tree to 10 m; drought tolerant but found along streams.
3. Valued as drought-season fodder.

Acacia tortilis (Forsk) Hayne

1. Africa; introduced to tropical Asia; firewood, fodder.
2. Flat-topped tree to 15 m, but often shrubby; thorny, bipmnnate; dry tropics, to 100 mm, alkali tolerant, not frost tolerant, to 1,200 m in Kenya.
3. Leaves browsed by goats, pods are main feed (“tortilis” = curled pod).

Acacia trachycarpa E. Pritzel

1. Australia.
2. Small tree to 5 m; phyllodes; long life, fair drought resistance.
3. Readily browsed, but slow growing.

Acacia victoriae Benth.; “Gundabluey,” “Acacia Bush,” “Elegant Wattle”

1. Australia (widespread); fodder, ornamental, windbreak.
2. Shrub to 5 m; straggly, often thorny; short life, often in thickets, sandy soil, saline and drought tolerant (to 350 mm).
3. ¶ pods browsed, of moderate palatability; leaves retained year-round but low in yield.

Acacia villosa Willd.

1. Caribbean, common in Indonesia.
2. Shrub to 3 m; highly branched, bipinnate, compact leaves; low-elevation tropics.
3. Forage of low value, high tannins (6%).

Acacia Xanthophloeia Benth.

1. Africa, India; ornamental, fodder.
2. Tree to 20 m; handsome, yellow green, spiny, bipinnate, frost-free tropics.
3. High yields of lopped fodder.

Other *Acacia* spp. that are recorded as fodder trees (Everist 1969; Skerman 1977), but are of doubtful value are *A. argyrodendron*, *A. auqustissima, A. brevispica, A. cyperophylla*, *A. deanei, A. doratoxylon, A. gerrardii, A. harpophylla, A. kempeana, A. macrothyrsa, A. man qium, A. mellifera, A. nigrescens, A. oswaldii, A. salicina, A. shirleyi, A. sparsiflora. A. stenophylla*, *A. sutherlandii, A tetragonophylla, and A. tumida.*

Aeschynomene americana L.; “Thornless mimosa” (Leguininosae: Mimosoideae)

1. Tropical America; now widespread; fodder, hay.
2. Subshrub to 2 m; lowland mesic tropics, tolerant of waterlogged soils.
3. Fair palatability.

Aeschynomene elaphroxylon (Guill. and Perr.) Taub.; “Ambatch”, “Pith Tree”, “Balsawood Tree”

2. Shrub or small tree to 9 m = *Herminiera elaphroxylon* ; mesic and swampy tropics to 2,000 m.
3. Leaves palatable but sparse; thorny, with sticky hairs on branches.

Albizia chinensis (Osb.) Merr. (Leguminosae: Mimosoideae)
1. India; in North India to 1,300 m; timber, fodder, shade tree.
2. Tree to 15 m; deciduous; rapid growth, mesic and dry sub-tropics.
3. Low DMD (38%); toxic symptoms from prolonged feeding, notably on young leaves; is fed in mixtures.

Albizia falcataria
1. Indonesia, New Guinea; widespread in humid tropics; timber (low specific gravity, 0.33), pulpwood, soil improvement.
2. Tree to 40 m; humid tropics to 1,000 mm, midlands.
3. = *Periserianthes falcataria* ; low DMD (39.2%), intake low, tannins not high (2%).

Albizia lebbeck (L.) Benth.; “Siris”, “Woman’s Tongue”
1. Asia, Africa; worldwide now; ornamental, fuel wood, fodder, furniture wood.
2. Tree to 25 m; wide adaptability, dry humid tropics, to 1,500 m, to 600 mm rainfall, growth to 8 m in 8 years.
3. Supplementary fodder; DMD 45 - 55% (to 73%; Singh 1982)

Albizia odoratissima Benth.
1. Nepal, India; ornamental, fodder.
2. Tree to 25 m; humid sub-tropics, to 1,500 m.
3. Highly lopped for fodder in Nepal, fair quality.

Albizia procera (Roxb.) Benth.; “Safed Siris”
1. India, Southeast Asia; now widespread; lumber, fuel, furniture shade tree.
2. Tree to 20 m; humid sub-tropics, to 1,800 m, not frost tolerant.
3. Browse for buffalo, deer.

Albizia stipulata (DC.) Boiv.; “Rato Sins”
1. Nepal, fodder.
2. Tree, resembles *A. moluccana* ; highlands to 2,000 m.
3. Lopped fodder.

Other *Albizia* spp. recorded as fodders include *A. adianthifolia , A. amara, A. basaltica, A. harveyi, and A. richardiana.*

Baphia nitida Lodd.; “Camwood” (Leguminosae: Papilionoideae)
1. West Africa; wood for dyes, fodder, construction, medicinal, ornamental, fence rows.
2. Shrub to 3 m or tree to 10 m; humid tropical forests.
3. High palatability as browse.

1. Tropical Africa; now widespread; light, corky wood, fodder.

Cajanus cajan (L.) Millsp.; “Pigeon Pea”, “Dhal”, “Catiang”, (Asia) (Leguminosae: Papilionoideae)
1. Africa (cultivated around 2000 BC); India, worldwide; food, medicinal, green manure, fodder, windbreak, honey.
2. Variably perennial shrub to 4 m; annual types for food; dry tropics, low to midland, not frost or fire tolerant.
3. *; rare use as fodder, browse or hay (including pods); leaf DMD = 53%, small stem DMD = 42%; not persistent under grazing or coppicing.

Calliandra calothyrsus Meissn.; “kaliandra” (Leguminosae: Mimosoideae)
1. Central and South America; fuel wood, green manure, fodder, ornamental.
2. shrub to 8 m; moist tropics, cold tolerant, rapid growth, acid tolerant, poor on alkaline soils.
3. Low fodder value but fast growth; low DMD (4 1%), high tannins (7%).

Ca 1/ic’n dra eriophylia Benth.; “False Mesquite”
1 Mexico to USA; browse, fuel wood.
2. Shrub to 3 m, dense; thorniess.
3. Browse of unknown value to livestock and deer.

Casuarina L. spp. (Casuarinaceae)
1. Australia and Asia; widespread; firewood, charcoal, ornamental.
2. Trees; tropical, saline tolerant.
3. Browsed and sometimes fed but of poor quality, low intake and DMD (‘~40%), high fibre, low protein.

Cathormion umbellatum (Leguminosae: Mimosoideae)
1. North Australia; browse.
2. Shrub to 7 m, resembles *Samanea* spp.
3. Low leaf DMD (35%).

Ceanothus L. spp. (Rhaninaceae)
1. Americas; browse.
2. Shrubs to 4 m; drought hardy, diverse.
3. *C. cuneatus* and *C. diva ricatus* noted as good fodder plants.

Chamaecytisus palmensis (Christ) Bisby et Nicholls; “Tagasaste”, “Tree Lucerne” (Leguminosae: Papilionoideae)
1. Canary Islands, to New Zealand; hedges, fodder, bee pasture.
2. Shrub to 6 m; temperate, frost tolerant to -10 degrees C, drought tolerant, not tolerant of acid soils.
3. ****;** good browse or fodder, leaf DMD = 70%, browse DMD = 53%.

Codariocalyx gyrans (L.) Hassk.; “Telegraph Plant” (Leguminosae: Papilionoideae)
1. Indo-Malaysia, Philippines; green manure.
2. Shrubs and sub-shrubs; related to *Desmodium*.

Coda riocalyx gyroides (Roxb.) Hassk.

1. Indo-Malaysia and Philippines; green manure, coffee shade.
2. Vigorous tropical shrub to 2.5 m = *Desmodium gyroides* DC; wet tropics, tolerant of poor drainage.
3. Low palatability to stock.

Cytisus scoparius (L) Link.; “Scotch Broom: (Leguminosae: Papilionoidae)

1. Mediterranean region; ornamental, hedge, fence rows, browse.
2. Shrub to 4 m; temperate.
3. Browsed by sheep in New Zealand but considered poor; weedy; toxic alkaloids common in this genus.

Dalbergia sissoo Roxb.; “Sissoo”, “Indian teakwood”, “Tali” (Leguminosae: Papilionoideae)

1. India; timber,fuel wood, shade tree, fodder.
2. Tree to 30 m; mesic tropics and sub-tropics to 1,200 m and 800 mm rainfall.
3. Browsed (monkeys, deer), may be lopped for fodder; low silage; DMD (20%); poor feed in dry season, fresh leaves can cause digestive disorders.

Desmanthus virgatus (L.) Willd.; “Donkey Bean” (Leguminosae: Mimosoideae)

1. South and Central America; now worldwide; browse fodder.
2. Subshrub to 3 m; coppices and reseeds well; short-lived perennial, aggressive, unarmed; mesic tropics but drought tolerant; not acid tolerant.
3. ****:** ; leaf DMD good (53%); generally similar to but out-yielded by *Leucaena* spp.

Desmodium discolor Vog.; “Horse Marmalade” (South Africa) (Leguminosae: Papilionoideae)

1. South America; now widely distributed; fodder.
2. Subshrub to 3 m; woody when mature; subtropical, frost hardy.
3. ***;** highly palatable.

Desmodium distortum (Aubl.) Macbride

1. Venezuela; now in Africa; fodder.
2. Subshrub to 2 m; woody at base; moist tropics.
3. ***;** good palatability.

Dichrostachys cinerea (L.) Wight and Am.; “Kakada” *(Sudan) (Leguminosae: Mimosoideae)

1. Africa; now widespread; browse (especially pods).
2. Shrub to 5 m; thorny; mesic tropics, not tolerant of frost; weedy, forming thickets.
3. A common browse plant in Africa.

Erythrina L. spp.; “Coral tree” “Phaledo” (Nepal) (Leguminmosae: Papilionoideae)

1. Americas, Africa, Asia; ornamentals, fence rows, windbreaks, shade trees.
2. Trees to 20 m; often thorny; mesic to cool tropics.
3. Reports of fodder use include *E. arborescens*, *E. bertoeroana*, *E. hookeriana*, *E. stricta*, *E. suberosa*, and *E. variegata.* None have reputation as good fodders; the genus is noted as a source of alkaloids and poisons.

Flemingia
macrophylla (Willd.) Merrill; (Leguminosae) Southeast Asia; dyes, fodder, green manure.
Shrub to 2 m = *F. congesta* Roxb., *F. latipolia* Benth.; mesic to wet
tropics, moderately shade tolerant.
3. Low DMD (40%).

Gliricidia sepium (Jacdq.) Walp.: “Madre de cacao” “Quickstick” (Leguminosae: Papilionoideae

1. Central America/Mexico; now worldwide; firewood, timber, shade, ornamental, fodder.
2. Tree to 15 m; easily propagated by cuttings; rapid growth, dry to mesic tropics to 1,000 m.
3. ~ foliage variously appraised around the world, often unused, occasionally valued highly; DMD high (55% browse samples, 68% leaves); low tannins (<1%), high leaf lignin (5.5%), reportedly toxic to horses, carries toxins in bark, seeds, and roots.

Hardwickia binata Roxb.; “Anjan” (Leguminosae: Caesalpinioidea)

1. India; valued heavy wood, bark for fibre, soil stabilization, fodder.
2. Trees to 35 m; deciduous, deep taproot; slow growth, dry tropics (300 mm), needs drainage.
3. Fodder good; DMD low (47%), protein low.

Leucaena leucocephala (Lam.) de Wit; “Leucaena”, “Ipil-ipil”, “Lamtoro” (Leguminosae: Mimosoideae) *(See footnote)

1. Central America, Mexico; worldwide; fodder, fuel wood, shade, pulpwood, post wood, lumber, food.
2. Tree to 20 **in.,** widely studied and planted; dry to mesic tropics, fast growth, not acid tolerant, growth slow in highlands.
3. * high DMD (55 - 72%), good protein; restricted feed use to nonrunilnants because of mimosine and DHP.*(See footnote)

Leucaena
North America; uncommon yet international; food, fodder, fuel wood. Shrubs and trees to 20 m; dry to mesic, lowland to highland.
*; browse fodder common on *L. lanceolata ;* breeders using *L. pulverulenta*, *L. collinsii*, *L. diversifolia*, and others to improve cold tolerance, acid tolerance, and yield of *L. leucophala.*

Medicago arborea L.; “Tree Medic”, “Cytisus Shrub” (Leguminosae: Papilionoideae)

1. Greece; now common in Mediterranean; described around 100 AD as valuable goat fodder.
2. Small shrub to 4 m; grayish, silky hairs; subtemperate, not hardy against severe frost, drought tolerant.
3. **“‘;** goat browse, not widely used.

Millettia thonningii (Schum. & Thonn.) Bak. (Leguminosae: Papilionoideae)

1. West Africa; fodder.
2. Tree to 10 m, = *Robinia thonningii ;* deciduous mesic tropics.
3. Fair palatability.

Mimosa pigra L. (Leguminosae: Mimosoideae)

1. America; now worldwide; noxious weed, occasional fodder, medicinal.
2. Subshrub to 4 m; thorny; aggressive, widely adaptable, mesic tropics, weedy, makes thickets.
3. ***;** makes good leaf meal; DMD low (47%); tannins high (8%).

Mimosa caesalpiniifolia, *M. paupera* Benth., *M. somnians* H&B, and *M. uliginosa* Chod. & Hassl. are also described as browse plants; the latter two are spiny.

Ougeinia oojeinensis (Roxb.) Hochr. (Leguminosae: Papilionoideae)

1. North India; wood for implements, fodder.
2. Tree to 14 m; slow growth (2 m in 6 years), to 1,200 m in North India, frost and drought tolerant.
3. Lopped fodder considered fair.

Pith ecellobium dulce (Roxb.) Benth.; “Kamachili” (Philippines), “Dutch tamarind” (Leguminosae: Papilionoideae)

1. America; internationally spread; fuel wood, ornamental, fodder (pods).
2. Tree to 20 m; thorny; very wide adaptability from dry to humid tropics and subtemperate regions.
3. Pods and leaves browsed; seeds relished by monkeys and birds.

Pongamia pinnata L. Pierre; “Karang”, “Derris”: (Legu.minosae: Papilionoideae)

1. India to China, Australia, and Malaysia; oil seeds, shade tree, medicinal, firewood, fodder, craft wood, bark for fibre.
2. Small tree to 8 m = *Derris indica ;* mesic tropics (to 600 mm), salt tolerant.
3. Lopped leaves fed, but young leaves unpalatable and not browsed; DMD — 50%; seed cakes after oil removal can be used as poultry feed.

Prosopis alba Griseb., and *P. chilensis* (Mol.) Stuntz (Leguminosae: Mimosoideae)

1. Southern South America; firewood, timber, fodder (pods), shade.

2. Trees to 15 m; thorny; hot dry tropics,to 100 mm,also to highlands (3,000 m in Argentina).
3. * pods are staple cattle food, little use of foliage.

Prosopis cineraria (L) Druce; “Khejri”

1. India; used before 1000 BC; firewood, charcoal, fodder, green manure, post wood.
2. Tree to 9 m ; thorny; hot dry tropics to 100 mm, normally 500 to 800 mm, light demanding.
3. ***;** highly valued in desert areas; DMD very low (40%); tannins very high (>10%), seedlings heavily browsed.

Prosopis pallida H.&B. ex Willd. and *P. juliflora* (Swartz) DC; “Algaroba”, “Ironwood”, “Keawe” (Hawaii)

1. Central and South America; now widespread; fuel wood, charcoal, fodder (pods), honey, wood.
2. Trees to 15 m; thorny (segreg.); hot dry tropics (to 200 mm), saline tolerant.
3. ***;** pods important fodder source, 25% sugar, 17% protein; foliage little used.

Prosopis spicigera L.

1. West India; fodder.
2. Tree to 6 m; variably thorny; subtropical.
3. Good lopped fodder, good palatability.

Other *Prosopis* spp. providing animal feed, normally pods, include *P. glandulosa* Torr. (weedy) and *P. tamarugo* F. Phil.

Pterocarpus erinaceus Poir.; “African rosewood”, “Apepe” (Leguminosae: Mimosoideae)

1. West Africa; wood for tools and posts, fodder, dyes and tannin, afforestation.
2. Tree to 15 m; mesic tropics, good on shallow soils.
3. ***;** foliage considered good fodder; planted as stock feed. *Pterocarpus marsupium* Roxb.

1. India; fodder, fuel wood, timber.
2. Tree to 30 m; coppices and pollards well; mesic tropics, some frost tolerance.
3. ***;** widely lopped for fodder in India, quality fair.

Robinia pseudoacacia L.; “Black Locust” (Leguminosae: Papilionoideae)

1. North America; now widespread in highland tropics; fuel wood, ornamental, honey, reforestation, land stabilization.
2. Tree to 20 m; forms thickets; fast growth, highland tropics (to 3,000 in), one of the few temperate N-fixing legume trees.

3. *; fodder variously appraised, possibly genetically variable; low DMD (27%); toxicity of young shoots, bark, leaves, and seed reported (cattle, horses, man), alkaloids robitin and robin, also tannins (to 3%).

Samanea saman (Jacq.) Merrill; “Raintree”, “Cow Tamarind” (Leguminosae: Mimosoideae)

1. Central and South America; now pantropical; ornamental, timber, craft wood, fuel wood, feed (pods)
2. Tree to 40 in**,** spreading; mesic to wet tropics, fast growth, widely adapted.
3. Pods can be fed to animals or used as food.

Sesbania bispinosa (Jacq.) W. F. Wight; “Daincha” (Leguminosae: Papilionoideae)

1. India, now widespread especially in Africa and North India; fodder, green manure, possible pulpwood.
2. Annual shrub to 6 **in;** thorny, weedy; wet or saline tropics.
3. Young leaves used as cattle fodder.

Sesbania grandiflora (L.) Poir.; “West Indian Pea Tree”, “Katurai” (Philippines), “Turi” (Indonesia), “Gallito” (Carribean)

1. Indonesia?; worldwide; food (flowers, pods, leaves), fodder, pulpwood, ornamental.
2. Tree to 10 **in, =** *Sesbania formosa* F. Muell.; slow foliage regeneration; short life, fast growth, inesic tropics (1,000 mm), tolerant of waterlogging.
3. ***;** fodder of good quality.

Sesbania sesban (L.) Merrill; “Sesban’

1. Tropical Africa (widespread), Asia; green manure, fodder, fibre.
2. Shrub to 5 **in =** *Sesbania aegyptiaca* (Poir) Pers.; fast growth, moist tropics, saline and flooding tolerant.
3. Variously appraised as fodder, not widely used.

Other *Sesbania* spp. in use or under evaluation are subshrubs or shrubs and include S. *cannabina* and S. *speciosa.*

Sophora chrysophila [sic] (Salisb.) Seem.; “Mamani” (Leguminosae: Papilionoideae)

1. Pacific Islands; Hawaii, New Zealand; fodder.
2. Small tree to 8 in; highland tropics.
3. Browsed by ruminant animals; other *Sop hora* spp. carry serious toxins, notably S. *secundiflora,* which can kill animals.

Some outstanding fodder legume shrubs or trees that do not nodulate include *Bauhinia purpurea* L., *Bauhinia racemosa* Lam., L., *Butea frondosa* Roxb., *Butea monosperma, Ceratonia siliqua* L., and *Gleditsia triacanthos* L.

This Table is from J. L. Brewbaker, <u>Nitrogen-fixing trees for fodder and browse in</u> fzi~ Alley farming in the Humid and Subhumid Tropics, Proceedings of an International Workshop, Ibadan, Nigeria, March 10 - 14, 1986, pp. 63-70.

**Leucaena leucocephala*, widely planted in the tropics, has of recent years proved vulnerable to insects. Plant breeders have been testing for insect-resistant strains, and these should be investigated--contact Nitrogen-Fixing Tree Association

(GGW)

CHAPTER 6

HELPING SMALL FARMERS ON VERY STEEP SLOPES: A SPECIAL NEED

Millions of poor small farm families throughout the tropics live on very steep slopes, many sloping 40% to 60%. In many developed countries, such land remains idle or in forests; farmers do not cultivate it.

As populations increase, more people must try to grow food on steeper and steeper hillsides. Steep slope farming means farming under extremely difficult conditions and facing a number of problems—thin topsoil, quick and severe soil ~ excessive water runoff frequent lack of continuing soil moisture, inconvenience of farming and transportation, to name only a few.

Apororriate technology can heln these farmers. Throughout the Third World, certain farmers are already using methods which work even under these restricted conditions, with little or no outlay of capital.

APPROPRIATE TECHNOLOGY FOR STEEP SLOPES

How to Conserve Soil and Water

Every possible erosion preventative measure is vital on steep slopes. Usually the topsoil is already very thin. It must not be lost!

- Choose the right combination of water and soil conservation practices. Some combination will work successfully on steep slopes. Farmers on steep slopes have great need to use the methods of Chapters 3 and 4 as fully as possible. The steeper the slope, the more stringent the need.

  The choice of techniques will depend upon soil characteristics (such as the permeability and the rooting depth of the soil), the weather characteristics, the resources and the needs and desires of the farmer, and the % slope.

- Look at needs for more details. Use good contour and exit drainage ditches. On steeper slopes, contour ditches must be closer together.

- If soil depth allows, consider a few bench terraces to be mixed with live tree barriers and/or in-row tillage.

- On steepest slopes, live grass barriers give way to live tree barriers.

- Consider intermittent orchard terraces.

- Cover the soil surface to Drevent erosion. Look at all feasible ways to cover the soil: in-row tillage, agroforestry and alley cropping, growing combinations of crops which cover the soil surface well while maintaining high soil fertility.

Figure 6-1. Farmers on these steep slopes need more trees, grass, and animals integrated into their farm plans. They also need the most adequate soil and water conservation technique; they have a ‘worst case” scenario for soil erosion. (Picture by author.)

Figure 6-2. All steep slope farmers should dig a contour (diversion drainage ditch) at the top of their fields, such as this young farmer displays so proudly. Such a ditch will protect land from flood waters above. (Picture by author.)

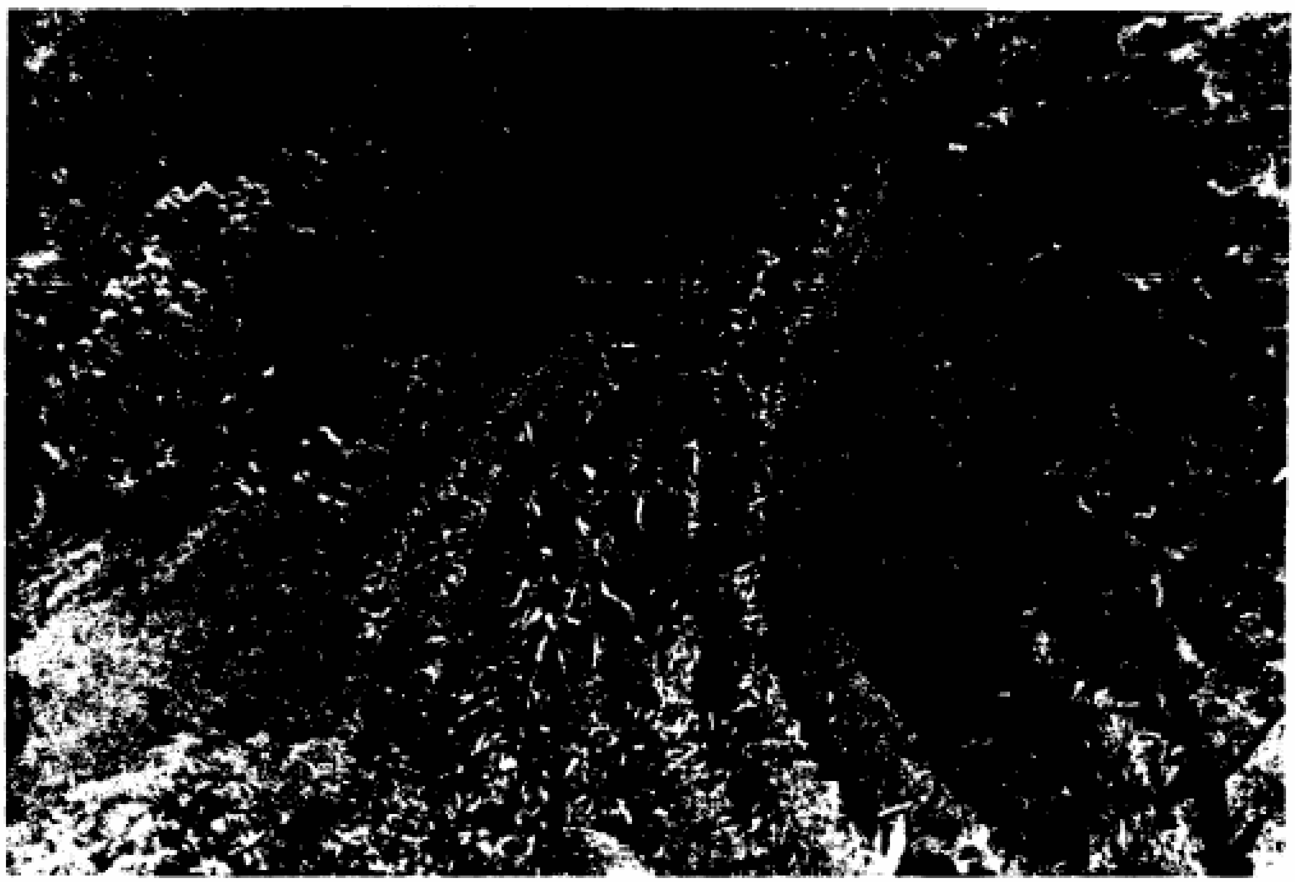


Figure 6-3. On steep slopes, cover such as grass, trees, and other plants is vital to keeping the soil. This farmer is using “in-row minimum tillage” successfully. Note seven rows of maize in this protected strip between his strips of trees. He also has a diversion drainage ditch above the maize. (Picture by author.)

Figure 6-4. Building rock walls. Where farmers on steep slopes have many rocks, constructing rock walls may be the recommended practice. Here, farmers are working as a team on this project. Next, they face the challenge of increasing soil fertility. Some green manure cover crop may be feasible. (Picture courtesy of Soil and Water Conservation Society.)

How to Keen and Increase Soil Fertility

Maintaining and enhancing soil fertility is urgent. Keep soil fertility high to produce healthy crops which cover the soil, build up organic matter, and increase yields.

- Return crop litter to the soil for mulch and compost. Use crop residues instead of burning them.
- Use green manure cover crops to the maximum. This is the cheapest, most efficient way to mulch and fertilize the soil. Adapt the appropriate legume green manure crop into the row crop program (the poor farmer's nitrogen fertilizer factory).
- Also plant multi-purpose leguminous trees and bushes.
- Hoard animal manure until crop planting time, or use it to help make high quality compost.
- Use much compost and animal manure.
- Urge farmers to have their soils tested where testing is available. They should add recommended amounts of commercial fertilizers, if available, and if the cost is in line with the selling price of the farm products.
- Since much grass and legume tree vegetation will be growing to control erosion (live barriers), use much of this to feed additional livestock as well as for green manure and mulch.
- Plan carefully for more in the farm program for fruit, nuts, firewood, and market.
- Plant fenced vegetable gardens for family use and for market.
- Increase the numbers and types of animals on the farm where feasible.

Figure 6-5. In-row tillage increases soil fertility in the food crop row. Above we see a comparison of contour drainage ditches combined with in-row tillage (on the right). Note the burn field trash and plant? farming on the left side of the picture.

In the minimum tillage field, maize stalks and grass have not been burned. Erosion is being controlled here, and yields have increased 3- to 4-fold. Note the erosion in the burned section. (Picture by author.)

Figure 6-6. This farm is in a distant isolated area, far from markets--a common problem. Even the smallest, roughest road may be several kilometers away from market. Horses, donkeys, mules and oxen are used as pack animals, hauling over narrow hillside trails.

Animal manure is a very valuable by-product if properly used. Notice the large stack of mature compost behind the horse, on the left side and in the center (covered with metal sheets on the left and with plastic weighted down with poles in the center). A fresh stack of manure on the extreme right will soon be added to a third compost pile. (Picture by author.)

INTEGRATED DIVERSIFIED FARMING SYSTEMS FOR STEEP SLOPES

Combining Conservation Methods with Mixed Farming Systems

In addition to utilizing conservation and soil fertility enhancement methods of all suitable kinds, the farmers should diversify the farming enterprises. In other word~, they should combine various kinds of food crops, tree products, and animal products in their farming operations. A combined package of the best management practices plus specific crop and enterprise planning can lead to a productive sustainable farm system and a better quality of life. I have visited many such farms in Asia. A diversified program can augment income and provide a hedge against disaster.

BRAINSTORMING THE POSSIBILITIES FOR STEEP SLOPES

1. Make preliminary evaluations

a. An.a1yze with the farmers, their neighbors, and village leaders the needs the many problems and possible solutions which the farmers, the community, and you see. What needs and problems do the farmers themselves perceive? Their input is vital to successful implementation.

b. Supplement with discussions with your PCV friends, and specialists if available, government researchers and specialists. What are the possibilities for this particular location and situation? How can the farmer achieve a satisfactory, sustainable way of life? There are usually many possibilities.

2. Consider and analyze various opportunities

a. Grow other marketable crops and products.

Besides the usual food crops, what other kinds of food or products can be produced? What are their potentials for local markets? For distant markets? How could the farmer transport the products?

b. Grow cool season crops

If the community is in the mountains, what cool season crops could be grown? Many foods or products which do not do well at sea level will grow in the high. cool elevations of the tropics. They are often in demand at markets in the lower elevations. Examples: cabbage, certain kinds of peas, broccoli, berries, etc.

Figure 6-7. Where multipurpose legume trees are grown, not only feed for animals and leaves for fertilizer-mulch are produced, but often firewood becomes a cash crop as well. This young man is making the long trek to market.

c. <u>Grow more tree products</u>

- <u>Why tree products</u>?

  ••The steeper the slopes, the more the need for trees to stabilize the steep countryside.

  •• Trees often survive where other crops do not thrive.

- <u>Is there a local market</u> for more tree products? What about more distant markets? Consider more fruits, firewood, poles, lumber.

3. <u>Encourage and develop cottage industries</u>

a. What opportunities and markets exist for things which local people might make from products raised on the hill farms? Some possibilities:

- Weaving from wool or other fiber products
- Building furniture--chairs, cabinets, beds, etc.
- Wood carving. You might find local talent to teach wood carving skills, or bring in special teachers to the village if the local people like that idea. Where unique and beautiful wood can be grown, wood carving has special possibilities.
- Basket-making from tree and vine fibers.

b. Do the village leaders want to <u>develop craft cooperatives</u>? Do they need sponsors to help establish a training and marketing coop?

4. <u>Raise more animals</u>

a. <u>Why more animals</u>? On steep land, the soil needs more grass as well as more trees to stabilize it. This means more feed for animals, both from grass and from tree leaves of certain varieties.

b. Can farmers increase the number of animals they raise? Can they raise <u>more kinds</u> of animals? Can markets be developed for other kinds (for instance, rabbits or Guinea pigs for home use and for restaurants)?

c. <u>Animals as part of soil conservation on slopes</u>:

(1) <u>Ruminant animals</u>.

- Ruminants have a special extra stomach containing microorganisms which break down tough materials like cellulose. Therefore, they can be healthy eating nothing but grasses, tree leaves, and hay.

Figure 6-8. Women usually play an important role on farms. Always include women farmers and farmers' wives in meetings and workshops whenever possible. These women helped build rock barriers to control erosion, for which they were paid by the government. They pooled their earnings to buy sewing machines. The second lady from the left has been teaching them to sew. This group also developed youth 4-H Clubs which have soil and water conservation projects. (Picture by author).

- Ruminants such as cows, goats, and sheep are grazers of grasses and feeders of browse (i. e., leaves, stems, and tender twigs from shrubs and trees). These animals are therefore especially suitable for steep slopes.

- Caution: ruminants and other animals can destroy gardens, crops, terraces, green barriers, and seedlings if allowed to roam loose. Small farmers are wise to <u>pen their animals</u>, and to cut and carry the green feed to them. As an added advantage, all of the <u>valuable manure</u> fertilizer (for compost, garden, or crops) will then accumulate in an enclosed area. *(Note:* always keep the manure pile protected from sunshine and rain.)

  If ruminant animals run loose, the farmer needs to devise some scheme to protect his crops, including small trees, from destruction.

- <u>Useful ruminants for farm families to consider</u>:

- • <u>Milk goats-</u>- sources of milk and cheese for the family or to sell; occasional meat. Write Heifer Project International for an excellent manual on raising goats; also for instructions for making cheese and other dairy products.

- Milk cows-- milk for the family; milk, butter, cheese to sell.

- Sheep-- possible source of milk and cheese; food; wool for sale; wool to weave into clothing for the family or for sale. (Example: Indian fabric and garments made in the mountains of Central and South America)

- • <u>Oxen or water buffalo-</u>- power for pulling plows, carts, wagons or for carrying goods (pack animals)

- Local breeds of ruminants.

(2) <u>Non-ruminant animals</u>. Certain non-ruminants deserve consideration, for size, ease of raising, or suitability for special products. Useful non-ruminants to consider include:

- <u>Rabbits and Guinea pigs</u>. These are not ruminants but they can eat much the same foods. They do need a small amount of energy food (table scraps, root crops, or grains), but mostly green leaves and hay. They are usually easy to care for and reproduce well. The animals are small and easy to handle.

  The farmer can build raised cages out of bamboo or small tree branches at no cost. The farmer can secure two or three females and a buck; the total investment can be almost nothing to produce a prodigious amount of protein. Rabbit meat is also extremely low in cholesterol.

  Although using rabbits and Guinea pigs as food repels some people, both supply excellent meat. Usually the market for rabbits (and sometimes for Guinea pigs) is easy to develop. They can be sold to restaurants or used as family food. People who enjoy chicken, which has a similar flavor, adapt readily to eating rabbit or Guinea pig if a local cook prepares them an introductory meal by traditional methods of cooking chicken. A good chance for a feast or party!

Additional uses: Rabbit hides can be tanned and sold in the market, or turned into purses, rugs and clothing. The manure is excellent fertilizer.

- Fowl (not only chickens, but special ducks, geese, turkeys, etc.) Sources of meat, eggs, feathers, and manure. Many fowl can find insects, wild seeds and weeds to supplement their diets. However, they must be from the family garden.

  The manure from fowl contains 2 times more nitrogen fertilizer than most other manures. Caution: When using fresh manure, mix it thoroughly with the soil, Do not expose the roots directly to it, or the raw manure may burn the plants.

- *Bees.* Raising bees and selling honey can be an excellent additional income enterprise for hill farmers, especially where trees and bushes with nectar (or other nectar-producing crops or weeds) grow.

  Beekeeping can be handed down from father to son--an ideal family enterprise. The bees can be kept in the homestead near the farm house, or scattered on several locations on the property of friends or relatives.

  Bees are sometimes especially important to maximize pollination or certain field crops being grown for seed.

  Caution: Special precautions must be observed where spraying with pesticides or weed killers takes place. The hives must be moved and not returned until spraying has finished, the spray residues dried, and enough time lapsed to make the chemical harmless. Otherwise the bees will die.

- <u>Animals for transportation</u> and burden-bearing. A horse, donkey, ox, or mule can be important to some mountain families who are isolated or long distances from markets. The manure is also very valuable.

- Animals suggested by farmers, village leaders and extension people. These may include specific local kinds, such as llamas.

d. <u>Some Precautions</u>

(1) If you plan to help with raising animals, be sure to secure good practical instruction manuals. Check the Appendix, also the Peace Corps ICE publications at your local Peace Corps office. Consider writing Heifer Project International, a private charitable group specializing in animals, for booklets, and help on special problems. Special conditions, such as local animal insects or diseases, can raise havoc. However, local animals often already have resistance to them.

(2) Sometimes cross-breeding with imported breeds can improve production while retaining the resistance of local breeds to disease.

(3) Know local sources of veterinary help.

e. <u>Ways to develop additional markets for animals</u>

(1) In addition to the regular traditional type of market, investigate <u>other sources</u>. What local restaurants could buy rabbits to serve their clientele? What local stores might have a deep freeze

and carry frozen rabbits or chickens? What store might stock fresh cow or goat milk? Yogurt? Local cheese? Honey? Can local cooks sell grilled chicken or rabbits at small roadside stands?

(2) Some PVO or other organization might help, especially after farmers form a small cooperative. Certain Private Volunteer Organizations deal with cooperatives but not individual farmers. (See Appendix.)

5. Investigate using irrigation

This may be possible in the mountains during the dry season. You may find a small, ever-flowing stream, or a big spring located some distance above a farmer's field.

How do you ~et the water to the farm?

A large open delivery ditch may result in the loss of too much water if the volume of water is small and it is transported very far to the farm. Some possible ways to handle and use the water are:

- One or more farmers can bring the water down in a small plastic pine. Water brought down through a pipe may produce enough pressure to operate irritation sprinklers. If not, some type of drip irrigation may help conserve water.
- In some cases lye seen farmers use home-made bamboo pipes to convey water a considerable distance. These pipes can be used either for drip irrigation or narrow row irrigation.
- Will a hydraulic ram work for your situation? If you find a stream flowing on a relatively steep slope below a farm, you may want to help build a very inexpensive or water-powered hydraulic pump, to lift the water up the hillside. When properly constructed, the water ram will force a considerable amount of the stream up to the farm. Given a good-sized stream with a fairly steep slope (to build up a strong 'head'' of pressure), it can supply enough water for small scale row irrigation or drip irrigation. It can also provide water all the year around, for family and for farm animals, a major consideration if water has to be carried up the hill. (Check with other PCV's and contact the PC Library for plans. A local plumber or mechanic, if available, could help you follow the plans.)

THE SALT SYSTEM: A SUCCESS STORY

Here and there in the tropics, AG workers and farmers are controlling erosion on small hilly farms with new and successful methods that show excellent crop yields in addition to conservation benefits. Certain projects can give you ideas that you may want to use in your own location.

We will look in detail at one of the most outstanding demonstrations, a project called the SALT method. Developed at the Mindanao Baptist Rural Life Center in the Philippines, it is now known worldwide. It has many advantages over both slash-and-burn and regular terrace farming. It not only controls erosion but also shows excellent integrated crops and increased yields.

SALT is an abbreviation for Sloping Agricultural Land Technology. It was developed as an easier and less expensive way of erosion control than the traditional ways of bench terracing. It has been worked out and tested successfully for more than ten years at Mindanao Baptist Rural Life Center farms. The technology has also worked well for individual small farmers throughout the Philippines and in other tropical countries. It is now known world-wide.

(Author's note: For SALT to be successful, an appropriate nitrogen-fixing tree or shrub must be used, one which grows well, and which resists drought, diseases and insects. Also, the farmer should have secure land tenure. SALT is an outstanding demonstration of a "live barrier" complete erosion control system. It is a successful agroforestry steep slope farming system.) It uses the basic idea *of* alley cropping, but modifies it into a unique farming system.

Setting Un the SALT System on Farms

SALT various soil conservation methods and agroforestry with food production at a particular location. This method grows field and permanent crops in 3 to 5 meter bands between rows of nitrogen fixing trees. The trees are planted thickly in double rows on the contour. When the tree hedge is 12 to 18 months old and reaches a height of 2 meters or more, the trees are cut back to a height of about 40 centimeters. The clippings are spread in alleyways to become mulch and organic fertilizer. Like alley cropping done in Africa, the legume trees are allowed to grow in the dry season, but are cut back when the crops are planted or when the hedge competes with the food crop.

A typical SALT farm is set up like this:

- Permanent shrubs or trees like coffee, cacao, citrus and other fruit trees are planted in some of the strips between the legume tree hedge rows.

- Other strips are planted alternately to cereals (corn, upland rice, sorghum, etc.) or other crops (sweet potato, melon, pineapple, castor bean, etc.). This cyclical cropping gives the farmer some crop yields throughout the year. At the same time the live legume tree barriers minimize water runoff and soil erosion.

- The system also includes planting trees for timber and firewood on top of the hill and on surrounding boundaries. Tree species for 'boundary forestry' in SALT include mahoganies, casuarinas, sesbanias, cashew nuts, pili nuts, etc. Note: the varieties mentioned might not be applicable in all cases to your location, but the SALT method can be adapted effectively to local varieties in your area.

Figure 6-9. Small scale irrigation in the dry season from small streams or springs in the hills and mountains may be possible.

Here irrigated maize is inter-planted with beans for the local market. Water is brought through small plastic pipes from a developed spring. Row irrigation is used together with a minimum tillage (in-row tillage) method. (Picture by author.)

Basic Requirements Which the System Meets

The people designing the SALT program in Mindinao felt that the following guidelines had to be met:

- The method must adequately control soil erosion.
- It must help rebuild soil structure and fertility.
- It must be efficient as a food crop production system.
- It must apply to and be helpful to at least 50 percent of hillside farms.
- Upland farmers must be able to duplicate it easily using local resources and preferably without borrowing money.
- Minimum labor must be needed.
- The method must be culturally acceptable.
- The farmer will be the chief focus, and producing food will be the main priority.
- The system must be workable in a relatively short time and be economically feasible.

Most of these criteria are necessary in any transfer of SALT technology to your location if this method is to succeed. (For that matter, any technology transfer for any project with the small tropical farmer must meet most of these criteria. They are fundamental considerations.)

Advantages of the SALT Method

Simple and low in cost

2. Easy to apply--A farmer needs few tools, little money, minimum knowledge of farming. It employs “appropriate technology”.
3. The farmer can grow crop varieties which he knows.
4. The farmer can use old farming methods which he knows.
5. If the farmers abandon the land, the trees serve as a deterrent to soil erosion, and any nitrogen fixing trees or shrubs continue to nourish the soil. Clippings from the trees can also still be harvested for firewood, charcoal, compost, feed, poles, etc.

Different Forms of the SALT Method

The SALT approach may be used in several different forms:

- A plan has been developed which stresses agroforestry, called S.ALL. Sustainable Agroforest Land Technology. The scheme also includes food for the family and sometimes food for livestock.

- Another plan, called SALT 2 Simple Agro-Livestock Technologv incorporates animal production into a program of food crop and fodder production. It explains a model for an agroforestry-goat dairy (12 does)-food crop farm.

- If the land is too steep for row crops, hedgerow crops (tea) can be planted on the contour between the contoured rows of such crops as coffee or fruits.

- In other words, all sorts of adaptations can be made! (Please see the Bibliography if you are interested in the manuals on the SALT methods.)

How to Install the SALT Method--Ten Steps:

1. Make an A-Frame **.** (This is taken from SALT I).

a. You can make an A-frame from material on the farm. You will need three strong wooden or bamboo poles; something to saw or cut with; a carpenter's level; and some string, rope, or nails.

b. Make the legs of the A-frame by cutting two pieces of wood to a length of **1** meter. A third piece of wood which will serve as the cross bar should be cut at least 1/2 meter long.

c. To put the A-frame together: Tie the upper ends of two meter-length poles together. Stand the lower ends on the level ground. Spread them to form a good angle (about 1 meter apart). Use the shorter pole as a horizontal brace. Fasten the carpenter's level on top of the crossbar by tying it. Be sure that the instrument reads level on level ground. (Note:
if carpenters level is not available, see Appendix A--the tool kit.)

You will use the A-frame to find the contour lines.

2. Locate the Contour Lines

A contour line is an imaginary level line or level pathway around a hillside or along a mountainside (author's note).

a. Remove anything that will keep you from moving freely about and marking lines (tall grass, obstructions, etc.). If possible, use two people, one to work the A-frame and one to mark the contour lines with stakes.

b. Begin marking the contour lines near the highest point of the area. Stand the A-frame on the ground. Raise the front leg while the rear leg remains on the ground. Place the front leg on ground that is on the same level as the rear leg. You will know the legs are on the same level when the bubble in the carpenter's level stays in the middle. You now have a level line between the two legs of the A-frame. This is a contour line between them. Use a stake to mark where the rear leg stands.

c. Now move the A-frame. Put the rear leg on the place where the front leg stood before~ Now move the front leg as described in Part b, so that it is level with the rear leg. Mark the contour line every two or three meters. Do this for the entire length of the mountain or hillside (or to the property line).

3. Prepare the Contour Lines. First, find and mark the contour lines. Set stakes to serve as your guide during plowing. The contour line should be one meter in width.

4. Plant Seeds of Nitrogen Fixing Trees

a. Dig two (2) furrows spaced 1/2 meter apart on each prepared contour line. Plant at least 2 to 3 seeds in each hill, with the hills spaced about 5cm apart. Cover the seeds firmly with soil. (Soak pili seeds overnight in water before planting.)

b. Nitrogen fixing trees are important because they will grow in relatively poor soils; will replenish areas which have been heavily deforested; will do well in regions with long dry seasons; will act as a fertilizer; will compete with weeds and grasses in heavily damaged environments.

c. Some varieties of nitrogen fixing trees-pili *(Leucaena leucoceph ala)* is perhaps the best known for use in hedgerows. Others include *Leucana diversifolia* (considered a more acid-tolerant pili), *Flemingia congesta*, *Acacia villosa*, *Gliricidia sepium* and the *Desmodiums (gyroides, distortum, and discolor)*

5. Cultivate Alternate Strips. The SALT manual calls a strip The space of land between the thick rows of nitrogen fixing trees where the crops are planted."

Before the nitrogen fixing trees are grown to maturity, cultivate only alternate strips to keep down erosion--in other words, cultivate only strips 2, 4, 6, 8, etc. The strips you have not plowed will help hold the soil in place. You can cultivate every strip after the trees are full grown. (Authors note: This will usually take about two years.)

6. Plant Permanent Crops. At the time that you plant the seeds of nitrogen-fixing trees, you can plant permanent crops. However, you should clear and dig only the immediate spots for planting; and you should use only ring weeding until the legume trees reach sufficient size to protect the soil. (Do not plow or dig up the entire strip.)

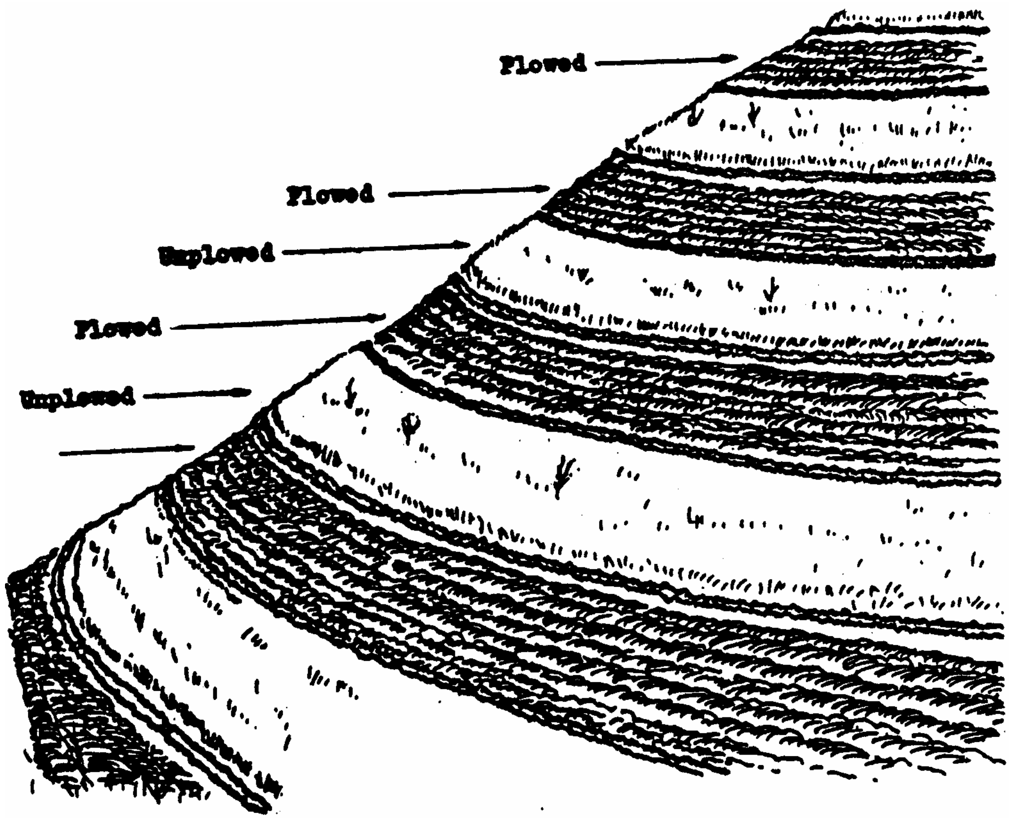


Figure 6-10. SALT step five. Cultivate only alternate strips until legume seedlings are well established. (Preliminary steps one through four are not illustrated.)

Plant short crops at the top of the hill and taller ones at the bottom.

The manual suggests coffee, banana, citrus, cacao as good permanent crops. However, you may need to find others in your particular locality.

7. Plant Short-Term Crops. Between the strips of permanent crops you can raise crops which can produce income and food while you are waiting for the permanent crops to yield. These can produce short and/or medium term income.

   Plant tall crops away from short ones to prevent shading. Some possible short or medium-term crops might be: corn, sorghum, upland rice, melon, mung bean, peanut, pineapple, camote, ginger, castor bean, gabi.

8. Trim Nitrogen-Fixin2 Trees. Out these trees down once a month to about one to 1 and 1/2 meters tall. Pile the leaves and twigs around crops for a good fertilizer. This will reduce the need for chemical fertilizer to about one-fourth of the total requirement.

9. Practice Crop Rotation Rotate crops which are not permanent in order to maintain good soil condition and fertility. 'A good way of rotating is to plant grains (Corn, upland rice, sorghum, etc.), root crops (camote, cassava, gabi, etc.) where legumes (mung bean, bush sitao, peanut, etc.) were planted previously and vice versa.' In your area, other crops may of course be useful or better adapted.

   You will want to follow such good practices as weeding and control of insects and pests.

10. Build Green Terraces. Dense double rows of nitrogen-fixing trees are already helping control erosion. So are natural terraces developing along the contour lines of the hill. Regularly gather and heap up straw, stalks, twigs, branches, leaves, rocks, and stones of nitrogen-fixing trees. This helps build strong, permanent, naturally green and beautiful terraces.

More about SALT

The work with SALT continues at the Mindanao Baptist Rural Life Center.

This report comes primarily from work on a one-hectare farm (and on some neighboring farms). The soil is a clay loam; it is pH 5.5; the soil tests low in nitrogen and phosphorus, and medium in potassium. The land slope is about 25%. The rainfall is 2500 mm or more per year, so that with good management two crops of maize can be harvested each year.

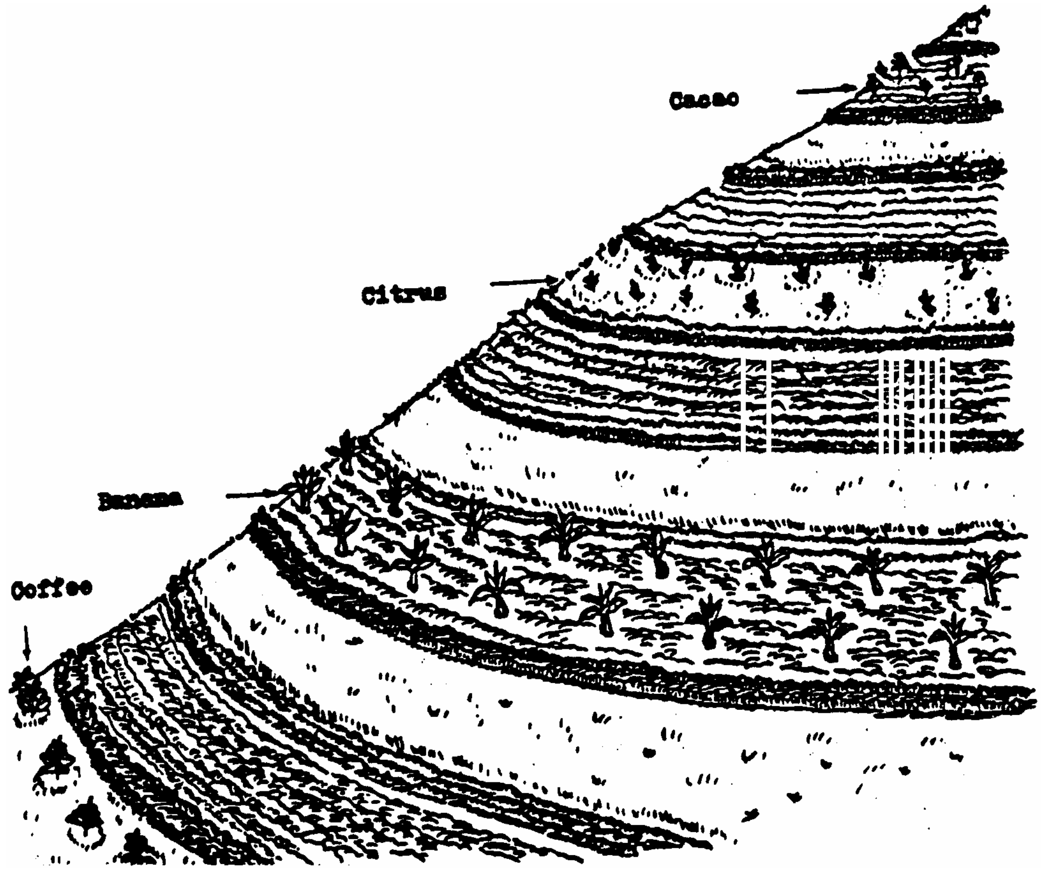


Figure 6-11. SALT step six. Plant permanent crops. During the same season, nitrogen-fixing trees are planted.

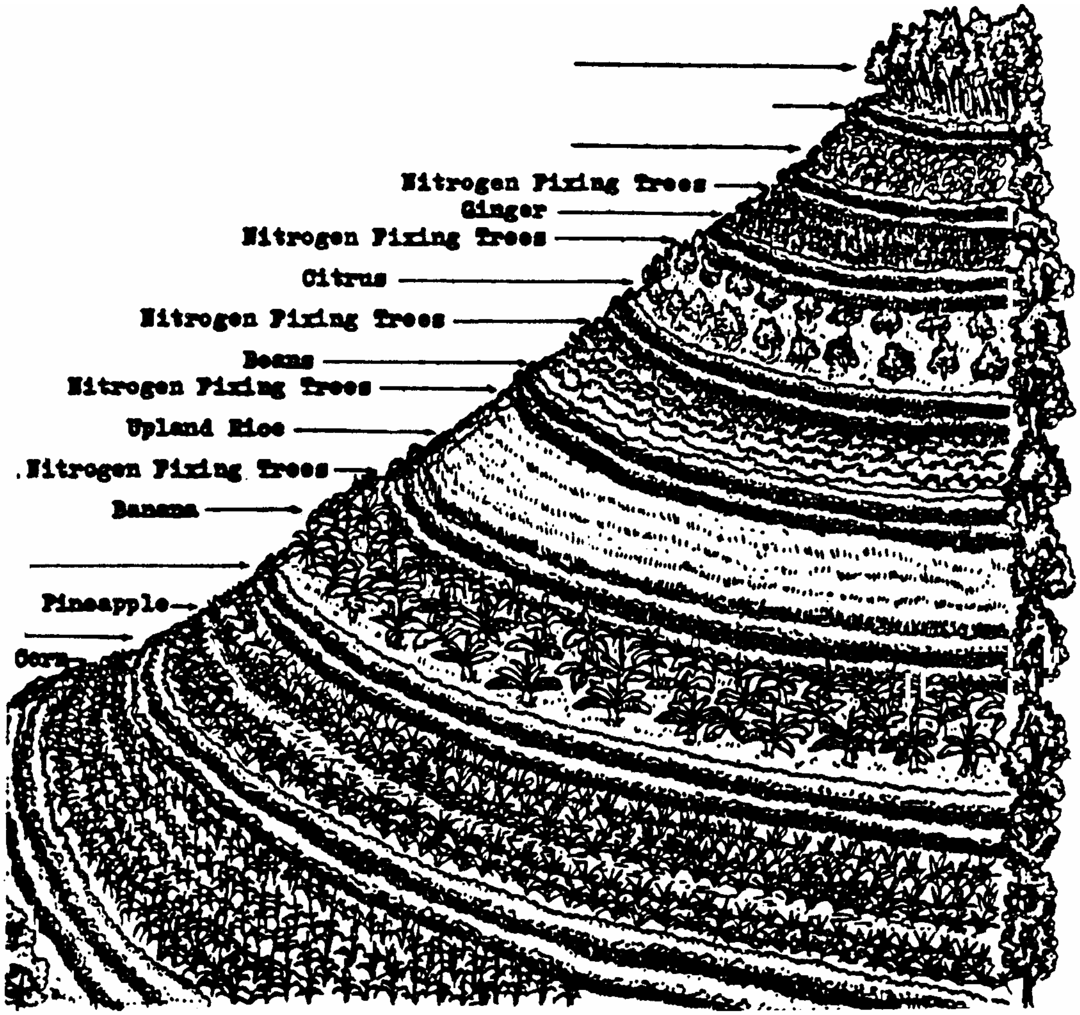


Figure 6-12. SALT step seven. Plant short-term crops in the strips between permanent crops.

Figure 6-13. SALT step eight. Trim nitrogen-fixing trees and distribute the leaves and twigs around crops as mulch and fertilizer.

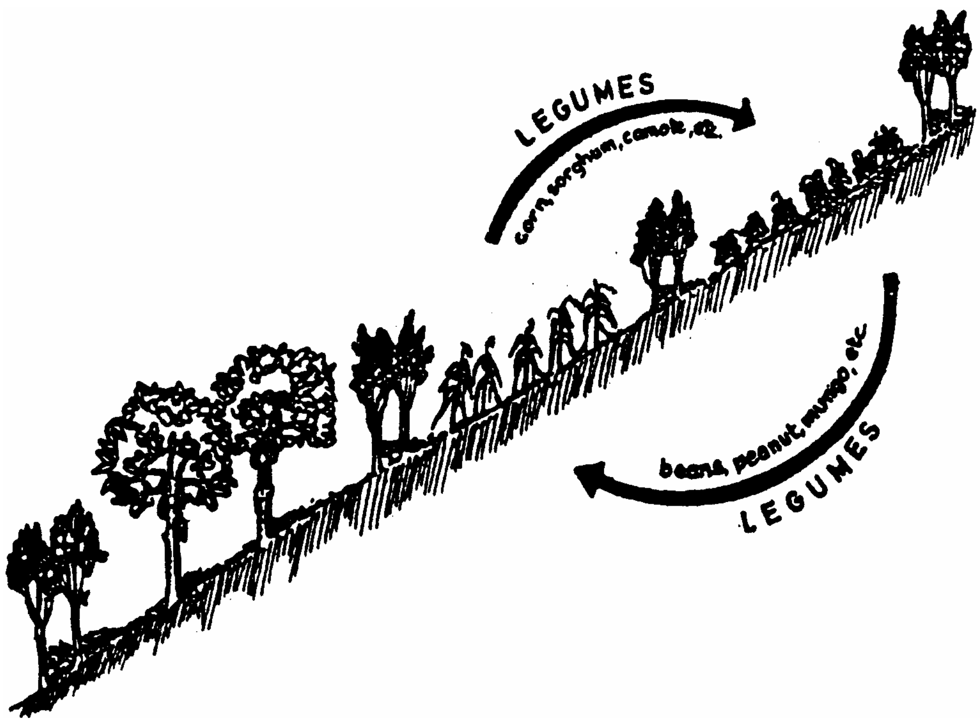


Figure 6-14. SALT Step nine. Practice crop rotation. Alternate a legume crop with non-legume crops.

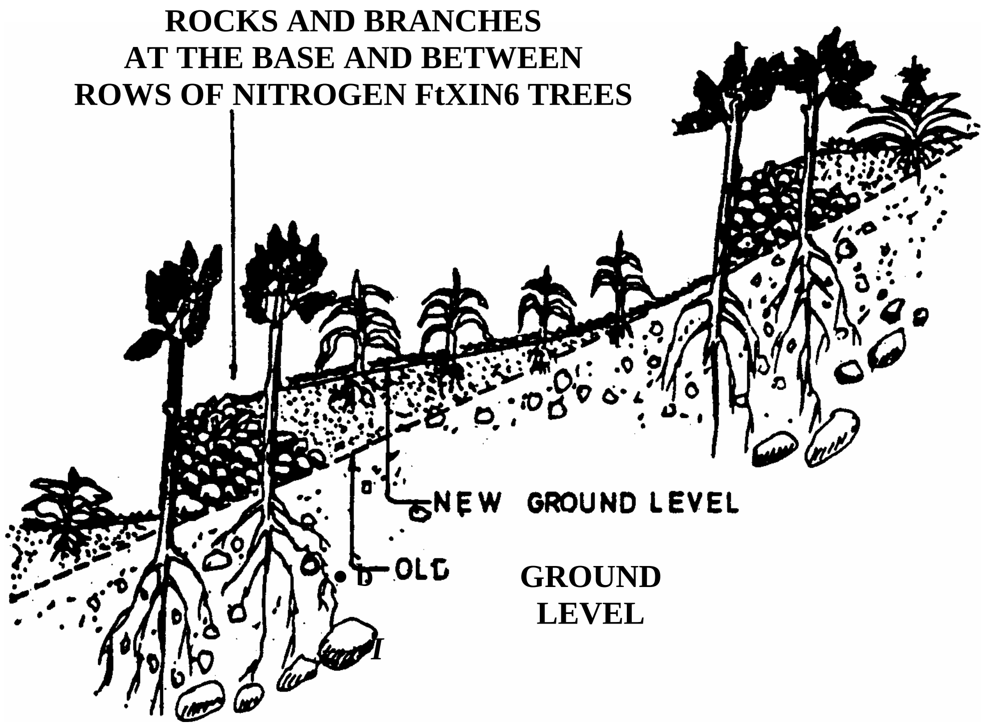


Figure 6-15. SALT Step ten. Build green (bench) terraces. From time to time during the farming operation, pile stones, branches, and twigs at the base of the trees to improve the barrier. As the years go by, beautiful terraces are built as the topsoil accumulates above the barrier walls. (All the above sketches of the SALT method used with permission.)

Over a seven-year period (1980-1987), corn yields grown in the conventional way by farmers gave yields of 1.5 T/Ha/yr. Yields in the SALT system were 3.3 tons.

Yields where commercial fertilizer (100-50-0) was used were 4.3 tons. After the first four years, when the permanent crops commenced producing, net farm income increased three and four fold.

The above instructions and information were based on various SALT publications (See the Bibliography). For more information, contact Harold R. Watson, Mindanao Baptist Rural Life Center, P. 0. Box 94, Davao City, 8000 Philippines.

IW~D[T] D NEIGHBORS CASE STUDY: THE GUINOPE PROGRAM, AN ~ TEGRATED DEVELOPMENT PROGRAM IN HONDURAS

The Guinope program, begun in 1981, is an agricultural extension small farm integrated development program in Honduras. It is a cooperative effort of World Neighbor, the Honduran Ministry of Natural Resources, and the Association for the Coordination of Development Resources ~ Note: This program dealt with slopes un to 45%.

The Problem

Continual mono-cropping of corn for many years and extreme erosion had caused severe soil deterioration of a large area. Much of the topsoil had vanished. Some noticeable results were:

- Crop yields were extremely low.
- Many farmers walked for hours-or took buses to other areas to find land to farm. Other families had left farms and villages to move to city slums in the capital to search for work.
- Malnutrition was common among those remaining.
- Abandoned fields plus empty houses in the town of Guinope witnessed to impoverished local economic conditions.

Organization for Action

The Ministry of Natural Resources in Honduras provided tax-free status, some logistics, and handling of legal papers. ACORDE offered certain ecologically sound agricultural technologies. They also gave some administration support. World Neighbors supplied program personnel, financial support and general orientation with regard to development strategies and philosophy.

Methodology

- A limited number of technologies were introduced to deal with the limiting factor in the local agricultural production. This was done with field demonstrations and with the use of farmer-run, small-scale experimentation on the farmers' own land.

- The technologies were: (a) extremely inexpensive (b) easy to understand (c) productive of significant increases in yields (d) directed at traditional crops of the villagers (d) appropriate technologies.

- Technologies were taught largely in the field through hands-on activities by the farmers. At least 75% of the facts and technologies taught were practiced rather than theoretical.

- Village farmers taught all classes. A farmer taught only that technology with which he had had success himself. (Originally, farmers from Guatemala who had had experience were brought in to teach. Later, farmer teachers from the Guinope replaced them.)

- Grain farming proved successful. As basic yields exceeded local ~ people became interested in growing cash crops and in improving family nutrition.

- Classes in nutrition, hygiene, and raising vegetables were held. Since few vegetables had been grown in the region, no market for them existed in the village. The project therefore established a vegetable store in the capital, Tegucigalpa.

The Technologies Used

Previous World Neighbors agricultural programs in Guatemala had used most of the technologies. The programs in Guinope replicated them. The technologies included:

1. contour ditches, contour grass barriers and drainage ditches (on lesser slopes)

2. methods of bean improvement

3. in-row tillage (minimum tillage)

4. standard non-mechanized methods of vegetable production

5. green manure cover crops. The use of small farmer adapted green manure cover crops is a major technology which was largely developed by the Guinope program and a sister program in El Rosario, Honduras.

This system was used in the Guatemalan programs and is widespread within Honduran, where it is used by a dozen or more development agencies. Through the work of development agencies, these technologies are now used in successful programs in Mexico, Haiti, El Salvador, Nicaragua, Peru, Bolivia, Indonesia and the Philippines.

The green manure technology is still new enough that it is still largely in the experimental stage in many countries. However, in Guinope and El Rosario, at least 500 farmers use it.

At least 15 agencies in Honduras and another 80 elsewhere in the world are experimenting with green manure crops. (Author's note: using well adapted, very high-producing legumes.)

1. Many other agencies from many countries have sent technicians to the project for training.

2. One of the program objectives is to reach the very poorest farmers. This has been accomplished because of the inexpensive, simple, labor intensive technology, and because of using farmers as teachers.

   Even the landless or nearly landless have benefited. Wages for farm labor have risen from $2 per day to $2.50 or $3.00 per day <u>within the program area</u>, though not outside it.

3. Many new residents have come into the area. Worn-out, formerly abandoned land is now farmed again. Land formerly thought to be useless and abandoned around the town of Guinope could be had if a family fenced it and lived on it. Many families have been doing this. Dozens of 2 to 5 hectare fields have recently been claimed by fencing.

4. Dozens of new houses are going up in the town as people return from the slums or other areas.

5. The previously mentioned technologies have <u>eliminated erosion</u> on <u>hillsides up to 45% slope.</u> <u>Long term fertility</u> has been ~

6. Local farmers have built more than 198 kilometers of drainage ditches, 80 kilometers of grass barriers, and 31 kilometers of rock walls to protect 449 hectares of hillside land from erosion.

7. Soil fertility has also been enhanced by (a) elimination of agricultural burning (b) widespread use of chicken manure (risen from 0 to more than 700 truck loads per year in 6 years) (c) use of cow manure and compost (d) introduction of a number of tropical green manure cover crops (e) limited use of chemical fertilizers.

8. Air and water quality: environmental conditions have improved. (a) Formerly, chicken and egg producers around Tegucigalpa dumped tons of chicken manure into the river. Now the demand for the manure is sufficiently great that it is sold to farmers. b) The elimination of burning of crop residues has noticeably reduced the quantity of smoke in the air from February through May.

9. Some trees have been planted by farmers: (a) farmers have planted coffee and fruit trees (b) they are farming fewer hectares, leaving more for trees and pastures.

<u>Problems</u>

Probably the biggest problem of the program has been locating markets for cash crops (vegetables). Finally the project established a vegetable store in Tegucigalpa.

Cost and Benefits

Cost

Agricultural production and extension	$254,000
Health extension work	$44,000
Vegetable marketing (much of this a loan being repaid)	
Total	$332,665

Average cost per family (1200 families)

The farmer pays all agricultural production costs such as labor, equipment or raw materials. The project maintains a small revolving fund for buying and selling equipments such as sprayers and pitch forks.

Benefits

For participating families, per-hectare grain production has tripled. All technologies are simple. Repair and replacement are done locally at prices affordable by the farmers.

The Future of the Program

The program hopes to "work itself out of a job". The farmers learn to do the necessary on-the-farm tests and experiments. As they learn to teach and to share results with one another, large numbers of them will develop their agricultural skills for many years after the program closes.

For example, farmers were taught the same way. Only corn and beans had been grown for hundreds of years, but World Neighbors taught soil conservation, and corn, bean, and wheat production. After four years, the farmers were growing cabbages. broccoli, and cauliflower. They had eliminated the wheat, which they found to be not as profitable a crop as the vegetables. The farmers' belief in experimentation and trying new things gave them the ability to adapt to change.

In Guinone an organization composed of village agricultural clubs will coordinate experiments each year and share their findings. If other vegetable markets do not develop, the vegetable store in Tegucigalpa will be run by the vegetable producers' association. (This case study used courtesy of World Neighbors.)

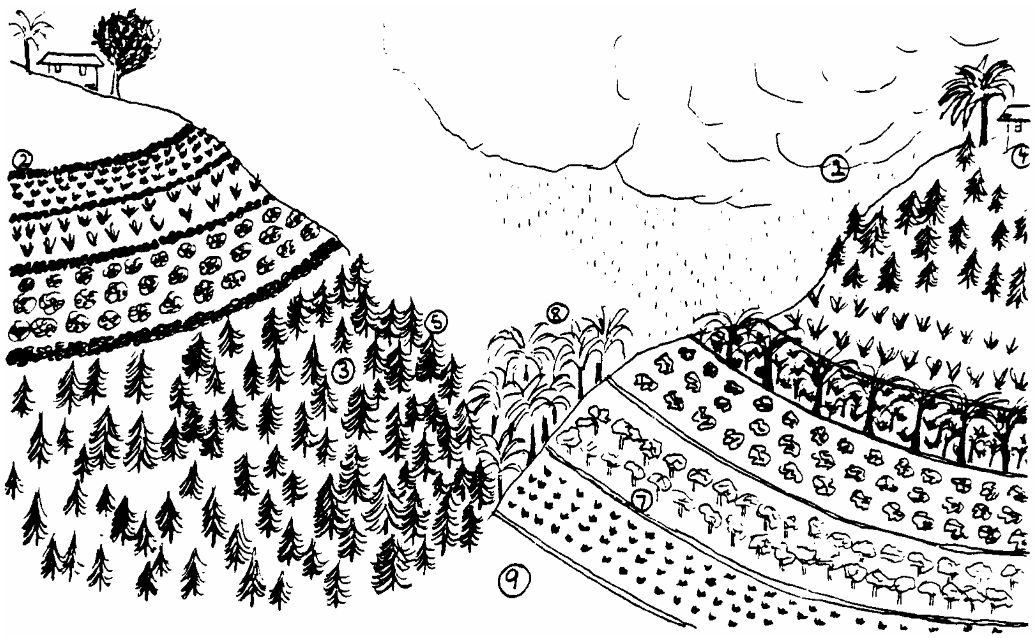


Figure 6-16. Getting the most from the land--A pictorial summary of excellent steep slope farming. (Modified from World Neighbors.)

1. Associate planting trees with more rainfall.
2. On rocky soils, build rock barriers to save soil and water.
3. On very steep slopes, grow trees for lumber, fuel, and feed.
4. Plant trees near the house for shade, food, fuel, compost, and feed for livestock--grow more animals to eat the feed.
5. Protect more steep land with combined forest and grass.
6. Grow coffee and other tree crops on steep slopes. Soil test. Use compost, manure and recommended amounts of commercial fertilizer for field crops.
7. Plant all field crops on contour rows with drainage ditch protection.
8. Grow bananas in ravines to prevent erosion, make good yields.
9. Save soil for growing crops by contour ditches and live barriers, especially multiple purpose tree barriers. Where topsoil is deep, use some orchard terraces for valuable fruit tree crops, or for coffee or tea.

CHAPTER 7

SOIL EROSION BY WIND

What Is Wind Erosion?

Soil erosion by wind occurs when wind dislodges soil particles and moves them to another location. Wind erosion will take place when wind with velocity of about 20 km per hour or more blows over very dry, loose, poorly structured soil.

How Serious Is Wind Erosion?

Wind erosion can be exceptionally serious in regions of fairly level frequently dry soil (low rainfall from 250 - 500 mm), and significant wind velocity. Under these conditions, huge amounts of valuable topsoil can be removed from a farm in a day or two.

Wind-borne soil moves sand and silt onto neighboring land, or even considerable distances away, sometimes destroying both the land it came from and the land where it goes. It covers roads and railroad tracks.

Dust storms can vacuum up fine soil particles and organic matter a kilometer or more into the air, transport them 800 km or more, and deposit them as fine particle dust. In northwest Cameroon, during 198 1-1984, we saw fine dust settle everywhere during yearly Harm tans (dust storms). Throughout the dry season, dust permeated the air like fog and coated everything indoors and out. It came from the Sahara, hundreds of kilometers away.

The wind picks up and transports the finest lightest soil the clays silts and organic matter. Since clays, silts and organic matter hold most of the plant nutrients, the larger soil particles which are left will be much less fertile. Wind erosion can produce heavy loss of soil fertility over wide areas of land.

The ultimate long-term result can be desertification. Wind erosion now destroys millions of hectares of land each year. Both wind and water erosion are denuding land at an alarming rate.

How Have Farmers Helped Cause Wind Erosion?

Except in natural deserts, wind erosion did not seriously threaten the land before man began to cut forests and to plow fragile areas which should have been left undisturbed. As man moved in, the picture changed.

During the 1930’s, the ‘dust bowl years” in the United States, wind erosion devastated farms in the high plains country. You have seen pictures of the “dust bowl’ in which clouds of blowing dust darkened the skies for hundreds of miles.

The winds severely eroded millions of acres once covered by a carpet of sod and grazed by wild animal herds. The Grapes of Wrath tells a tragic story of a typical farm family, destitute and hungry, leaving the dust bowl in search of work. There were thousands of such families.

The tragedy of the 30's occurred because farmers had plowed the natural grassland of this semi-arid region--land which should not have been plowed. They farmed the land year after year without proper conservation methods. Gradually, cultivating crops used up the organic matter, destroying the soil structure. Following several years of drought, the dry topsoil blew away.

In many other parts of the world today, men are still making similar mistakes:

- Farmers plow up land which should not be plowed.

- In some places, animals are overgrazing grasslands and brush lands, leaving the soil bare. By trampling the land with their hooves, especially ~ areas surrounding watering holes, animals compact the topsoil, destroying the soil structure and creating the conditions for wind erosion.

Which Parts of the World Are Especially Susceptible to Wind Erosion?

The most far-reaching problems occur in the Great Plains of the United States and Canada, the Sahara and Kalahari deserts in Africa, Central Asia (the steppes of Russia) and central Australia. However, wind erosion also occurs elsewhere, particularly in other arid and semi-arid regions (300 - 500 mm rainfall).

Under What Conditions Can You Find Wind Erosion?

- Soil erosion by the wind can occur anywhere dry bare soil is exposed to prevailing winds of significant velocity--20 Km/hr (12 miles per hour) or above. Arid and semi-arid areas are especially vulnerable. Wind erosion is most serious in areas prone to dry soil, especially if the land is level so that the terrain does not obstruct the force of the wind.

- Wind force does not move wet soil. However, this does not mean that humid areas are necessarily free of wind erosion. Lands which experience heavy rainfall and erosion from raindrop splash during wet periods can suffer from wind erosion during dry periods.

- Erosion by wind can occur in special situations in humid areas. For example, during droughts, winds in Ontario, Canada erode the land in the farming areas between Lake Ontario, Lake Erie and Lake Huron, and also in the Coastal Plains of the southeastern United States. In other humid areas, winds carry away soil from peat land if the soil has been plowed and left bare, and becomes too dry.

- You can find some soil being eroded anywhere dry soil is exposed to too much wind. Dry. silty-sandy soils with very poor structure are the most vulnerable of all.

- You may have farmers with very small plots (1/4 hectare) where soil blows when dug up at the end of the dry season before the rains begin. Look at the edge of this field on the down wind side. Is much soil being deposited there? If the problem is serious, next season persuade them to leave one meter wide strips uncultivated every 5 meters until the first light rains fall. The strips should be perpendicular to the direction of the wind. Also leave the surface of the tilled strips rough until the first rains. Caution: if the farmer has problems with erosion from rainfall, he may have to place these strips on the contour and also use live or dead barriers on the contour.

THE MECHANICS OF WIND EROSION

We first began to the understand the mechanics of the movement of soils by wind from the work of two pioneer researchers in the early 1940's: Bagnold (working in Great Britain and North Africa) and Chepil (working in Saskatchewan, Canada and Kansas, USA). They found that wind forces move soil using three processes:

Suspension: The wind vacuums up small, fine particles of clay, silt, and organic matter (those particles which are less than 0.1 mm in diameter). It holds them in suspensions at heights of thousands of meters, to be transported lone distances.

One study found that a strong dust storm, originating in 1937 in West Texas, deposited its suspended dust load in Central Iowa. The dust was left on top of a deep crust of snow in Iowa where it could be measured. The snow kept the deposited dust from coming in contact with the soil beneath the snow bank, making accurate analysis possible.

In Table 7-1 you can readily see the damage to the quality of soil caused by this one storm alone. Compare the organic matter; the amount of nitrogen, phosphoric acid, and potash; and the amount of fine clay in the Dalhart, Texas soil before and after the storm. Notice the great increase in the nutrients and also the characteristics of the soil deposited in Iowa.

Table 7-1. Analysis of West Texas Virgin Soils, Dune Sand and Dust from a Texas Storm, Deposited on Snow in Iowa

Samples from a protected virgin soil near Dalhart TX	Organic matter Nitrogen Phosphoric Acid Potash Sand (coarse, medium fine, and very fine) Silt-clay Ultra-fine clay (colloidal)	1.06% .06% .04% 2.05% 79.2% 19.6% 8.1%
Samples from sand dunes near Dalhart TX recently formed during storm	Organic matter Nitrogen Phosphoric acid Potash Sand (coarse, medium fine, very fine) Silt clay Ultra fine clay (colloidal size)	0.33% 0.02 (trace) 1.77 91.8 7.5 5.2
Samples from the dust deposited on snow in Iowa fields	Organic matter Nitrogen Phosphoric Acid Potash Sand (coarse, medium, fine, Very fine) Silt and clay (colloidal size)	3.35% 0.19% 0.19% 2.58% 0.0% 97.0% 33.4%

The storm blew away most of the fertility from the West Texas fields. It removed 2/3 of the nitrogen and organic matter along with much phosphorus and potassium. It also removed about 37% of the very finest clay particles. The soil structure in Texas had to be very poor for such serious erosion to happen.

Notice the richness of the dust deposited in Iowa. As compared to the virgin soil, the dust exhibited a three-fold increase in organic matter and a fourfold increase in amount of ultra-fine clay.

Saltation.

- Soil particles with diameters from 0.05 to 0.5 mm can be transported by saltation-- moved along by the wind a few millimeters at a time, bouncing and rolling. Most of the particles so transported are medium size, and fall in the range of 0.1 to 0.15 mm diameter. The name ‘saltation comes from the name of a similar process whereby sand particles are moved by the force of water bouncing along the sandy bottom (bed) of a stream.

- When small sand grains blow along the surface of the topsoil at a rapid rate, some of them will bounce almost vertically into the air. The medium sand particles affected by this energy often rise 30 cm or more, but not above 1 meter. Those which have bounced up to 30 cm high will encounter considerable wind force blowing horizontally. Pushed by the strong lateral force of the wind plus the pull of gravity, they fall back to the earth at various acute angles. The effect will be similar to cutting with a knife at an angle, or to sand-blasting.

  Many of the grains will land with great force at sharp angles (10 degrees or less). The strong cutting and scooping force tosses more grains vertically. These sand grains, also, will rebound strongly at acute angles when returning to the surface. They in turn bounce increasing numbers of grains, and so on and on. The process builds upon itself in an intensifying and accelerating system which can move huge amounts of particles in a short time.

- In addition, saltation loosens smaller particles, freeing them to be sucked up and suspended easily by vertical air streams.

- The larger particles (usually from 0.5 to 2 mm) are too heavy to be lifted into the air. Nevertheless they can be affected by saltation. The bouncing grains from saltation strike them, nudge them, and push them along the with help from the wind force. The word “creep” describes the process very well! As long as the wind blows, these larger particles will keep moving until they encounter an impediment such as a fence, vegetation, etc. These larger particles move less distance and more slowly than the medium ones moved by saltation.

Amounts of Soil Moved by the Wind Processes

Of the three processes, saltation moves the most soil. Estimates of the amount of soil moved by saltation range from 55% to 70% of the total amount eroded by wind. Suspension apparently removes from 3% to 38%. Amounts of soil removed by creep range from 7 to 25%. Most of the soil movement by wind takes place immediately above the soil surface. Fifty percent occurs within the first 5 cm above the soil surface and as much as 90% within 30 cm of the surface.

Hence any obstruction 30 cm high will stop most saltation and creep. However, to stop suspension and crop damage from wind, the obstruction must be higher or placed very close together.

Wind tunnel experiments suggest that 150 tons per hectare per hour can be moved from a field when a 40 kin/hr wind is blowing. Most of this would be from saltation. Some observers in the field report that strong wind storms can move more than 100 tons of soil per hectare in an hour. As stated earlier, an acceptable guide fur the farmer, depending on his circumstances, might be the loss of no more than 11 or 12 tons of soil per hectare per year from any cause.

WHAT FACTORS AFFECT WIND EROSION?

1. Wind velocity.

The higher the velocity, the more soil is moved. When wind speed increases, its destructive ability becomes proportional to the square of the velocity of the wind.

Example: Let us assume that a shelter belt of trees reduces the wind speed 40% at a distance of 25 meters downwind from the tree belt. A 60 Km per hour wind blowing over the field before reaching the trees would have a destructive force of 602 or 3600 units. Twenty-five meters beyond the trees (on the lee side) the speed would only be 40 % x 60 = 24 Kin/hr. Here the fraction would be:

$$\frac{(24)2}{(60)2} = \frac{576}{3600} = 16\%$$

The destructive force is therefore reduced by 84% at a distance of 25 meters from the tree belt. This simple calculation indicates the importance of taking measures to slow the wind speed.

Good windbreaks greatly reduce wind speeds on the lee side of the barriers, for a horizontal distance of 4 to 6 times the height of the barrier.

2. Soil texture--soil structure

Sandy-silty soils are more susceptible to wind erosion than are clay soils. Fine sandy soils with low organic matter content and poor structure are highly vulnerable to the wind.

3. Smoothness of soil surface

A seedbed of finely prepared soil encourages wind erosion. A very rough soil surface can help control wind erosion.

4. Dryness of soil

Certain very dry soils blow easily. Moist soils do not blow.

5. Amount of vegetative cover on the soil

The more vegetative cover on the soil, the less erosion occurs. Also, plant root help anchor the soil.

HOW TO FIGHT WIND EROSION

Basic Recommendations to Farmers (Details explained below)

1. Follow good land use methods.

2. Develop and keep good soil structure in the topsoil.

3. Leave a rough surface on the field when plowing, and where crops are not present.

4. Keep live or dead vegetative cover on the soil during the windy season.

5. Keep the wind velocity below 20 Km/hr at the soil surface by using ~ windbreaks or tall crop windbreaks.

How to Carry Out These Recommendations

1. Follow Good Land Use Practices.

Proper use of the land is the best way to prevent wind erosion.

- Many sandy-silty soils with poor structure which are already growing good grass should remain in grass and shrubs. Usually the grass should not be plowed un for row crops. This means using the land for grazing.

- To keep the grass cover from dying out, do not over-graze. Move the cows, oxen, goats, and/or sheep often enough for the grass to re-grow. Rotate the areas you graze.

- Where poorly structured land must be plowed for the family to have food, stress using many of the good land practices discussed below to prevent wind from blowing the loose soil and also damaging the crops.

2. Develop and Keep Good Soil Structure

- Do not burn the post-harvest trash--stalks, leaves, stems. Leave it all to be turned under. Or turn part of it under, and leave part on the surface as mulch. This will both help protect from wind blowing the soil surface and add organic matter to improve the soil structure.

- Rotate crops so that legume crops grow in the soil every 2 or 3 years. Legumes improve soil structure as well as produce nitrogen. Depending on rainfall and other climatic factors, certain types of legumes will do better than others. Check with Peace Corps specialists.

- Use much animal manure, compost, and some commercial fertilizers for healthier plants, more crop yield and more organic matter.

- Keep the soil moisture high when possible, especially during high winds.

3. Leave a Rough Surface on the Plowed Field Use some of the following tillage systems:

- When plowing fields, leave some crop residue on top of the soil.

- Run the rows and strips perpendicular to the prevailing wind (assuming that erosion from water is not occurring). If the farmer plows the furrows perpendicular to the wind, the ridges on the sides of the furrows will give some wind resistance.

- The rougher the soil surface with clods, and trash, the less vulnerable it is to the wind. If possible, plow deeply enough to bring up large clods of dirt from below.

- Leave the surface unbroken or rough. Do not harrow or pulverize the soil. Do not prepare extensive, finely textured seed beds.

- Plow some strips in the field later than others, so that some unplowed strips remain with crop stubble still in place.

- If the soil is heavy and drainage is a problem, use a blister which forms ridges when it plows.

    • • Put the ridges on the contour if the land is rolling. If the land is level, run the ridges and rows perpendicular to prevailing winds.

    • • Mix trash into the soil, or leave as much crop residue as possible on ~ of the ridges.

    •• Plant crops on top of the ridge.

4. <u>Keen Vegetative Cover on the Soil Surface</u>

Keep some type of crop cover, stubble or mulch on the land, especially during those critical months when winds are frequent and strong. When possible, avoid plowing up large areas of sod or other vegetation. Cultivate in strips, leaving some untilled.

a. Do not gather crop post-harvest trash for feed or fuel. Leave it in the field. (Investigate other solutions for feed and fuel needs.)

- When plowing the field, or when cultivating or weeding with a hand hoe, leave the dead plant material on the soil surface (unless it is a noxious weed.)

- If the field is to lie fallow, control the weeds to preserve soil moisture.

- At plowing time, consider using tools to cut the weeds ~ the soil surface and loosen the soil <u>under the surface</u> without turning it over. The cut stubble stays on the soil surface. This is called <u>field-trash farming</u>.

• • Plant the crops through the mulch, leaving the soil protected. The limited rainfall penetrates the soil more quickly; the mulch protects the soil from wind, reduces moisture evaporation, and lowers soil temperature.

- Together with one or more farmers, you may be able to devise some innovative types of trash-mulch or minimum tillage system.

- When harvesting grain or other food crops, leave either long stubble or the whole plant standing in the field. These have resistance to wind.

- Where firewood or fodder is scarce, the farmer may need to plan ~fl4Jy in advance and plant trees especially for fodder and firewood. Plant in such manner as to provide wind protection.

b. Use a strip crop rotation system.

- In strip cropping, grow crops in strips planted to different crops, with the strips from 5 to 15 meters wide. Usually the farmer alternates strips of 2 to 3 different crops.

- Ordinarily, run the strips of crops perpendicular to the wind direction Caution: Where water erosion also occurs, put the stripe on a contour.

- One or more of the crops might be a ~ variety which would serve as a cover crop during the strong windy season. This could be planted in every other strip if only 2 crops were planted, or every third strip if three crops are planted.

- Depending on what crops grow well, plant one tall crop in the rotation. (Tall crops act as "micro-windbreaks.") Wind speed is greatly reduced for a horizontal distance of, 6 plant heights on the lee side. The tall crops therefore can protect the adjacent strips of low-growing crops or of plowed soil downwind.

    - In some areas, sorghum and ~ are useful tall crops to plant in strips. (Note: pigeon peas are also legumes) If a sorghum plant is 2 meters tall, the soil downwind from it can have good protection for up to 12 meters.

c. Include legumes in the rotation.

- If the farmers need livestock feed, look at growing grass-legume strips for 2 or 3 years. Grass (together with a legume) could grow in one strip, tall crops in one strip, and a low food crop in another strip, etc.

- Consider growing a nitrogen fixing-multiple purpose tree or shrub strip for feed and demonstrating a windbreak. (See the section below.)

5. Practice Water Conservation

The farmer should practice good soil and water conservation methods on all rolling lands. Some soils are endangered by raindrop splash erosion as well as wind erosion. Also capturing rainwater and conserving soil moisture is especially important in arid and semiarid regions. Keep as much moisture as possible for crop growth in the topsoil. Another benefit--moist soils do not blow.

6. Use Tree Windbreaks (See below)

HOW TO CONTROL WIND EROSION WITH TREES IN WINDBREAKS

Choose Suitable Tree Species

Mature trees make wonderful windbreaks. However, many varieties will not be feasible for very low rainfall areas. Check with your local agricultural specialists and farmers about the seriousness of wind erosion in the area, and recommended tree species. Are there farmers who may already be using tree barriers (shelter belts or windbreaks)?

Consider these tree varieties: (I) *Albizia lebbeck* (2) *Cajanus cajan* and (3) *Chamaecytisus palmensis.* All three are recommended for erosion control, alley farming, and green manure in arid and semi-arid climates. *A. lebbek* and *C. palmensis* produce nectar for honey bees. *C. cajan* provides human food. *A. leb beck* produces rough lumber. *C. cajan and C. palmensis* are recommended for growing to maturity for windbreaks if needed. Also see list suitable trees to be found in this manual at the end of Chapter 5 and see Chapters 4 and 5 for instructions for planting trees and care of trees.

For other tree varieties which might be grown to maturity as windbreaks and for excellent instructions for establishing windbreaks, see PC-ICE R0008, Soils. Crops. and Fertilizer Use by Leonard, pages 56 to 61.

Consider Multipurpose Trees and Alley Cropping

A combination windbreak-agroforestry approach with multipurpose trees can be helpful. The need for fodder is the most serious constraint to raising animals in arid and semi-arid lands. Firewood, is also a major concern. Certain trees can provide both.

In many areas, appropriate trees can fit into some type of modified alley cropping or other type tree and food crop farming system. The rows of trees will need to be widely-spaced to avoid competition with food crops for moisture, but they can also act as windbreaks and of course provide desperately needed fodder and firewood. If the land is flat, the rows should be planted perpendicular to the prevailing winds.

Agroforestry researchers are now very busy testing tree varieties and studying farm systems for drier areas. There are real benefit for the farmer who plants more trees. Contact the Nitrogen Fixing Tree Association for trees recommended for your area.

Although windbreaks often work well, some of the land will blow in spite of them if the soil does not have good structure. Many farmers can best control wind erosion by careful land husbandry--(good farm management). This also will help increase the crop yields.

Farmers must maintain an adequate organic matter level in the topsoil in order to keep and build good soil structure. They should not denude the fields of crop stalks and leaves, not even for livestock feed or cooking fires. This will be possible only if other farm planning provides for these serious needs by growing some trees especially for these purposes.

Fortunately, well-chosen varieties of trees or shrubs in windbreaks can help. Finding the right-fast growing multiple-purpose trees and starting some demonstrations is a first step. These trees might be planted in a block for fuel or feed, or as windbreaks, or as some type of special widely spaced alley cropping. In any case the trees would furnish badly needed feed for livestock and firewood so that crop residue could be left in the field.

Where possible, natural grasses and vegetation (not, however, serious weed pests) should be allowed to re-cover unused areas. The rules for covering the soil stressed throughout this manual apply equally to wind erosion. They are, however, hard to carry out successfully in the drier zones.

What are the Benefits from Growing Windbreaks?

1. From windbreaks in the fields (rows of trees, shrubs, tall grasses, or other tall crops used to reduce wind speed.

- Soil erosion is greatly reduced.
- Young plants are protected from blowing sand.
- With proper management, food crop yields increase noticeably.
- Efficient use of soil moisture increases because evaporation of moisture by wind from the soil is reduced, leaving more water for the food crop.
- Quality of the food crops improves noticeably.
- Stems and leaves harvested from tree windbreaks make good mulch and compost. Trees also supply fuel, food, and fodder.

2. From windbreaks for farmsteads (used to protect the home, barns, gardens, orchards, people and animals)

- Protection from strong wind and sandstorms for people and animals. More day-to-day comfort, health and well-being
- Protection of buildings and equipment
- Protection of the water supply
- Better quality and higher yields from the garden and orchard
- Useable by-products such as nuts, fruits, firewood, fodder, food, and lumber for family use and for sale.

Learning from the Experience of Others

1. The Niger Experience--an outstanding Peace Crops demonstration

- During 1975, at the request of farmers, a local forester and a PCV with funds from CARE planted a total of 16 kilometers of double-row windbreaks of Neem *(Azadirachta indica)* on various farms in the Majjia Valley, Niger.
- From that demonstration, today more than 300 kilometers of these Neem" windbreaks have been planted by farmers there. Usually, the windbreak rows are spaced about 100 meters apart. The trees are spaced about 5 meters apart in the rows. CARE has continued to fund the project.

- These windbreaks are protecting more than 30,000 hectares from hot winds of the dry season and from crop-damaging winds during the monsoon season. At the same time they also produce poles, lumber and fuel for the region.

- Eighty percent of the farmers have had ~ from crops grown in the protected zones. Grain yields increased more than 15%.

- Tree harvests of wood in 1985 yielded about $15 per hectare a year for the farmers. Future harvests will be almost as good. To many of the really small farmers, this is a significant amount of money.

2. Experience from Egypt

- Egypt has some of the oldest continuously farmed land. The network of windbreaks in Egypt is one of the most extensive in the world.

- Hot, dry winds buffet Egyptian soils in late spring and summer, as do sandstorms.

- Forestry and agriculture are commonly integrated on farms, with most of the trees planted in windbreaks.

- Trees used for windbreaks are usually varieties of *Eucalyptus* and *Casuarina*. *Eucalyptus camaldulenis* comprises 20% and *Casuarina equisetifolia* over 70% of the windbreaks in Egypt.

- For special problems like saline soils and waterlogged conditions, or where brackish water is used for irrigation, farmers plant *C. glauca.*

3. Handling Problems in Establishing Windbreaks and Shelter Belts

- Experienced field workers all say the main problems in establishing windbreaks stem from:

- • lack of farmer understanding and interest

- • lack of care of seedlings after they are transplanted. The tender plants need water from time to time, weeding, and protection from grazing animals.

- The most effective teachers for farmers have consistently proved to be other farmers who have successfully established windbreaks on their own farms and have benefited from them. Good farmer demonstrations and farmer field ‘know-how make the best classrooms and teachers.

APPENDIX A

A BASIC TOOL KIT OF TECHNIQUES FOR THE FIELD

HOW TO MEASURE RAINFALL INTENSITY AND TOTAL RAINFALL

Certain commercially made devices measure rainfall intensity and amount--namely a recording rain gauge or the (less sophisticated) standard rain gauge. You are in luck if either is available to you. They probably will not be. Even if they are available, farmers will need less expensive ways to measure rainfall at more than one location. You can teach them to make a satisfactory rain gauge from a straight-sided round metal can.

You may want to have several farmers make simple gauges and measure the depth of water in millimeters with a stick--and keep careful records. These records would be invaluable! This is also an excellent way to teach farmers about rainfall, raindrop splash erosion, and the importance of careful record keeping.

HOW TO MAKE A SIMPLE RAIN GAUGE

1. Locate a water-tight can which is open at one end. It should have a diameter of 5 to 10 cm and should be 25 cm or more tall. The sides should be straight, not tapering, in order to insure fairly accurate measurement.

2. Mount the can on top of a building or a post, away from the reach of children and animals. Mount it so that it is level.

3. The can should be in the open, away from buildings or trees which might interfere with its catching an accurate sample of the rainfall. It should be <u>at least one height away</u>. That is, it should be at least 10 meters away from an obstruction which is 10 meters tall, or 30 meters away from a tree which is 30 meters tall.

4. Mount the can so that it can be <u>emptied each time</u> after the farmer reads and records the rainfall.

5. Be sure the can is well enough secured with wire or string so that it will not blow away during a high wind.

6. Make a stick ruler to measure the water depth in the can. Put some notches as well as written indicators on the ruler. The measurement will give you the amount of rain which has fallen (in centimeters or inches--however you have marked the ruler). Depending on the needs, the rain can be measured after a particular rain, or for a twenty-four hour period. If records are made during a season of continuing rain, record at the same definite time each day.

7. A glass or plastic container is ideal. You can mark it and measure the water quickly by sight through the glass to gauge intensities during a rainstorm. Remember that high intensity rains have more large raindrops and do maximum damage to soil surface. Rainfall of 4 mm per hour does no damage, but that of 50 mm can cause much erosion.

8. Keep accurate data. After each rain, record the date, time, amount of rainfall--and peak intensity also, if possible--in a sturdy notebook.

HOW TO MEASURE STEEPNESS OF SLOPE

As steepness of slope increases, the force of runoff water increases. Therefore, the contour ditches and barriers must be closer to each other to control erosion. Also, steepness of slope often changes at different places on the same hill, and the distances between contour ditches, barriers, etc. should vary accordingly. (See Chapter 4, Figures 4-7 and 4-16.)

How to Calculate Slope

- Slope can be expressed as the degree the slope makes with the horizontal (i.e., a 90 degree slope is vertical; a 45 degree slope is halfway between the 0 degree slope [horizontal] and the vertical).

- However, an easier way to express this is as **"%** slope". This is an expression of the vertical distance units (inches, centimeters, etc.) divided by the horizontal distance units x 100. See the sketch of slopes drawn for 10%, 40%, 60% and 100%. (See figure 2-3 in Chapter 2.)

Formula: % slope = the units of vertical drop or vertical elevation divided by the units of horizontal distance x 100.

Examples: A field with a 10% slope has a vertical drop of 10 meters for every 100 meters horizontal distance. Or if you are looking up the hillside, it has 10 meters vertical rise for every 100 meters horizontal distance. Similarly, a 30% slope would have 30 meters fall (or vertical rise) for every 100 meters measured on a horizontal line.

How to Make the Measurements.

- Remember when you are measuring vertical distance that the horizontal line must be level with the point of origin. In other words, to measure true horizontal, the measuring tape, rod or string must be held level when the vertical distance is measured at the end of the tape.

Examples: If the slope is 100%, it will drop down vertically as in an elevator for the same distance as the horizontal distance involved. This is often called a 1 to 1 slope--one unit down (or up) for every horizontal unit. A 20% slope would be a 1 to 5 slope, or a drop of 20 meters for every 100 meters horizontal. (A 100% slope makes a **450** angle with a level horizontal line.)

How to Measure Slone with a Hand-Held Above Level or Inclinometer

The Abney level, or inclinometer, is a sight level: You hold the instrument to your eye as you focus on a distant target which another person holds. The target is the same vertical distance from the ground surface as your eye is. By rotating the instrument dial until the bubble indicator is level, you can read directly the percent slope or (the degree of slope angle). You may find it useful for making quick, rough estimates.

How to Measure Slone with a Carpenter's Level

1. If you have access to a carpenter's level you can tie it to the top side of a board or rod which is 2 to 4 meters long.

2. Place the board on the ground, pointing down slope. Hold the upper end firmly to the soil; then raise the lower end of the board until it is level with the upper end. It is level when the bubble in the carpenter's level is between the two indicator lines.

3. To get the vertical distance, measure the distance from the lower end of the board (while held level) to the soil surface immediately below.

4. Express this as % slope by using the following formula:

% slope = vertical units divided by horizontal units x 100

Example: If the vertical distance is 20 cm and the board is 4 meters long:

20 cm/4M = 20 cm/400 cm = 5/100 x 100 = 5% slope

How to Measure Slope with a String Level

You can also teach farmers to measure slope with a string level (a mason's or carpenter's string level). This is a small (about 10 cm long), inexpensive, simple device which you will be able to find in your host country. It has a bubble in the middle, and a loop on each end through which to pass a string. It can be used two different ways:

1. Use this small level as we did the large carpenter's level above. Tie the string level to a board or rod as above. (A board is more accurate than a string, especially in a high wind.) It works well for marking the elevations when making bench terraces or digging drainage ditches with a specific grade or slope.

2. Or use it suspended from a string. Measuring this way may require two people.

a. Pass a 2 or 4 meter length of strong string through the two holes for this purpose at the top of the instrument. Be sure the string is strong, and exactly 2 meters or 4 meters long. Slide the level near to the down slope end of the string.

b. While you hold one end of the string on the ground, another person should take the other end around, stretch the string and lay it on the ground so that it is pointing straight down the hill. Now raise the down slope end of the string and stretch it very tight, while the other person holds the other end of the string snugly to the ground. When the small bubble in the instrument is exactly in the center between the instrument indicator lines, the string is level.

c. With the string held in that level position, measure with a ruler the vertical distance from the down-slope end of the string to the soil surface immediately below.

d. If the vertical distance is 6 centimeters and the horizontal distance is 2 meters (200 centimeters), percent slope = 6/200 X 100 = 3%.

How to Measure % Slone with an A-Frame which Has Been Calibrated

1. Begin by studying and understanding in advance the entire section below which deals with the A-frame level device--how to make it, how to calibrate it, and how to use it.

2. Make an A-frame (See below). (You will also find other slightly different directions given for the SALT method in Chapter 5.)

3. Go to a spot on a hillside which appears to be an average slope. Put one leg of the A-frame on the ground and point the other leg straight down the hill.

Keeping the first leg firmly on the ground and keeping the two legs lined up to point straight downhill, bring the lower leg to the elevation required to make the hanging string come to the level marker. Keeping the instrumental level position, measure the vertical distance from the bottom of the lower leg to the ground. Measure with a ruler in millimeters. Repeat this five or six times at different locations. Compare it to other methods. To get more accuracy, make a special A-frame with 2 meters instead of 1 meter between the legs.

THE A-FRAME: HOW TO MAKE IT AND USE IT

How to Make a Simple A-Frame Field Level and Calibrate It

The A-frame, though crude and simple, is adequate for determining level contour lines (i.e., lines at 0% slope). Once farmers understand how this simple device works, and its importance to them, they use it with pride. Most of the lines are surprisingly accurate. Its simplicity encourages a farmer to demonstrate it to a neighbor. The idea spreads quickly.

The farmer needs a sharp knife (machete, bob, cutlass), three poles, a piece of cord, string or wire, and a rock. The poles should be sturdy enough to stand upright without bending under a little stress.

1. Tie two of the poles together at the top, with the bottom of the poles spread out a bit. Tie the tops very securely, cross-wrapping so that they do not slip.

2. Tie the other pole as a horizontal brace across the other two poles (these last with their legs spread apart) to form the letter “A’. The bottom of the A-frame should have the bottom of the legs exactly either 1 meter, 1 1/2, or 2 meters apart, so distance can be measured with it. Tie both ends very securely. Be sure they cannot slip. Ideally, in addition to the string wrapping, all three joints should have a nail or wooden peg driven through them, in order to help keep the poles from slipping.

3. Tie a free-hanging string at the top point of the A-frame so that it is centered, swings free, and hangs down below the crossbar.

4. Tie the rock to the bottom end of the cord so that it swings free below the crossbar. A plumb bob would be best, but a rock will work. I have used a rock successfully when necessary.

5. Now find the <u>spot on the cross-bar</u> which can indicate when the legs are <u>level</u> on the ground. The cord-plus-rock in a state of rest will hang at a true vertical line with the earth. Therefore the legs are level at the point indicated by the string when it has ceased swinging.

   To do this:

a. Stand the A-frame up, with the two legs standing on level ground. If the ground is not level, drive two strong stakes (pegs) vertically into the ground so they are exactly the same distance apart as the bottom legs of the A-frame (so the bottom of the A-frame legs can sit on top of the vertical pegs). The tops of the pages should be <u>approximately level</u>.

b. Place the A-frame legs on top of the pegs. Let the string and rock come to a state of rest. Be sure the wind is not blowing the string at an angle. <u>Mark with a pencil on the crossbar</u> the point at which the string crosses it.

c. Now rotate the frame so the placement of the legs is reversed. The left leg will now be where the right leg was, and the right leg will be exactly where the left leg was.

d. When the string comes to rest again, mark again on the crossbar the point at which the string crosses the crossbar. There will be a space between the marks unless the pegs are level. If they happened to be level, the marks would be on top of each other.

e. <u>Mark the point which is halfway between</u> the two marks on the crossbar. When using the A-frame in the field, you will know the two legs are level on the ground when the free-swinging rock-line comes to rest at the exact mid-point on the crossbar.

f. Make a notch on the crossbar at this point with a knife or a machete so that you can see it easily and will not erase it.

g. <u>The legs are level when the string-and-rock hangs directly over the</u> flower.

h. You are now ready to run the first contour line around the top of the hill.

6. <u>Calibrate the A-frame</u> from time to time. To do this, periodically repeat the same steps for finding the center point. Even though the A-frame is well made, its accuracy should be checked, i.e. calibrated.

<u>How to Find Contour Lines Using the A-Frame</u>

1. Start near the top (highest point) of the field.

2. Cut a number of stakes to use for marking the level lines (contour lines).

3. Drive in the first stake near the top edge of the field. This will be the marker stake from which you will lay your contour lines.

4. Work in a level line (contour) around the hill. Position one leg of the A-frame so that it is slightly above, and touching, this first stake. Move the other leg of the A-frame so that the string is in front of the notch on the crossbar--the notch which marks level position point on the crossbar. Have the string swinging free when the reading is made.

5. Keeping the string carefully at the level point, sink another stake into the ground. This one should be slightly above and touching the second leg of the A-frame.

6. Move the A-frame, touching one leg of the A-frame to the last stake which you drove. (Alternate the leading leg of the A-frame, swiveling one and then the other of the legs into the lead position as you work around the hillside.)

7. Always adjust the leading leg of the A-frame, moving it until the cord is in line with the center notch, your level position marker. Drive the pegs alternately above and below the legs of the A-frame, barely touching the leg.

8. Proceed around the field until you have completed the length of the row. You have now set forth the first contour row in the field. Marking the remainder of the lines will come much more quickly and easily.

Note: These directions for making and using the A-frame owe a heavy debt to information from the World Neighbors filmstrip Saving Our Soil with the A-Frame.

HOW TO CONTROL GULLIES

1. Prevention is the best gully control.

2. Sometimes small gullies can be erased by using a contour diversion ditch above the area, plowing across the gullies on the contour and planting the area with appropriate grasses and legumes.

3. If larger gullies present, use a contour diversion ditch and different types of check dams as shown below.

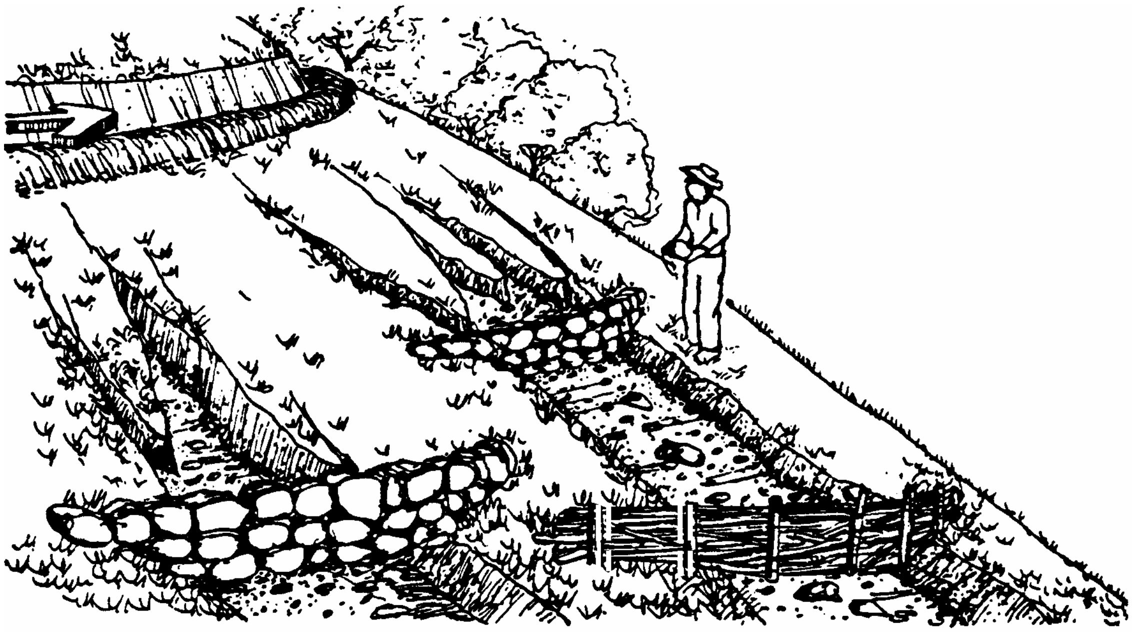


Figure A-1. A contour diversion ditch and check dams can effectively control gullies. Tree seedlings and grasses and/or legumes can also be planted below the ditch to control raindrop splash erosion over the area. (Sketch from Carl Crozier PC R062.)

HOW TO PLAN SMALL FARM FERTILITY PROGRAMS IF SOIL TESTING LABS AND COMMERCIAL, FERTILIZER ARE NOT AVAILABLE

<u>How to Test Soil Acidity with a Quick Test on the Farm</u>

If a soil testing laboratory is available and affordable, by all means have a fertilizer and pH test done at the laboratory and follow their recommendations where possible.

Where no soil laboratory is available, the agricultural worker can test for pH with a test which can be done on the site. It will not be as accurate as a laboratory, but will give a good indication.

1. Take a composite soil sample as if you were sending it to a soil-testing laboratory. (See Chapter 1 for directions.)

2. While you are testing the ~ you may wish to dig deeper and get separate samples from the ~~ai1 to check its pH. You would make composite samples of the subsoil as you have done for the topsoil. You would, of course, test topsoil and subsoil <u>separately</u>.

3. Take 1/2 cup of soil from the well-mixed composite sample and place it in a clean plastic or glass bowl or jar. Add one cup of clean, untreated drinking water, or better yet, clean rainwater. Mix thoroughly and let the sample set for 5 or 10 minutes or longer.

4. Remove a small sub-sample from the top after the soil has settled.

5. If you are testing with liquid tester, follow the directions accompanying liquid kits. These come in various forms:

a. One simple system you may wish to consider is the “Hydrion One Drop Indicator. Add one drop of this solution to 4 cc of soil-solution water as instructed in the kit directions. Read the color change on the accompanying chart to determine pH values by half units.

To order, ask for One Drop Indicator--Hydrion # UL-109. Catalogue # 15-240-2V. Price $10.

Address: Fisher Scientific Headquarters, 711 Forbes Avenue,
Pittsburgh PA 15219-4785. Telephone (412) 562-8300 (in the United
States 1-800 766-7000 or FAX 1-800-926-1166). For Technical Assistance
in the U.S. call 1-800-388-8355. You can also contact the Atlanta Fisher
Customer Service Center, P.O. Box 4829, Norcross GA 30091.
Telephone (404)449 5050.

b. Other liquids are available for more complex and thorough analysis. Check with Fisher at the address given above.

6. If you are using strips or ribbons of testing paper, put several drops of the soil water on the bit of paper ribbon; or follow the manufacturer's directions. Read the pH from the color chart. You can order these as follows:

a. Micro Essential Laboratory Soil pH Testing Paper (Range pH 4 to 9). Two rolls of paper in dispenser. Catalogue # 151. Price $10 in U.S., $11 for overseas airmail.

Address: Micro Essential Laboratory, 4224 Avenue H, Brooklyn NY
11210. Telephone (718) 338-3618.

b. Alkacid Soil Test Ribbons. A paper test for acid soil--(pH 4-5); (pH 5-6); (pH 6-8). Includes roll paper and dispenser; also manual listing over 300 plants, their pH preference and soil treatment. Catalogue # A 989. Pack of 6, $22.05. Add extra for airmail cost and specify airmail. Use the Atlanta Customer Service address for Fisher Scientific Equipment given above.

c. Check with your in-country Peace Corps office for other possible sources of testing liquid, ribbons, or paper.

How to Estimate Fertilizer Requirements without a Soil Test Laboratory

1. List the crops the farmer grew last year. Estimate the crop yields.

2. Use Table 1-6 from Chapter 1 to reach a rough estimate of plant nutrients drawn from the soil last year by the crops, especially nitrogen, phosphorus, and potassium.

3. Try to replace these and add 30 to 50% more to the field. Do calculations in kilograms nutrient/hectare.

4. Compare this farmer's crop yields to crop yields of good soils in the area.

5. Watch for signs of nutrient deficiencies. Use Table A-2 below.

How to Supply Required Plant Nutrients from Compost. Manure. Mulch. Green Manure Cover Crops. etc.

Plan to fully use the farm's potentials for producing high quality organic fertilizer.

1. Begin by reviewing Table 1-7 from Chapter 1 for nutrient content from manure, compost, etc. Analyze and plan what the farmer can produce.

2. Use the farm's crop production capabilities well.

- Plan for, make, and use all the high quality compost the family labor and farm can supply.
- Grow as many green manure crops as possible. (See Chapter 3.)

- Use crop rotation, planting food grains alternately with other (especially legume) crops. Example: corn following beans.

3. Know and maximize the use of animals' manures, using the table below for values.

Table A-1 Approximate Composition of Various New. Wet Manures

Fresh Manure with Bedding or Litter	Percent Moisture	Kg of Nutrients per 1000 Kg of Manures		
		N	P20	K20
	70%			
Chicken*		11	11	5
Sheep and Goat Cow	70%	10	7.5	10.5
	86%	5.5	2	5
Horse	80%	6.5	2.5	6.5
Pig	87%	5.5	3	4.5
Rabbit	60%	15	10	10

*Chicken manure is usually higher than this.
Table from David Leonard's Peace Corps R0008, Soils. Crops. and Fertilizer Use.

- Gather, accumulate, and use all manure. Keep animals penned and cut and carry feed to them, thus collecting manure in one place.

- Keep manure stored in a shady, dry place. If the manure is exposed to hot sunshine or rainfall, the fertilizer value will be reduced more than 50% in a short time.

- The fertilizer value of the manure will vary with the nutrient content of the foods the animals eat.

  For example, note the (K) potassium value of maize stover (stalks and leaves) as compared to that of sorghum. (See Table 1-6 Chapter 1.)

- Where bedding from straw or stover is used for animals in stalls or in covered pens, the nutrient from urine and manure in the bedding makes a ~

- Caution: **Mix animal manure (especially chicken manure) well with soil when applying, to avoid burning the plants.**

4. Apply organic fertilizers (manure, compost, green manure crop leaves) in narrow row strips and work it into the soil. Use the "V" ditch row as in minimum tillage. Use minimum tillage if possible.

5. Use some commercial fertilizer if possible.

How to Double Check Soil Fertility Status while Crops are Growing.

Deficiencies in plant nutrients mean reduced yields at harvest time. Consider the nutrients needed to grow a healthy maize crop. In Table 1-6, you have seen that maize requires heavy amounts of nitrogen (N) and potassium (K) to produce a crop. The demand increases greatly as yields increase. If these are deficient, the yield can only be greatly reduced.

How can the farmer determine when the soil lacks enough of certain nutrients for good crops?

1. <u>Use Row Testing</u>.
   When you are applying fertilizer to the field, use “test rows” to decide whether the crop needs more fertilizer.

   A. Make a map of the field with locations of different crops.

   B. Apply the regular fertilizer amounts to the whole field.

   C. Choose 2 separate locations in the field. In addition, mark off 25-meter lengths alongside each other in ~ On one row, leave the regular field fertilizer treatment. On the 25 meter strip adjacent to it, add 50%, more fertilizer. On the third adjacent 25 meter strip, add 100% more fertilizer. Record the location so that you can observe the harvest jater.

   D. Repeat this in the second location.

   E. Observe the test plots throughout the growing season for rate of growth, color, and, finally, yield.

   F. Harvest separately when crops are mature. This should show some interesting results for comparison.

2. <u>Read hunger signs of</u> <u>plants</u>.

   - Symptoms of nutritional deficiencies or “hunger signs” can help the farmer determine what particular plant nutrients are needed; i. e., what hunger signs are specific to N, P, K or other nutrients.

     In the absence of a fertilizer test from a soils lab, the farmer must watch crops carefully and learn to identify specific crop hunger signs.

   - Certain crops are easy to read as indicators of a soil’s fertility status; i.e., their deficiency signs show up clearly. Maize plants are good indicators:
     they clearly show deficiencies from nitrogen, phosphorus, potassium, calcium, magnesium, and other nutrients.

     Learn the signs of nutrition deficiency of maize and teach them to others. This will be a fair indicator of the soil deficiency for many other crops. This can help guide the farmers fertilizer program.

Table A-2 Signs of Nutrient Deficiencies in Plants

Nitrogen Deficiencies

Plant	Growth	Leaf Color	Flowers & Fruit	Other Comments
Grass Family (Maize, rice, millet, wheat, sorghum, pasture grasses)	Slow growing, spindly stems	Pale green or yellow green. As plants grow older, lower leaves show yellowing of the tips, then yellowing moves up the leaves in a V-shaped pattern; often yellowing of lower leaves or all leaves have yellow-green appearance. Lower leaves may turn brown and die.		Caution: drought can also cause browning of lower leaves.
Legumes (Field beans, soybeans, pasti] re legumes)		The leaves are pale green with a slight amount of yellowish color, Look first at the lower leaves		Legumes make their own nitrogen if the appropriate Rhizobia bacteria are present in the soil. For the Rhizobia to be healthy, the soil must not be too acid and must have the needed soil nutrients for normal growth. When Rhizobia are performing abnormally, nitrogen deficiency signs appear on legume plant leaves.

		where it begins,		
Other crops	Retarded growth	Leaves are pale green or lack green color on leaves and stems.	Lower yields, smaller fruit	Signs are the same for many vegetables as well as other crops.
Tomatoes	Slow growth, smaller leaves	Change in color, fading through various shades of green leaves to pale green and then yellow. Look also at top of plant where green becomes lighter.	Flower buds turn yellower and fall off. Fruit is small.	
Cucumber	Stunted	Few leaves, pale green	pale green fruit	
Radish	Slow, stunted	Small yellow leaves		
Potato	Stunted	Yellow leaves	Smaller tubers, Fewer tubers.	

Phosphorus Deficiencies

Plant	Growth	Leaf Color	Flowers & Fruit	Other Comments
Grass Family	Retarded rate of growth; slow rate of maturity. Spindly stalks	Purplish leaf coloring		Phosphorus is concentrated in the youngest growing tissues; the tips of roots and shoots.
Maize	Spindly stalks	Purplish leaf coloring. Small mature leaves	Fewer rows of grain on the cob.	Maize which is developing kernels will transfer phosphorus from leaves to grain to meet phosphorus deficiency. Phosphorus deficiencies not as easily noticed as in grasses.
LegLimes	Slow growth; fewer side branches	Younger leaves become dark green but are smaller than normal.	Flowering and maturation retarded. Fewer seeds.	
Other Crops (vege-tables)	Slow, delayed maturity; hunger signs appear early on young plants & continue to harvest.	Underside of leaves of tomatoes may show purplish color. Turnips and other cabbage family plant leaves tend to turn purplish. (Cabbage, Brussels sprouts, broccoli, etc.)		Crop yields reduced.

Potassium Deficiency

General note: Potassium~ s many functions include giving plant stalk and stems strength--resistance to wind, etc.

Plant	Growth	Leaf Color	Flowers & Fruit	Other Comments
Grass family	Signs appear later when plant is several weeks old.	Margins or edges of the lower leaves turn yellow, beginning at the tip, then brown, and die. Leaves may appear too long and thin for the plant height.	Stalk has relatively short internodes.	Potassium starvation produces a very weak plant with badly damaged leaves.
Legumes		Look on around edges of leaves for irregular yellow mottling.		
crops: Cabbage Cucumber		Many vegetables show discoloration along the leaf edges. Cabbage leaves show bronze color along edges which spreads inward as leaves grow older, later showing brown spots. Leaves show firing--brown then yellow on leaf edges.		

Aids to Diagnosis: A Summary

- Phosphorus deficiency signs appear early on young plants.
- Potassium deficiencies appear later. Plant stalks will be weak.
- With nitrogen deficiency, the yellowing and the brownish color goes up the middle of a maize leaf, beginning at the leaf tip.
- With potassium deficiency, the yellow or brown coloring stays on the outside edge of the leaves, beginning also at the tip.

How to Use the “Hunger Signs”

When you see signs of nutrient deficiency, there is little you can do to help the current crop unless you have some commercial fertilizer or manure available that you can immediately apply. The main benefit of these signs is to help you plan the plant nutrient needs for next year’s crop.

For example, if nitrogen deficiency is noticeable across the field, by all means persuade the farmer to use crop rotation and plant demonstration plots of several green manure crops. These crops will also help some with phosphorus and potassium deficiency.

If phosphorus and/or potassium deficiency signs are showing, encourage the use of some commercial fertilizer high in P and K as a side dressing to the row, or in the bottom of the seed bed at planting time. Also encourage the use of more manure and compost in the row under the seed at planting time.

HOW TO INOCULATE LEGUME SEEDS WITH *RHIZOBIUM* BACTERIA BEFORE PLANTING

All legume seeds, both field crops and trees, need to be treated with the special bacteria *Rhizobium* unless the same legume plant has already been grown in the soil where the seeds are to be planted. Legume roots house the *Rhizobium* bacteria, which manufactures nitrogen fertilizer. The bacteria take elemental nitrogen from the air and convert it into nitrogen fertilizer. They will produce enough nitrogen fertilizer for the plant to use and have extra left over for other nearby plants.

Seed treatment is done by taking topsoil from around growing legume roots and rubbing it on the new seed. Each legume species requires a specific strain of *Rhizobium.* If you can't find soil containing the needed *Rhizobium*, you can order the pure *Rhizobium* from a number of places. (See Appendix D.)

HOW TO TREAT TREE SEED BEFORE PLANTING

Some tree seeds have a tough water resistant coating. The seed skin is tough. The following treatments are recommended for treating the seeds prior to planting.

- Most tree seeds will germinate if soaked in water all night before planting the next morning.

- Other tree seeds are especially tough. The seed of the legume tree *Leucaena*, for example, needs extra help. You can use either of the following methods of scarification.

  - Take a knife blade or sandpaper and nick or scratch the back side of the seed. This breaks the tough skin so water can penetrate and usually produces nearly 100% germination.

  - When dealing with large volumes of *Leucaena* seed, you may wish to use the hot water treatment. Take 1 pound of seed in a small bucket. Heat water in metal bucket or pot until it boils. Pour exactly 1 gallon of boiling water over the seed and leave it alone for 4 minutes. Then quickly pour off the hot water and put the seed on a flat surface to drain dry. This weakens the seed coating so water will enter.

- Treat legume seeds with the appropriate strain of *Rhizobium* before planting.

HOW TO DETERMINE SUITABLE SOIL AND WATER CONSERVATION NEEDS AND TECHNOLOGIES

How to Rou2hlv Determine the Rainfall Infiltration Rates of Soils

Classification of Infiltration Rate

Excellent	All rainfall water enters the soil during heavy rainstorms. This kind of water disappearing act you will usually find if you pour a bucket of water on dry beach sand. No runoff results.
Good	This is almost as good as “Excellent”. There is some runoff during heavy rainstorms, but less than 10% of the total rainfall.
Moderate	Some runoff can be noticed during storms of medium intensity, and much runoff during major, highly intensive storms.
Poor	Most of the water runs off during moderate rainstorms and all of the water runs off (except a small fraction) during an intensive storm.

Note: Remember you will always have runoff if the soil is not deep enough to hold the volume of water from a rainstorm. Also, if one rainstorm follows another after a few hours, the soil volume may be full of water already. Much runoff will then occur since the soil storage is already full. For this reason, in tropical conditions you should always install contour drainage ditches and exit control drainage ditches and exit control . They will be needed.

How to Distinguish Usable Soil Depth

1. Dig several holes in the field through the subsoil down to the parent material. If this is done toward the end of the rainy season, you can determine how deep different crops go into the subsoil.

2. The vertical distance from the top of the soil surface to the bottom of the subsoil can usually be considered the usable soil depth. However, be sure that plant roots are growing well into the subsoil.

3. As a rough method for discussion, the soil is divided into four classifications of depth.

Name	Depth of usable Soil
Deep soils	90 cm or more
Moderately deep	50 - 90 cm
Shallow	**25 to 50 cm**
Very Shallow	Less than 25 cm

Remember that plant roots must be able to penetrate the subsoil and grow there. Be sure there are no restrictions in the subsoil (hard compacted layers, poor drainage, rock layers, or strongly acid subsoil). If there are such restrictions, this part of the subsoil cannot be considered in determining the usable soil depth. Plant roots must actually use the soil

Example: the maize plant roots will penetrate to 90 cm if the subsoil is relatively fertile. This might be your best test plant.

How to Choose the Appropriate Methods of Soil and Water Conservation for a Given Situation

The table below lists 10 soil and water conservation technologies. It compares their effectiveness and appropriate use on different slopes, soil depths, infiltration rates, drainage needs, construction costs, complexity, tools required, etc. It compares their contributions to soil fertility, usable by-products, ease of field work and maintenance, and limiting factors. You will also find recommendations on each one.

Table A-3. A Guide to Choosing the Appropriate

Factors	Contour ditches to catch and store	Contour ditches offer slow drainage	Loose rock barriers	Earth barriers (covered with grass)	Grass barriers (with ditches?
Construction Costs (Money & Labor)	Moderate labor	Moderate labor	Very moderate labor	Much labor if large done with hand tools	Moderate labor
Tools Required	Hand Tools. A-Frame.	Hand Tools. A-Frame.	Hand Tools. A-Frame.	Hand Tools. A-Frame.	Hand Tools. A-Frame.
Complexity of Construction	Very simple.	Very simple.	Very simple.	Simple.	Simple.
Maintenance Tasks	Minimal. Keep ditches clean.	Minimal. Keep ditches clean,	Minimal. Keep rocks in place.	Keep earth mound intact w/grass cvr	Keep grass stands solid and ditches clean.
Contribution to Soil Fertility	None.	None.	None.	None.	None.
Bonus By-Products: (human food, animal feed, firewood, nitrogen fertilizer) Efficiency of Erosion Control (raindrop splash erosion)	None.	None.	None.	None.	Cut & Carry livestock feed.
	Does not stop splash but holds soil in ditch.	Does not stop splash but slows water runoff.	Does not stop splash but slows water flow,	Does not stop splash but slows water flow,	Does not stop splash but slows water flow.
Rainfall Expected	Very heavy.	Very heavy.	Very heavy.	Very heavy.	Very heavy. Variable
Relative Infiltration Rate Needed	Moderate to good.	Poor to moderate.	Poor to moderate	Poor to excellent	
Soil Depth Needed	Moderate to deep	Various depths	Various depths	Various depths	Various depths
Percentage Slope of Field	5% to 50%	5% to 50%	5% to 30%	5% to 20%	5% to 25%
Most Rain Captured and Stored?	Yes, if soil depth/ infil-tration rate allows,	Partly	Flow slowed	Yes, if soil depth/ infil-tration rate allows,	Yes, if soil depth/ infil tration rate allows.

Soil and Water Conservation Technologies.

Factors	Legume tree barrier (with ditches)	Continuous bench terraces	Discontinuous beach terraces	Minimum tillage (in row tillage)w/ contour drainage ditches	Contour drain ditches with green manure crop leaving mulch on field.
Construction Costs	Moderate labor and seed cost.	Very expensive, One man/year labor to construct one hectare.	Less expensive, One-half labor cost of continuous terrace.	Less expensive than discontinue. terrace	Labor moderate plus cost of seed first year.
Tools Required	Hand tools. A-frame.	Hand tools. A-frame. string level,	Hand tools. A-frame. string level.	Hand tools. A-frame.	Hand tools. A-frame.
Complexity of Construction	Not simple. Must have very close growing trees.	Very complex for good job.	Complex for good job.	Follow very simple instructions. Manage ment needed	Very simple.
Maintenance Tasks	Trim trees; keep grass stand under trees.	Good manage-ment; moderate labor.	Good manage-ment; moderate labor.	Trim excess grass with knife; minimal	Keep ditches clean, mulch on surface.
Contribution to Soil Fertility	Nitrogen fert; mulch orgnc matter	None.	None.	None.	Nitrogen fert; mulch, orgnc matter
Bonus By-Products: (human food, animal feed, firewood, nitrogen fertilizer)	Nitr fert; mulch; animal feed; firewood, etc	None.	None.	Mulch.	Beans for food or sale; feed for animals.
Efficiency of Erosion Control (raindrop splash erosion)	Leaf mulch greatly reduces splash- -slows_flow. Very heavy.	Holds soil in place only	Holds soil in place only	Excellent	Very Good
Rainfall Expected		Very heavy.	Very heavy.	Very heavy.	Very heavy.
Relative Infiltration Rate Needed	Moderate	Good except for paddy	Moderate	Moderate.	Moderate.

		rice.			
Soil Depth Needed	Variable depths.	Relative deep soils.	Moderately deep.	Variable depths,	Variable depths.
Percentage Slope of Field	5% to 50%	Any slope (15% to 50% suggested.)	Any slope (15% to 60% suggested.)	5% to 50%	5% to 30%
Most Rainfall Captured and Stored	Yes, if soil depth/infil-tration rate allows.	Yes if soil deep enough	Much	Mulch cover stores water if soil is deep	Much if infiltration/ soil depth allows.

Factors	Contour ditches to catch & store	Contour ditches offer slow drainage	Loose rock barriers	Earth barriers covered with grass	Gras s barriers (with ditches)
Contour Diversion Drainage Ditch Needed at Top of Field?	Yes	Yes	Yes	Yes	Yes
Exit Control Drainage Ditch Needed	Yes	Yes	Yes	Yes	Yes
Other Drainage Needs	None	None	Contour drainage ditches as needed	Empty into exit drainage ditch	None
Comments	If ditches spill over, space closer and dig them deeper. Empty into exit drain-age ditch.	Be sure all ditches have 1% fall toward exit ditch.	Can plant vegetables against the upper side of barrier,	Used to hold rainfall, guide runoff water slowly to exit drainage ditch.	Grass hedges do not hold well at slopes above 25%; use trees instead.
Limiting Factors	Do not use in shallow soils w/poor infiltration	Use on shallow soil or very slow infiltration	Keep livestock from destroying	Effective on steep slopes when used with adequate ditches	Keep grass stand solid ditches clean
Recommendations	All three of these are simple technologies and effective. A good way for beginners to start. Encourage these farmers to also use green manure cover crops.			Earth barriers are often used to slow runoff outlet.	Do not use grass barriers on steep slopes. Instead usenitrogen fixing trees.

Factors	Legume tree barrier (with ditches)	Continuous bench terraces	Discontinuous bench terraces	Minimum tillage (in row tillage) w/ contour drainage ditches.	Contour drain ditch w/ green manure crop leaving mulch on field.
Contour Diversion Drainage Ditch Needed at Top of Field	Yes	Yes	Yes	Yes	Yes
Exit Control Drainage Ditch Needed	Yes	Yes	Yes	Yes	Yes
Other Drainage Needs	None	Appropriate contour drainage ditches as needed		None	None
Comments	Closely deep rooted N-fixing trees do OKup to 50% slope if supprt by adqt contr drnge dtchs	Excellent for high cash value crops w/good fertilizer program.	Excellent for steep slopes; perennial crops; orchards; tea; coffee	(Countour drainage ditches about 20 m apart or closer if needed.) Excellent System!	Keep Mulch on surface and ditches clean.
Limiting Factors	Find the right tree. Needs some management	Need good management for operation & maint. Keep livestock out.	Need good management for operation & maint. Keep livestock out.	Need good cover of native grass to begin with or one seeded.	Find appropriate legume seed. Keep ditches clean
Recommendations	Search diligently for excellent tree legume seeds to produce 200 Kg/N/Ha.	Where labor is plentiful and soil is deep; where some row crops are to be grown for market, use this type of terrace on moderate to steep slopes.	Orchard terraces; individual tree; basic terraces--all up to 600. For upland cultivatedcrops only use on 15% to 50% slope.	Farmers should begin with a small plot. They will want to increase it later.	An excellent, quick, inexpensive way to control erosion & runoff. Expect 2 to 3 times increase in yields if can find right legume seed.

APPENDIX B

SOURCES OF TECHNICAL INFORMATION AND SUPPORT

Various International Research Institutes publish excellent guides, references, and helps. You can order a catalog which gives a detailed list from:

Publications of the International Agricultural Research and Development Centers, 1985, GTZ-CGIAR-IRRI. (Order from the Agri bookstore, Winrock International, 1611 N. Kent St., Arlington, VA 22209, USA.)

International Research Institutes and Centers

CIAT: The International Center for Tropical Agriculture. (Apartado Aereo 6713, Cali, Colombia, S. A.). Emphasizes work with beans, maize, rice, cassava, tropical pastures.

CIMMYT: The International Maize and Wheat Improvement Center. (Londres 40, Apdo. Postal 6-641, Mexico, D. F.)

ICARDIA: The International Center for Agricultural Research in Dry Areas. (P.O. Box 5466, Aleppo, Syria). Special interest in chickpeas, pigeonpeas, various arid land crops.

ICRISAT: The International Crops Research Institute for the Semi-Arid Tropics. (Patancheru P. 0., Andhra Pradesh, 502-324 India). Now has a center in Niger, West Africa. Emphasizes work with pigeonpeas, chickpeas, peanuts, millet, and sorghum

IITA: The International Institute for Tropical Agriculture. (P. M. B. 5320, Ibadan, Nigeria). Work with maize, pulses, rice, root and tuber crops. This group has pioneered work with alley cropping.

ILCA: The International Livestock Center for Africa. (P.O. Box 5689, Addis Ababa, Ethiopia). Emphasizes combined livestock and crop production. Also works with breeding.

ILRAD: The International Laboratory for Research on Animal Diseases (P. 0. Box 30709, Nairobi, Kenya). Especially concerned with wiping out Theileriosis and Trypanosomiasis (sleeping sickness).

ICRAF: The International Council for Research on Agroforestry. (P.O. Box 30677, Nairobi, Kenya).

NFTA: The Nitrogen-Fixing Tree Association. (Address: 1010 Holomua Road, Paia, Maui, HI 96779-9744, USA. Telephone: 808-579-9568. FAX: 808-579-8516. Telex: 510-100-4385). Focuses on the use of N-fixing trees for small farmers in the Third World for many purposes such as erosion control, green manure, income production, etc. Membership fee is $10 for persons in developed countries and $5 for Third World persons. Members receive certain issues of NFTA Highlights, NETA News, and 2 research reports. Several publications are available, with excellent, practical manuals on specific N-fixing tree species (see listing of some of them in the bibliography.)

WINROCK INTERNATIONAL: Formed by merging three groups: The International Agricultural Development Service, Winrock International Livestock Research and Training Center, and the Agricultural Development Council. (Headquarters at Route 3, Morrilton, AR 72110, USA. Washington address: 1611 N. Kent St., Arlington, VA 22209, USA). Works in crop and livestock research and extension programs in the Third World.

Private Voluntarv Organizations

A number of private voluntary organizations give superb support to workers ~ farmers and village groups. Several of these PVO’s are noted for their helpfulness, their realistic approaches to grassroots agricultural development, and the exceptionally high quality of their technical support. Among these are:

CARE: Its purpose is to assist the world’s poor and victims of disaster. Stresses self-help and self-development to overcome poverty, hunger, and malnutrition. Focuses on working with Third World Countries in “integrated rural development” programs, but also continues to distribute much food to victims of disasters. CARE has had, and may continue to have, some agricultural projects in some developing countries.

ECHO: The Educational Concerns for Hunger Organization, Inc. Works with agricultural missionaries and other ag development workers. Promotes grass-roots agricultural networking and experimentation. Maintains a seed bank; will send trial packets. The Echo Develonment News (quarterly) is a useful technical information clearinghouse; it also gives information on sources of technical support, and on references. Subscription free to people working in Third World ag development. You might also find copies at your Peace Corps country office. All back issues since 1981 can be bought for $10. Excellent and worth the price! Address: ECHO, 17430 Durrance Road, North Fort Myers, FL 33917, USA. Telephone: 813-543-3246.

HEIFER PROJECT INTERNATIONAL: This nondenominational Christian organization supplies small farmers with appropriate types of animals together with training and support. A special feature is that the recipients pass on the gift”--give the first female offspring to someone else, and provide training. You can secure a few excellent “how-to” manuals from them on raising animals. If your programs integrate crop and animal production, this is a good group to contact. Over the years, HPI has worked with many Peace Corps individuals and groups. This groups works well with mission groups and service workers, and is now beginning to push for sustainable agriculture. Look for more materials and technical support coming in this field. Address: Heifer Project International, Global Services Department, Little Rock AR 72203,

VITA: Volunteers in International Technical Assistance. Furnishes information and technical services to promote self-sufficiency. Can be either by mail or by on-site consultation. Publishes technical papers, manuals, bulletins, and a quarterly magazine. Address: VITA: 1815 N. Lynn St., Suite 200, Arlington, VA 22209, USA.

WORLD NEIGHBORS: Stresses self-help, grass-roots programs based on suggestions by, and utilizing, local leaders and volunteers. They distribute a large selection of excellent books, manuals, filmstrips, slides, flip charts in many areas of agriculture, health, community development, etc. These are at a level easily understood by Third World farmers and villagers. Available in various languages, according to need. Publishes two newsletters: World Nei&hbors in Action, an excellent quarterly field-practical newsletter ($5 a year for airmail postage) and Soundings from Around the World, a twiceyearly newsletter which reviews World Neighbors development materials and exchanges information. Address: World Neighbors, 4127 NW 122 Street, Oldahoma City OK 73 120-8869. Telephone: (405) 752-9700 or (800) 242-6387 (in the United States). FAX: (405) 752-9393. Telex: 510-600-2674.

APPENDIX G
SOME WEIGHT AND MEASURE EQUIVALENTS OR CONVERSIONS

1 ounce

1 pound (16 ounces) Factor: pounds per acre x = 3.2808 feet

1 kilogram 1.20838 = kilograms per hectare kilograms per

1 short ton hectare x 0.89 = pounds

1 long ton per acre

1 ton (of 2240 pounds)

1 metric ton = 25.4 millimeters

= 0.3048 meter

1 inch = 0.9144 meter

1 foot = 1.609 kilometer

1 yard

1 mile = 0.0394 inch

= 39.37 inches

1 millimeter = 0.6214 mile 107,640 sq.ft.

1 meter = 3.2808 feet

1 kilometer

= 0.4047 hectare 1.196 sqyds

1 acre = 645.2 square millimeters 247.1 acres

1 square inch = 0.0929 square meters

1 square foot =0.836 square meters

1 square yard =2.59 square kilometers

1 square mile = 2.471 acre

1 hectare = 0.00155 square inch

1 square millimeter = 0.155 square inch

1 square centimeter = 10.764 square feet

1 square meter = 0.386l squaremile

1 square kilometer

= 453.6 grams

= 35.274 ounces

(about 2 115 pounds)

1016 kilograms

= 28.4 grams 2204.6 pounds

= 0.4536 kilograms

= 2.2046 kilograms pounds

= 2000 pounds

= 2240 pounds

= 1.016 metric ton

= 0.9842 ton (of 2240 lbs) = 2.54 cm

1 cubic inch	= 16.387 cubic centimeters	= 28.3 17 liters
1 cubic foot	= 0.0283 cubic meters	
1 cubic yard	= 0.7645 cubic meter	1.308 cubic yard
I cubic meter	= 35.314 cubic feet	
		= 2 tablespoons
1 kilogram per hectare	0.895 pounds per acre	standard level
		= 6cc(ml)for liquids
1 fluid ounce	= 30 cc (ml)	= 18 cc (ml) for liquids
		= 1.06 quarts
1 teaspoon (standard)	= 5 cc (ml) for solids	
		= 0.943 liter
1 tablespoon (standard)	= 15 cc (ml) for solids	= 3.78 liters
		= 4.725 liters
1 liter	= 1000 cc	
	= 1000 ml	or5 U.S. quarts
1 quart (16 ounces)	= 2 pints or 4 cups	28.3 liters
1 U. S. gallon 32 oz	= 3780 cc (ml)	9.375 US gallons
1 gallon (Imperial)	= 4 Imperial quarts	
1 cubic meter	= 1000 liters	
1 cubic foot	= 7.48 U. 5. gallons	
1 bushel	= 1.25 cubic feet	
	= 35.4 liters	
1 acre-inch of water	= 56 pounds shelled dry maize or sorghum	
	= 60 pounds dry wheat	
Degrees Centigrade (C)	kernels or beans	
Degrees Fahrenheit (F)	= 26,928 U.S. gallons	
	= (F-32) x 0.55 (some people use 5/9 instead)	
	= (C x 1.8) + 32(some people prefer 9/5 to 1.8)	

EXAMPLES OF ALLEY CROPPING RESEARCH

1. Growing Maize in Alley Crotrning (B. T. Kang, G. R. Wilson and L. S. Sipkens)

This study took place at Ibadan in the forest zone of southern Nigeria from 1976 to 1980 on very poor, nitrogen deficient sandy soil. Maize was grown in 4 M width alleys between *Leucaena* hedge rows. The hedges were pruned 5 or 6 times a year. The yield of leaves, twigs and small limbs was 5 to 8 tons of dry matter per hectare per year. The nitrogen produced was 180 to 250 Kg N/Ha/year. Without the addition of commercial fertilizer, the yield was 3.8 tonnes/Ha/yr of maize grain on this poor sandy soil.

(Reference: Alley Cropping Maize *(Zea maize L.)* and Leucaena *(Leucaena LeucoceDhala* LAM) in Southern Nigeria by B. T.Kang et.al., Plant and Soil 63:165-179).

2. Alley CroDping for Food Crop Production in Humid and Subhumid Tropics. In another study in southern Nigeria on a different soil, B. T. Kang et.al. produced much higher yields when maize and cassava were grown in alleyways made by rows of *Leucaena* or *Gliricidia* planted 4 M apart, as compared to field crops grown by themselves.

They also found that the above two tree species did n~j grow well in highly acid soils. *Cassia siamea* and *Acioa berterii*, however, proved to be promising trees for alley cropping on very acid soils.

These studies showed that long term improvements in soil conditions occurred when *Leucaena* or *Gliricidia* are grown in hedge rows and the prunings left on the soil surface or worked into the soil. Organic matter increases and runoff and soil erosion decreases.

(Reference: B. T. Kang et. al. Alley Cronping for Food Crop Production in Humid and Subhumid Tronics: Proceedings of International Workshop at Ibadan, Nigeria, March 10-14, 1986; International Institute of Tropical Agriculture PMB 5 320, Ibadan, Nigeria).

3. Alley Farming with Livestock. (L. Reynolds and A. N. Atta-Krah).

These studies point out that alley farming is an ideal low input system which both protects land and produces food and animals in a long range, sustainable way. On very marginal steep slopes this system offers even more advantages for small farmers, who usually need more legume trees and grass in their living barriers to control water runoff and erosion. Since living barriers can produce animal feed, the farmers can often increase the numbers of livestock.

Trees were established in many combinations with food crops. Farmers planted the tree rows from 3 to 4 M apart. Planting the tree crop seed in the row with first rainy season maize crop was observed to be the best way to establish the legume trees.

It is well known that too much *Leucaena* in an animal's diet can cause toxicity or illness. No problems were observed when *Gliricidia sepium* was fed to goats. *Gliricidia* and/or grass should be fed along with *Leucaena* leaves in order for the goats to be healthy. Of 25 legume species tested, *Leucaena* and *Gliricidia* were preferred.

The number of farmers using alley cropping increased from 2 in 1981 to 100 in 1985, and 40 more farmers requested seed in 1986, showing their happiness with the results at that location.

'*Reference:* L. Reynolds and A. N. Atta-Krah, Alley Farming with Livestock, International Livestock Center for Africa PBM 5320, Ibadan, Nigeria, March 10-14.

4. Alley Farming in Semi-Arid Regions of India. (R. P. Singh, et. al.)

This summation of seven studies is important because it shows the need for caution with alley cropping under certain conditions, especially where competition for moisture prevails. Studies were conducted at seven different locations under a wide variety of conditions. Rainfall varied from 560 mm/year to 878 mm/year. The soils were either red type (Alfisol) or black soils (Entisols or Vertisols). The red soils have low water holding capacity, near neutral pH with low nitrogen and low phosphorus. On these soils, crops must be planted during the rainy season. The black soils have low infiltration rates but good water holding capacity. These must be planted to crops in the post rainy season. They have good cation exchange capacity but low organic matter and low phosphorus.

All of the trials used *Leucaena leucocephala* as the hedge row nitrogen fixing tree. Alley row widths varied from 2M to 8M. Food crops grown in the alleyways were sunflower, sorghum, pigeon pea, ground nut, millet, castor bean, and/or mung bean.

A farmer survey showed that a lack of fodder during the dry season was the highest concern among the farmers. In these drylands during a drought, farmers are sometimes forced to sell bullock teams at 10% of their value because of lack of fodder. Consequently they value highly any system which will insure a fodder supply during an extended drought. Deep rooted legume trees used in alley cropping can meet this need.

On the other hand, closely spaced hedge rows (2 meters to 4 meters) reduced food crons drastically, depending on rainfall and location. The reduction was 30% to 40% in 1984 and 70% to 80% or more in 1985, a very dry year. Rainfall and wider spacing of the rows helped reduce the competition from the trees. More research is needed with this. In spite of diminished crop yields in the rows, the economic value of legume tree forage was more than enough to make the alley cropping economically feasible.

A word of caution should be added. Under these semi-arid conditions farmers will use legume hedges for fodder production. If erosion is not a nroblem, and/or if they are not planning to use tree prunings for mulch, there is no need for closely spaced alleyways. Farmers might prefer to grow the trees in blocks or in larger strips in the field and not in 2 to 4 meter-wide alleys, which in the research above reduced crop yields.

Without question, much more research needs to be done with alley cropping.