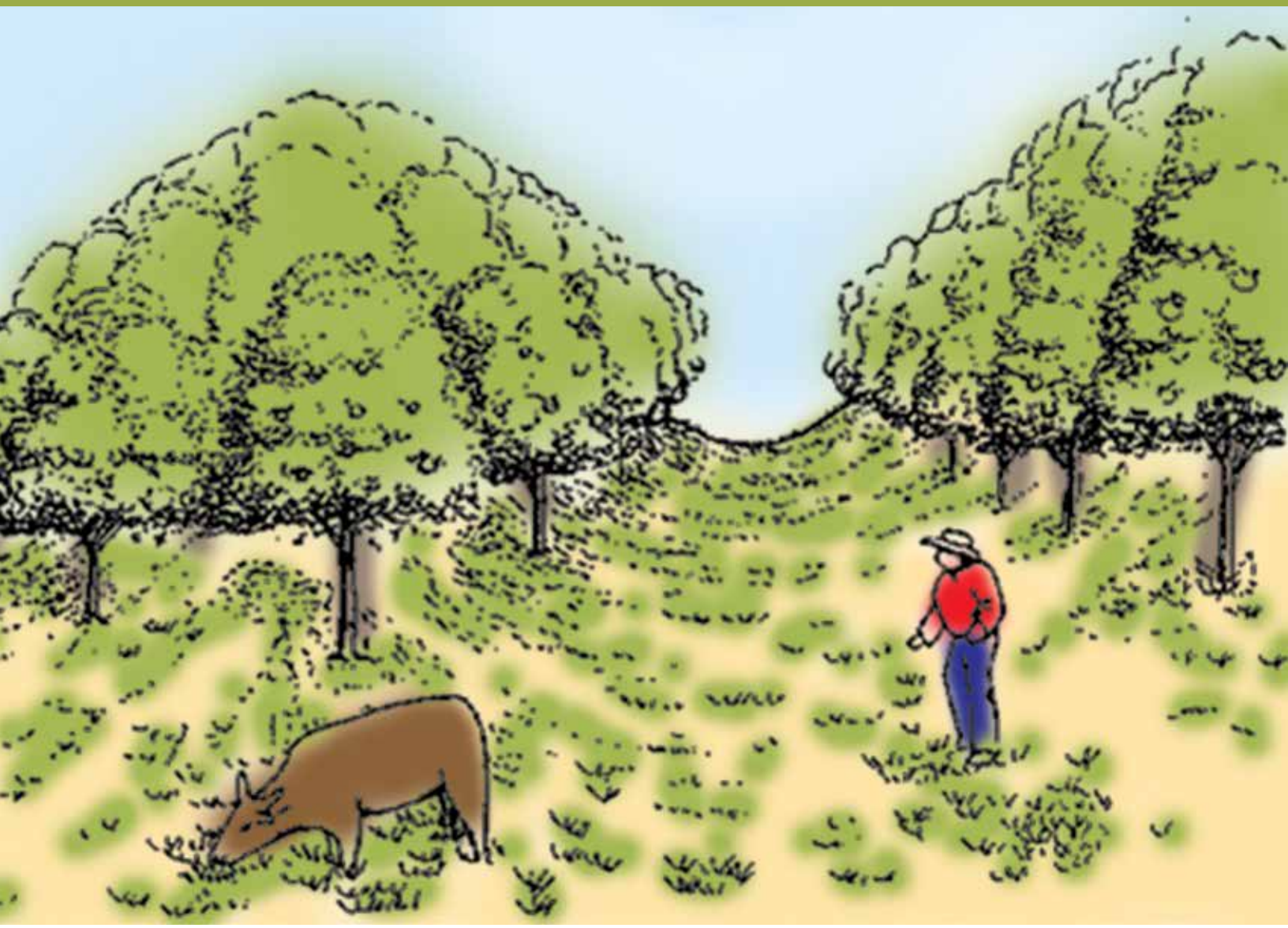
FEED THE FUTURE
The U.S. Government's Global Hunger & Food Security Initiative



SOIL CONSERVATION TECHNIQUES FOR HILLSIDE FARMS

USAID
FROM THE AMERICAN PEOPLE

PEACE CORPS

Knowledge and Learning Unit

The Peace Corps Knowledge and Learning Unit (KLU), a department of the Office of Overseas Programming and Training Support (OPATS), makes the strategies and technologies developed by Peace Corps Volunteers, their co-workers, and their counterparts available to development organizations and workers who might find them useful. KLU works with Peace Corps technical and training specialists to identify and develop information to support Volunteers and overseas staff. KLU also produces and distributes training guides, curricula, lesson plans, project reports, manuals, and other material.

Peace Corps-generated materials are also 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 submitted to KLU become part of the Peace Corps' larger contribution to development.

This publication was produced by the Peace Corps with funding from the U.S. Agency for International Development's (USAID) Bureau of Food Security. It is distributed through KLU. For further information about KLU materials (periodicals, books, videos, etc.,) and information services, or for additional copies of this manual, please contact KLU and refer to the KLU catalog number that appears on the publication:

Peace Corps

Overseas Programming and Training Support

Knowledge and Learning Unit

1275 First Street NE

Washington, DC 20526

Abridged Dewey Decimal Classification (DDC) Number: 631.4

Share your experience!

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

Soil Conservation Techniques for Hillside Farms

R0062

May 2014

Acknowledgements

Soil Conservation Techniques for Hillside Farms replaces an earlier publication of the same name that was originally produced by the Peace Corps in the 1970s and revised in 1986. This revision was done in 2014 under contract with EnCompass, LLC, through Feed the Future funding from USAID. The Peace Corps review team included Agriculture Specialist Gordie Mengel and Expert Consultant Lee Lacy. The original manual was developed from material produced by Volunteers and staff members in Washington, D.C. and at Peace Corps posts throughout the world. Jack Johnson provided initial sketches and suggestions for illustrations in the original version of this manual. Kimball Koch was responsible for the final illustrations, which were updated by EnCompass with this version.

Table of Contents

Table of Contents

Ch 1: Introduction

Agricultural Volunteers in a mountainous country are faced with an almost infinite number of variables that may affect decisions about optimal land use. The rugged topography provides a wide variety of macro and microclimates, bedrock types, soil types, soil depths, and drainage conditions. Equally important may be the variation in economic resources and markets available to farmers.

One of the more critical challenges to confront farmers these days is long term weather changes. These long term weather changes have changed everything. In some areas, the rainy and dry seasons have shifted significantly, with the rains becoming more variable and less predictable. Monsoon winds have grown weaker. Dry seasons have become longer. In addition, the geography of the agro-ecological zones where specific crops can be grown, along with pest and disease ranges, are all shifting.

Global environmental shifts are projected to have significant impacts on conditions affecting agriculture, including temperature, carbon dioxide, glacial runoff, precipitation, and the interaction of these elements. These conditions determine the carrying capacity of the biosphere to produce enough food for the human population and domesticated animals. The overall effect of environmental change on agriculture will depend on the balance of these effects. Assessment of the effects of long term weather shifts on agriculture might help to properly anticipate and adapt farming to maximize agricultural production.

Therefore, as a Volunteer strives to develop solutions to the problems most seriously affecting farmers of an area, each plot must be examined individually in light of the physical, economic, and possibly social or political factors that may affect an individual farmer's land use decisions. And, whenever possible, proven environmentally adaptive agricultural techniques and management practices, including those described on the following pages, should be promoted to sustainably increase farm productivity, enhance long-term soil health and strengthen farmer resilience.

The purpose of this guide is to provide agricultural Volunteers with basic information that will help them design plans for the conservation of soils and the management of water runoff in specific agricultural plots. It was written based on experiences with small hillside farms in Honduras, and takes into account the resources and constraints commonly encountered there. Included in this guide are some demonstrations that may prove helpful in the promotion of this technology. Through the use of this guide, it is hoped that Volunteers will find it easier to solve some of the common problems faced by hillside farmers.

This guide is not intended to replace more detailed technical works such as *Soil Erosion and Conservation* by R. Morgan and P. Charles (London: Wiley. 2009). The main purpose of this guide is to provide a more concise reference work geared more specifically toward small hillside plots. In doing so, much technical information and many techniques appropriate to larger, more mechanized farms are omitted. Information presented in other sources should be

consulted, when possible, for the solution of specific technical problems. There are also many important topics not covered in this guide, such as improved seed varieties, pest control, marketing, etc., which nevertheless should be considered by Volunteers in developing a complete plan for improving farming practices of an area.

Traditional Hillside Farming Techniques and Resulting Problems

Traditional hillside land-use patterns are based roughly on the following series of events:

1. Forested lot is clear-cut and residues are burned.

Figure 1-1

2. Crops are planted with rows going up and down the hillside.

Figure 1-2

3. Crop yields decline each year as soil erodes.

Figure 1-3

4. The land is planted in perennial pasture grasses or abandoned after having been cultivated for a relatively short time (often only 1-20 years, depending on site-specific factors).

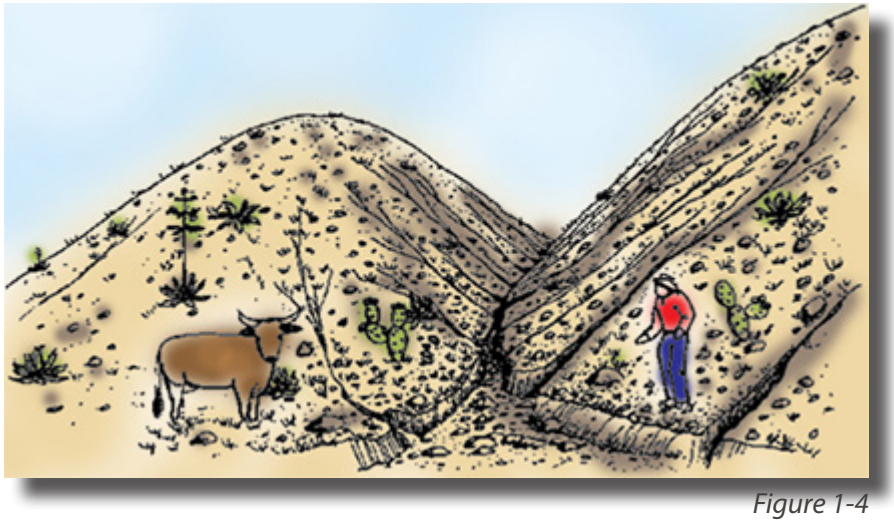


Figure 1-4

This pattern of land use may avoid some problems with crop pests and the need for supplemental fertilizer. However, in a densely settled area, land soon becomes scarce, and mature-forested, fertile plots are not always available to be cleared and cultivated. In such areas, a land use pattern that results in a permanent cultivation of the same plots is desired.

There are three related problems associated with this traditional land use pattern, which must be corrected if permanent cultivation practices are to be successful: soil erosion, rapid water runoff, and decreased soil fertility. As the native vegetation is cut and burned, the soil surface is exposed to the impact of raindrops, which dislodge soil particles. These soil particles and

the valuable nutrients they contain can then be carried out of the area by the water flowing over the soil surface. This rapid rainfall runoff means that less water infiltrates into the soil to be available later, exaggerating any natural flood/drought cycles.

When the native vegetation is intact, the force of falling raindrops is mostly absorbed by the vegetation, as there is much less bare ground surface exposed. The decaying leaf litter on the ground and in the upper soil layers also protects the soil, acting as a sponge, absorbing much of the rainfall and decreasing the amount that can freely run over the land surface. Since more of the rainfall remains in the soil rather than running off, the soil retains its moisture longer in the absence of rainfall. Since fewer soil nutrients are lost in runoff water, soil fertility is maintained.

A comparison of these two scenarios illustrates how in the traditionally farmed field, characterized by the absence of protective vegetation, the rainfall impact and the loss of soil particles, dissolved nutrients, and water are all increased. The rest of this guide focuses on techniques for reducing the soil erosion and water runoff associated with agricultural activities, techniques of maintaining or increasing the soil fertility necessary for permanent cultivation of the same plots, and extension methods useful in promoting the adoption of these different farming techniques.

Soil Conservation Strategies

There are two types of strategies that may be followed in attempts to reduce the detrimental environmental effects of agricultural activity. The most effective is to avoid the damage due to rainfall impact by minimizing soil disturbance and promoting practices that maintain a ground cover. The second is less effective, but easier to integrate into traditional land use practices. This strategy calls for continuing many of the typical agricultural techniques that result in rainfall impact, but minimizing soil loss and water runoff by crop rotations or by the placement of structures (barriers, ditches, terraces) to reduce the movement of soil and water along the soil surface. These two strategies make up the basis of all the conservation schemes discussed here. They are discussed as separate techniques, but the best control of soil erosion, water runoff, and maintenance of soil fertility results from combining all of the complementary techniques appropriate for a particular cultivation system.

Box 1-1. Recognizing the Importance of Female Farmers

Maintenance of soil fertility depends on the adoption of appropriate soil management techniques and practices, particularly by rural women. By custom, women in many societies produce the food crops and are, therefore, key to increasing domestic food production. Yet in their role as food producers, women often face the unique problem of lacking decision-making power within their own households.

Because women farmers are such important players in agriculture, the success of any strategy to replenish soils needs to answer such questions as: Will female farmers be free to adopt specific innovations or will they face limitations or constraints to adoption that are more severe than those facing male farmers? Do women have different motivations and reasons to adopt than men? Finally, do women's roles in female-headed households differ from those of women in male-headed households, and are the former more constrained than the latter?

Strategies to Minimize Soil Disturbance

Protect Native Vegetation

Ideally, the environmental damages associated with agricultural activities could be avoided by protecting native vegetation, which keeps the problem from arising. This method, however, ignores a farmer's dependence on traditional agricultural techniques and is difficult to promote, especially as human populations increase. This strategy does, however, provide other valuable benefits, such as maintaining a clean, reliable supply of drinking water and reserves for native fauna and flora, which also become increasingly important as the human population increases.

Agroforestry and Perennial Crop Cultivation

In view of the benefits of native vegetation, replanting on previously cleared land can be an effective method for protecting land, water supplies, and native wildlife.

Reforestation (or replanting of grasses or shrubs, depending on natural vegetation type) can be carried out using native species or introduced species adapted to local conditions, having some desirable characteristic (fast growth rate, the ability to fix nitrogen, forage or wood value, etc.), which will facilitate the return of a protective vegetative canopy (Figure 1-5).

Figure 1-5

Box 1-2. Agroforestry and Agriculture Biodiversity[1]

Intercropping woody species with annual crops, known as agroforestry, is an old practice. Trees and shrubs are important in the traditional farming systems of the tropics, where woody species form a major component of the bush fallow system and are widely grown in cropped land. Trees and shrubs benefit the farmer in three main areas:

- Direct agricultural benefits (e.g., plant stakes, mulching materials, green manure, animal fodder);
- Environmental benefits (e.g., shade, soil erosion control, nutrient recycling); and
- Socioeconomic benefits (e.g., marketable commodities like fruits, vegetables, nuts, wine, building materials, craft materials).

In agroforestry land use systems, trees and woody shrubs grow together with agricultural crops and/or pasture and livestock. An economic and ecological interaction exists between the tree and non-tree components of the system. The distribution of land between trees/shrubs and agricultural crops/livestock/pasture may be:

- Spatial: land zoned for tree and non-tree components; and
- Temporal: land used at different times for tree and non-tree components in sequence.

Agricultural biodiversity is the diversity of crops and their wild relatives, trees, animals, microbes, and other species that contribute to agricultural production. This diversity exists at ecosystem, species, and genetic levels and is the result of interactions among people and the environment over thousands of years.

The use of agricultural biodiversity can help make agricultural ecosystems more resilient and productive; and can contribute to better nutrition, productivity, and livelihoods.

1 See http://www.agroforestry.net/ for agroforestry resources.

Another technique that results in a minimized soil disturbance is the planting of perennial crops, such as fruit trees or pasture grasses, rather than annual crops, such as corn or beans (Figure 1-6). In this manner, after the initial disruptive clearing and planting of the land, a permanent ground cover is attained and environmental damages associated with raindrop impact are lessened.

Figure 1-6

Use of Ground Cover While Cultivating Annual Crops

There are techniques for maintaining a protective ground cover even while cultivating annual crops. These include minimum tillage (Figure 1-7) and mulching systems. Mulching is the use of dead material or the planting of a ground cover, which results in a covering of the bare soil areas in a field. As in the other techniques, the covered soil is less susceptible to erosion than bare soil. In the section on green manure crops (See Page 45), some suggestions for using legume cover crops are presented.

Figure 1-7

Strategies in Cultivation Systems Characterized by Extensive Soil Disturbance

Even though the techniques described in the previous section are more effective in reducing environmental damages associated with a farmer's agricultural activity, the techniques described in this section are much easier to promote because they are easier to integrate into the traditional cultivation systems.

Crop Rotation

The use of a crop rotation sequence, rather than continual successive plantings of the same crop, can play a role in reducing soil erosion in addition to providing other benefits (increases moisture and nutrient uptake, restores soil structure, breaks pest and disease cycles, and helps maintain soil fertility)[2]. When land is used repeatedly for cultivating relatively open row crops (i.e., corn, beans, tobacco, etc.), a rotation with a denser green manure or forage crop can reduce erosion because of the ground cover provided. In addition, the maintenance of soil fertility and structure will allow the next planting of the more open crop to grow more vigorously and develop better root systems, thereby helping to reduce some soil loss. Generally, however, on sloping lands (5–10 percent or higher), crop rotations alone will have little effect on erosion and should be used in combination with other techniques.

Contour Barriers (Live, Dead, and Mixed Barriers)

Contour barriers are contour strips that intercept downslope flowing water and soil particles. These barriers slow down the water movement and reduce its erosive force. They also filter out and trap many of the suspended soil particles, keeping them from being washed out of the field. A long-term advantage of barriers is that soil tends to build up behind them, creating a terrace effect. Barriers can be classified as live (strips of living plants), dead (rocks, crop residues), or mixed (a combination of the previous two).

Live barriers (Figure 1-8) are strips of vegetation planted along the contour that serve to anchor the soil in place with their roots and, with their stems and leaves, to slow down the movement of water downslope. They are planted above hillside ditches to prevent them from filling with soil and by themselves to prevent hillside erosion. The most common types of live barriers are plants of the grass family because of the dense foliage and root nets produced. As soil builds up behind them, a bench terrace with a grass-protected riser (sloping bank) is formed (see bench terraces on Page 24). In addition, the grasses are valuable as forage for animals, or for human consumption in the case of sugar cane or lemon grass. Many species of plants have great potential as useful live barriers (some possibilities are listed in Table 1-1). The table is by no means all-inclusive; the possibilities are almost limitless, especially when

2 Hudson, N. Soil Conservation, 3rd ed. London: BT Batsford, 1995.

considering agroforestry systems where contour strips of nitrogen-fixing or fruit-producing trees may be used as barriers. An effort should be made to discuss with farmers the available barrier plants in the area so they can select the ones most suited to their needs.

As a management practice, it is advisable to cut forage barrier plants and carry them to livestock rather than letting livestock graze them. If the barriers are not well established, the animals may uproot or overgraze them, thus wiping out the barrier. If farmers use the practice of opening their fields to grazing after the harvest, then an unpalatable barrier or early planting is necessary to ensure a well-established barrier. Maintenance of the live barriers is extremely important. Open spaces should be replanted so the barrier forms an effective soil filter. Barriers should be cut or pruned to avoid excessive shading or root competition with the crops.

Table 1-1. Some Suggested Live Barrier Plants[3]

Common Name	Scientific Name	Characteristics
Sugar Cane	*Saccharum officinarum*	Establishes vegetatively from rhizome or stems, forms thick barrier, may also serve as windbreak, useful for forage or human consumption, may cause excessive shading
Guatemala Grass	*Tripsacum laxum*	Establishes vegetatively from rhizome or stems, excellent forage, susceptible to overgrazing, smaller plant than sugar cane
King Grass	*Pennisetum purpureum*	Establishes vegetatively from rhizome or stems, excellent forage grass, tall plants, may cause excessive shading or competition if not cut
Merker Grass	*Pennisetum purpureum*	Establishes vegetatively from rhizome or stems, smaller and less succulent than King Grass, may be problem weed that spreads vegetatively and by seed if not cut
Guinea Grass	*Panicum maximum*	Establishes easily from rootstock or seed, excellent forage grass, relatively short, forms thick bunches
Bermuda Grass, Star Grass	*Cynodon spp.*	Establishes by stolons, may be a problem weed because of its vigorous spreading, suitable for stabilizing drainages, not for contour barriers, good forage
Lemon Grass	*Andropogon citratus*	Establishes well from rootstock, unpalatable to cattle, used in making tea, forms short, thick bunches

3 Note: More plants can be found at http://www.tropicalforages.info/, http://www.fao.org/WAICENT/FAOINFO/AGRICULT/AGP/AGPC/doc/GBASE/Default.htm, http://plants.usda.gov/java/

Common Name	Scientific Name	Characteristics
Maicillo	*Sorghum spp.*	Establishes by seed, if planted closely it forms excellent barrier, good forage, produces grain, grows well in arid zones, tall plant and may cause excessive shading, short-lived (2-3 years), may be alternate host for certain corn diseases
Jaragúa	*Hyparrhenia rufa*	Establishes by seed, forms thick closely spaced bunches, grows well in arid zones, good forage, problem weed if not cut before flowering
Vetiver	*Vetiveria sp.*	Establishes from rootstock, forms low thick bunches unpalatable to cattle, medicinal value
Cardamine	*Elettaria cardamomum*	Establishes as vegetative bulbs or transplanted from seedbed, forms thick bunches up to 3 meters tall, valuable seed crop, shade tolerant, only in cool moist climates, may cause excessive shading or competition
Gladioa[1]	*Gladiolus sp.*	Establishes easily from bulbs, has value as an ornamental
Pineapple[1]	*Ananas comosus*	Establishes easily from vegetative buds, grows well in poor sandy soils, edible fruit
Motate[1]	*Bromelia sp.*	Establishes easily from vegetative buds, grows well in wide variety of climates and soils, edible fruit
Leucaena[2]	*Leucaena spp.*	Establishes from seeds, leaves useful as nitrogen-containing forage or mulch, grows rapidly, produces firewood, best at low elevations
Madriago[2]	*Gliricidia septum*	Establishes from branches planted in post farm, also from seeds, leaves useful as nitrogen- captaining forage or mulch, produces firewood
Yucca[2]	*Yucca elephantipes*	Establishes from stakes, edible flowers, used in live fences or as an ornamental

1) These plants must be planted closely spaced in two or three rows to form effective barriers.

2) These plants are most effective as barriers when the rows are reinforced with crop residues or rocks to form a mixed barrier.

Figure 1-8

In planting contour barriers, the spacing from one barrier to the next depends on the slope of the land, with barriers spaced closer together on steep slopes and farther apart on gentler slopes.

Table 1-2. Spacing of Contour Barriers

Slope (percent)	Annual Crops Distance		Perennial Crops Distance	
	Meters	Feet	Meters	Feet
5	20.0	65.6	25.0	82
10	15.1	50	20.1	65.9
15	10.1	33.1	18.2	59.7
20	9.2	30.1	15.3	50.1
25	8.2	26.9	15.5	50.9
30	6.8	22.3	12.5	41
35	6.4	21	12.7	41.7
40	6.5	21.3	9.7	31.8
60			7.0	23

Note: From Suarez de Castro, F. Conservación de Suelos. San Jose, Costa Rica: Instituto Interamericano de Ciencias Agrícolas, 1980 (out of print), modified to show distance along ground surface rather than horizontal distance.

Contour planting of a crop and contour strip cropping are also techniques that may be considered functionally as live barriers since they are contour plantings that serve to control hillside erosion. The planting of windbreaks is also a use of live barriers (trees or tall grasses), in this case to avoid erosion or crop damage due to wind rather than water.

Dead barriers function similar to live barriers, the difference being they are composed of rocks, plant residues, or other non-living materials. If rocks are present in a field, it is useful to construct these and, in the process, make the soil easier to work. Another advantage is that they can be completed during the dry season, meaning they are in place and functioning at the start of the rainy season. If enough rocks are present, the barriers can be constructed as rock walls of sufficient height so that bench terraces are formed as the soil fills in behind each wall. If sufficient rocks are not present, the barriers lose their effectiveness as the soil fills in behind them, and they should be supplemented with the planting of live barriers.

The construction of dead barriers (Figure 1-9) is simple, but requires a lot of manual labor. Once contour lines are marked out according to the spacings given in Table 1-2, a hoe is used to form a furrow that serves to anchor the barrier (approximately 7.9 inches or 20 centimeters deep). Then the materials are laid out to form walls along the contour lines. Mixed barriers, a combination of live and non-living materials, are used in some cases. These can consist of strips of trees with the intervening spaces filled with rocks or crop residues, or combinations of grass and rock barriers. If using plant residues, be aware that as they decompose they lose their effectiveness as barriers and will erode, needing to be supplemented.

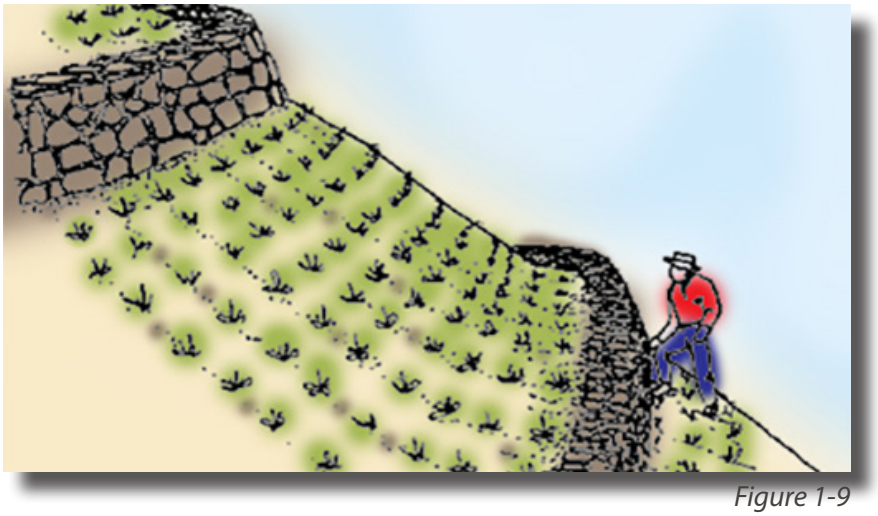


Figure 1-9

Contour furrows or raised planting beds may also be considered functionally as contour barriers (Figure 1-10). These techniques are useful in the cultivation of vegetables, basic grains, or any raw crops in which the soil is to be intensively cultivated. The contour furrows or beds serve various purposes: reducing water movement and, therefore, soil erosion down the slope; permitting drainage of excess soil moisture from the planting bed; providing for a more even distribution of irrigation or rainwater; and avoiding compaction of the planting bed surface by providing walkways. The construction is simple. If possible, the furrows are plowed along measured contour lines and then cleaned out with a hoe or shovel, spreading the soil in the space between the furrows. The width between furrows is variable and depends on the crop and any irrigation requirements.

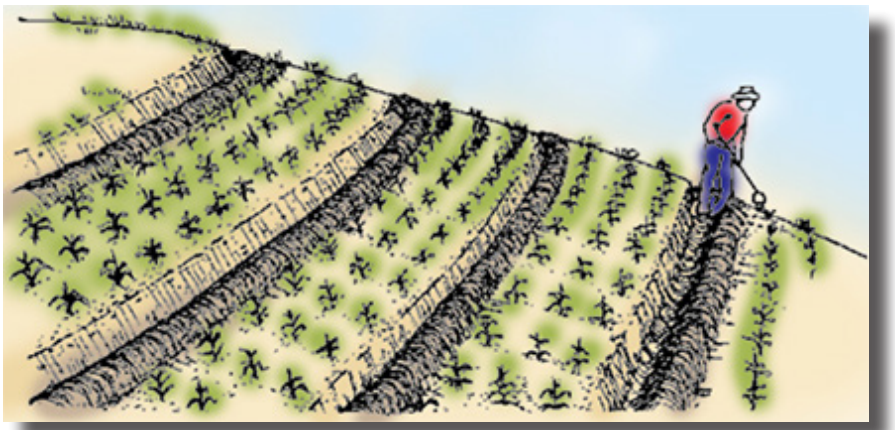


Figure 1-10

Contour Ditches (Drainage and Infiltration Ditches)

Contour ditches (Figure 1-11) serve many of the same purposes as contour barriers; in addition, they completely stop downslope water movement as the water falls into the ditch. These structures are some of the most useful for small-scale hillside farming since they require less work than terraces, are simple to build, and can be used to either divert or to retain water. If constructed at a 1-percent slope[4], they divert excess water to protected drainage ways, reducing soil erosion and leaching of nutrients. The uppermost ditch is very important if a great deal of water enters from above the field.

Figure 1-11

4 Hudson (1995) recommends a 0.25-percent slope for contour ditches (channel terrapin). Due to the relative inaccuracy of the rustic levels often used (See Appendix 4), a 1-percent slope is recommended here to ensure water flow in the proper direction.

If it is desirable to retain as much water as possible, earthen dikes can be left in the ditches or the ditches can be constructed at a 0-percent slope so that water infiltrates into the soil and is not diverted outside the field (Figure 1-12).

Figure 1-12

The ditches are constructed using pickaxes and shovels. If possible, plowing the contour line makes the construction much easier. The first stage in the construction is to excavate a 12-inch wide (30.5 centimeters) by 12-inch (30.5 centimeters) deep ditch (ditches can be constructed of any size, if desired). Then the banks are formed by cutting a slanted wall at each side. The removed earth is placed in a mound 6–9 inches (15.2–22.7 centimeters) below the lower lip of the ditch. A live barrier is necessary above the upper edge to prevent filling with soil. Especially on steeper slopes, it is often advantageous to plant the live barrier first, several months or one season in advance, so that the ditch will be adequately protected once built.

Table 1-3 should be consulted for the appropriate distance between ditches on hillsides of a given slope. If the ditches are to be dug with a 1-percent slope to drain excess water, there should be a 3.3- to 6.6-foot (1–2 meters) surface with a slightly steeper slope (1-2 percent) before emptying into a protected drainage way. Care should also be taken not to drain excess water into neighboring fields, houses, or other areas that may result in problems.

Table 1-3. Spacing of Contour Hillside Ditches

Slope (percent)		Annual Crop	Perennial Crop or Pasture	
Distance (Meters*)		Maximum Length (Meters)	Distance (Meters)	Maximum Length (Meters)
2	42.0	90		
4	25.0	120		
6	19.3	160		
8	16.6	200		
10	14.9	260	40.2	140
12	13.8	280	33.5	140
14	13.0	300	28.9	140
16	11.4	340	25.3	160
18	10.2	380	25.0	180
20	9.2	420	24.0	200
22	8.4	470	23.2	200
24	7.7	500	21.4	210
26	7.2	500	19.8	220

** 1 meter equals 3.28 feet*

From: Suarez de Castro (1980), modified to show distance along ground surface rather than horizontal distance.

Terraces

Terraces serve the function of stopping downslope soil and water movement and give the advantage of providing a flat surface for the planting of crops, thereby further reducing the possibility of erosion.

Since the formation of terraces requires a maximum of soil disturbance and rearrangement, they are extremely susceptible to erosion if not properly measured, compacted, and maintained with risers (sloping banks) protected by vegetation. When considering terracing a steep slope (25–30 percent or higher), it should be noted that a much deeper cut and fill will be needed. Also, much more land space will be lost in the sloping terrace walls and the useful planting space is likely to be extremely narrow unless a very deep soil is present.

Individual terraces are constructed to provide a level platform for the growth of an individual tree. They are always used in combination with another type of conservation structure (e.g., contour ditches) since the small platforms by themselves do not appreciably control surface water movement. When planting a hillside with individual terraces, the layout should be in

an equilateral triangular or hexagonal pattern, with the distances varying according to the variety of tree being planted. The terraces generally have a diameter of 3.28–4.92 feet (1–1.5 meters) and should be thoroughly compacted to prevent collapsing (Figure 1-13).

Figure 1-13

Discontinuous narrow terraces (orchard terraces) provide both a flat platform for planting crops and an inverse slope that allow them to serve as drainage or infiltration ditches (Figures 1-14 and 1-15).

Figure 1-14

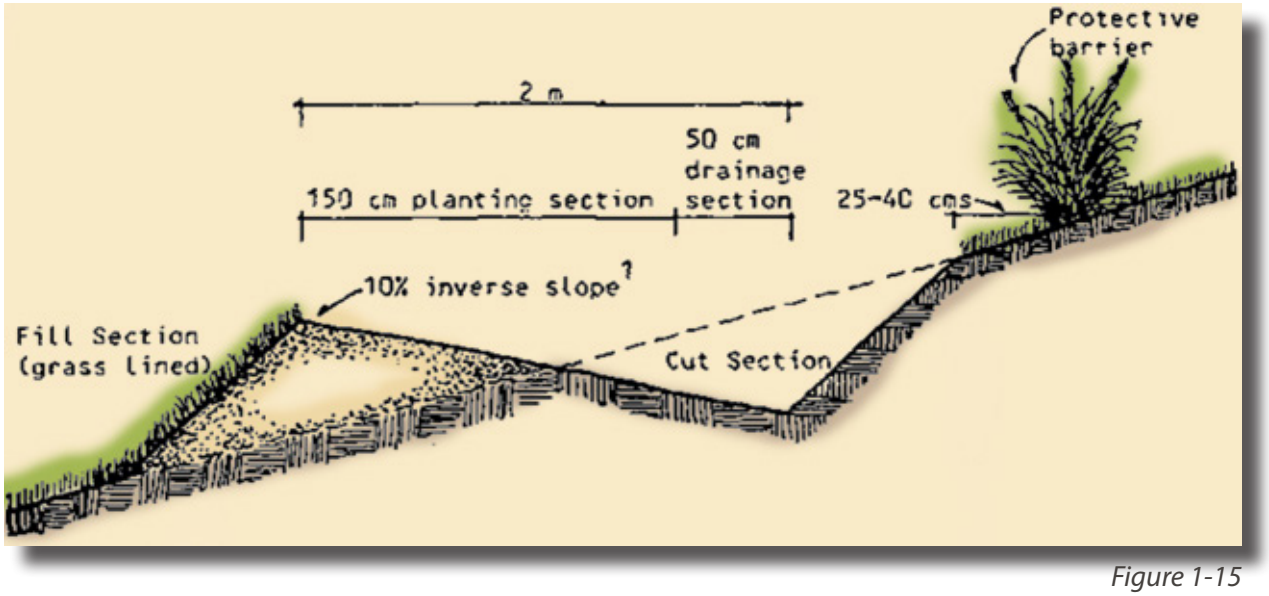


Figure 1-15

1. If initially constructed with an inverse slope of 15–20 percent, some self-compaction occurs, resulting in a slope of approximately 10 percent.

Construction is done, after plowing if possible, with pickaxes and rakes or hoes. Some design information is given in Table 1-4. Construction is most rapid in soft, deep soils.

In these cases the earth from the cut section is merely moved to the fill section, compacted, and raked smooth. If it is judged necessary to remove the topsoil and redistribute it later, then a construction sequence such as sequence "B," given for the bench terraces, is recommended. In order to keep the risers from eroding, grass should be planted on them. The drainage way for this type of structure should be constructed similar to that of the hillside ditch, slightly steeper right before emptying into the protected drainage area.

Table 1-4. Discontinuos Narrow Terrace Construction Guide

Slope (percent)	Distance between canals(meters*)	Total canal width of platform plus walls (meters)
5	18	2.22
10	14	2.32
15	13	2.40
20	12	2.52
30	12	2.71
40	12	3.00

**Based on 2-meter platform width, 1.5-meter wide platforms are also used, especially on steeper slopes with thin soils. 1 meter equals 3.28 feet.*

Continuous bench terraces are staircase-like structures that diminish erosion due to the reshaping of the land. The most feasible application is in intensively worked vegetable plots where each planting bed may be a separate terrace (Figure 1-16).

Bench terraces can be designed level (0-percent slope) for water retention or with a slight slope (0–1 percent) to facilitate water drainage or distribution of irrigation water.

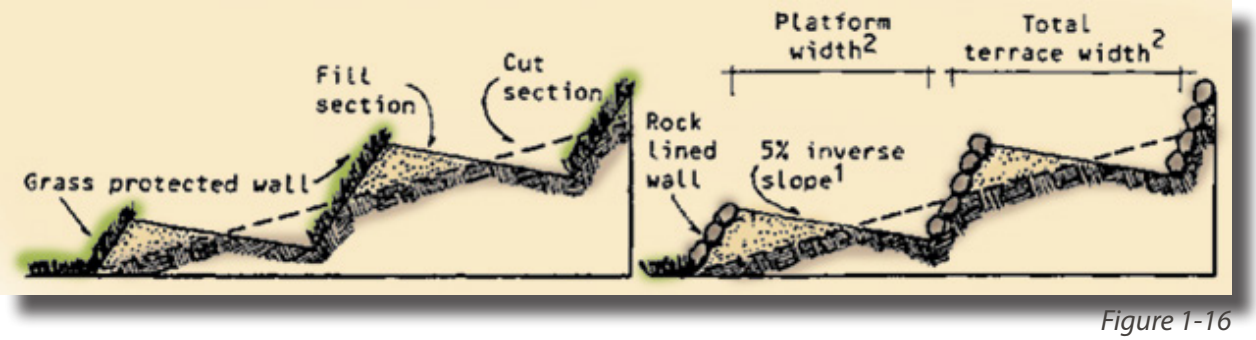


Figure 1-16

1. If initially constructed with an inverse slope of 10 percent, some self-compaction occurs, resulting in a slope of approximately 5 percent.
2. Platform width and terrace width vary according to slope and depth of soil.

There are many different terrace design specifications published in soil conservation books, but only the basic features are described here. Table 1-5 may be used as a general guide for designing terraces, with the total terrace width being dependent upon the slope of the hillside and the depth of fertile or tillable soil.

Table 1-5. Bench Construction Guide

Slope (Percent)	Soil depth* (Meters**)	Total Terrace Width (Meters)	Platform Width (Meters)
	.2	1.68	1.30
	.3	2.5	1.94
20	.4	3.34	2.60
	.5	4.26	3.30
	.6	5.02	3.90
	.2	1.16	.80
	.3	1.72	1.20
30	.4	2.3	1.60
	.5	2.98	2.10
	.6	3.46	2.40
	.2	.90	.56

Slope (Percent)	Soil depth* (Meters**)	Total Terrace Width (Meters)	Platform Width (Meters)
	.3	1.32	.82
40	.4	1.78	1.10
	.5	2.25	1.40
	.6	2.68	1.66
	.2	.74	.40
	.3	1.10	.60
50	.4	1.46	.80
	.5	1.84	1.00
	.6	2.20	1.20

**"Depth of A Horizon" in original changed to permit use in eroded areas where horizons are often indistinct.*
***1 meter equals 3.28 feet*
Source: Suarez de Castro (1980)

Bench terraces are constructed using pickaxes, hoes, and rakes. In some areas, large, specially designed hoes are available. Construction is much easier if the section of earth to be removed (cut section) is plowed beforehand to loosen the soil. If construction is being undertaken during the rainy season, it is advisable to begin construction near the drainage area and with the uppermost terrace. In this way, any rainwater will drain off without damaging the terraces.

There are several ideas as to the best method of constructing a series of terraces. One, which may require several years for completion, is the planting of a live barrier grass or the construction of rock walls along the contour. Over time, terraces are formed as soil fills in behind them. Two other construction sequences are presented below.

Bench Terrace Construction Sequence "A"

1. The lower most terrace is formed first and compacted thoroughly.

Figure 1-17-1

2. The topsoil from the area of the next higher terrace is removed and distributed evenly over the lower terrace.

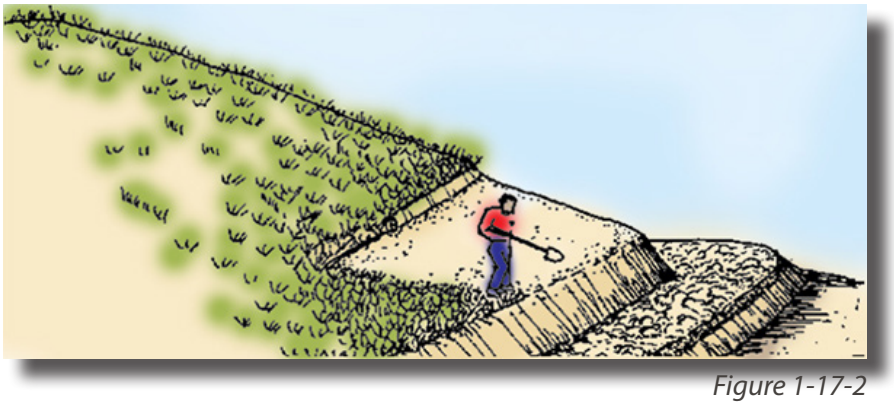


Figure 1-17-2

3. The second terrace is formed and compacted, then covered with topsoil from the area of the third terrace.

Figure 1-17-3

4. Work progresses up slope, each newly formed and compacted terrace is covered with topsoil taken from the slope immediately above, and grass is planted along the risers of all terraces.

Figure 1-17-4

Bench Terrace Construction Sequence "B"

1. Terrace construction begins with the uppermost terrace and width, the 6.6-foot (2-meter) segment, nearest the drainage side. The topsoil is pulled over to one side of the section.

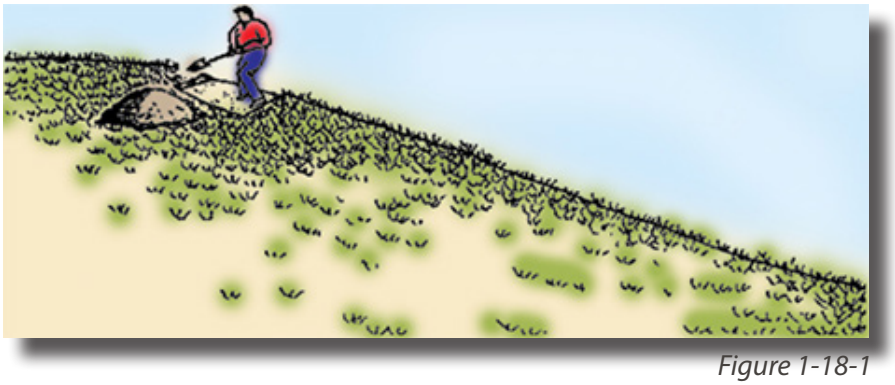


Figure 1-18-1

2. A well-compacted section of the terrace is formed.

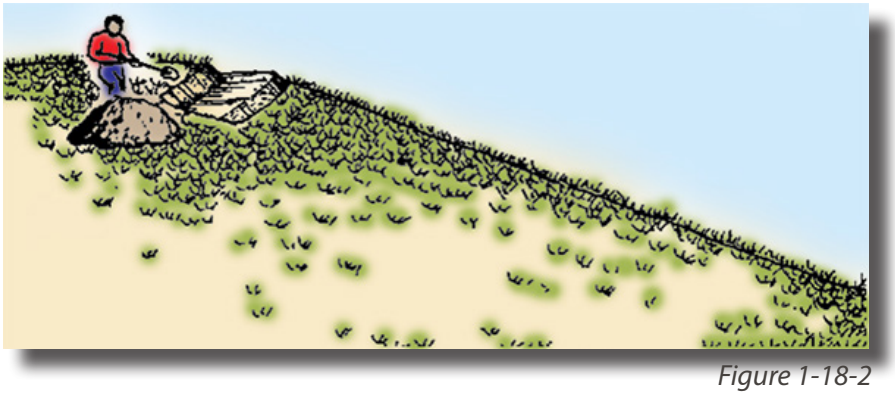


Figure 1-18-2

3. The topsoil is then redistributed over the same 6.6-foot (2-meter) terrace section.

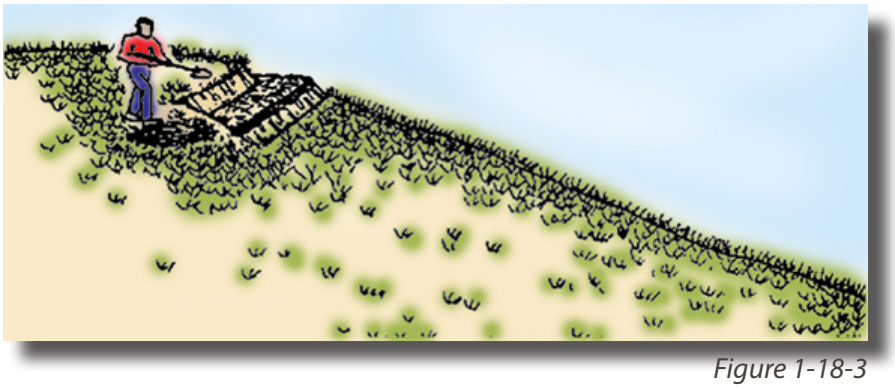


Figure 1-18-3

4. Work progresses sideways along the uppermost terrace.

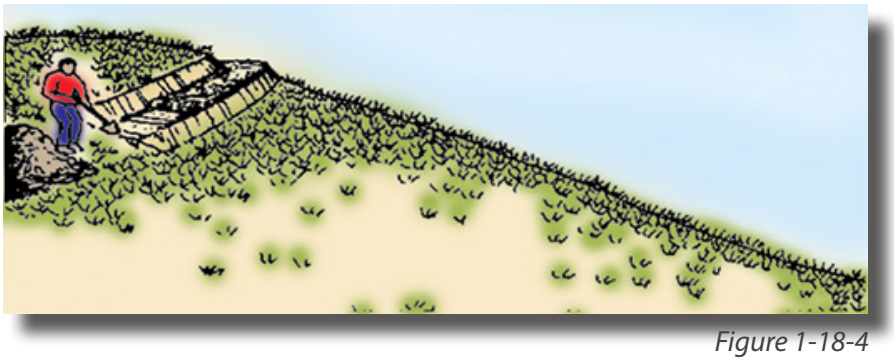


Figure 1-18-4

5. Work progresses downslope. Work begins at the drainage side of each terrace and progresses sideways.

Figure 1-18-5

6. Grass is planted on terrace risers.

Figure 1-18-6

Waterways for Draining Excess Water from Fields

In order to avoid problems of erosion at the site of emptying and to reduce the speed of watershed runoff following rains, soil conservation structures should be designed for water retention and infiltration whenever possible. If it is judged necessary to drain water from a field, special care should be taken in selecting areas to deposit all diverted drainage water.

Possible drainage areas include pasture areas with a thick ground cover, orchards, or forested areas where infiltration of the diverted water can probably occur with a minimum of erosion, especially if the water is spread over a large area. Existing waterways may also be used as drainage sites, although one should avoid exaggerating erosion problems by diverting water into areas of active gully formation. In all of these cases, if erosion problems are noted upon diverting runoff water, then a permanent, protected site for receiving runoff should be designed and constructed as soon as possible.

Protected drainage ways can be formed by reshaping natural drainage ways or digging artificial drainage ways of a low, broad shape, protecting them from erosion by lining them with rocks, planting grass, and/or placing drop structures or check dams periodically (Figure 1-19).

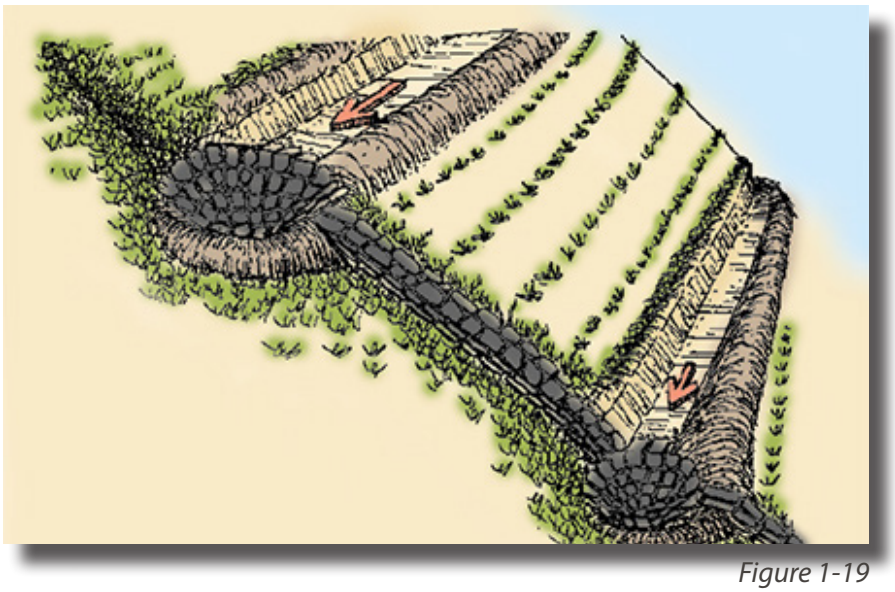


Figure 1-19

Waterway design specifications are given in more complete soil conservation guides (Hudson 1995; Suarez de Castro 1980). Such specifications account for the construction of waterways of an adequate size and the selection of an adequate lining method based on local meteorological conditions, soil properties, the area of land involved land slope, and the type of protective lining to be used. If sufficient data is available for the work area, such information can be useful in designing a drainage way of sufficient capacity, without overdesigning it and involving excess work.

If, however, insufficient local data is available, or one wants to teach farmers the conservation techniques without discouraging them with complicated tables or formulas, then the appropriate size can be estimated. Hudson (1995) mentions an extremely simplified method that ignores local climatic or soil-related factors: construction of a shallow 11.9-inch (30-centimeter) drainage way measuring 3.28 feet (1 meter) wide for every 1 hectare (2.47 acres) of land area in the drainage basin. While this is probably oversimplified, it does allow one to design drainages of probably adequate dimensions without having to deal with complicated methods.

When no appropriate drainage area is available around a field, retention wells can be dug and water diverted into and stored within them, allowing the water to gradually enter the soil or evaporate.

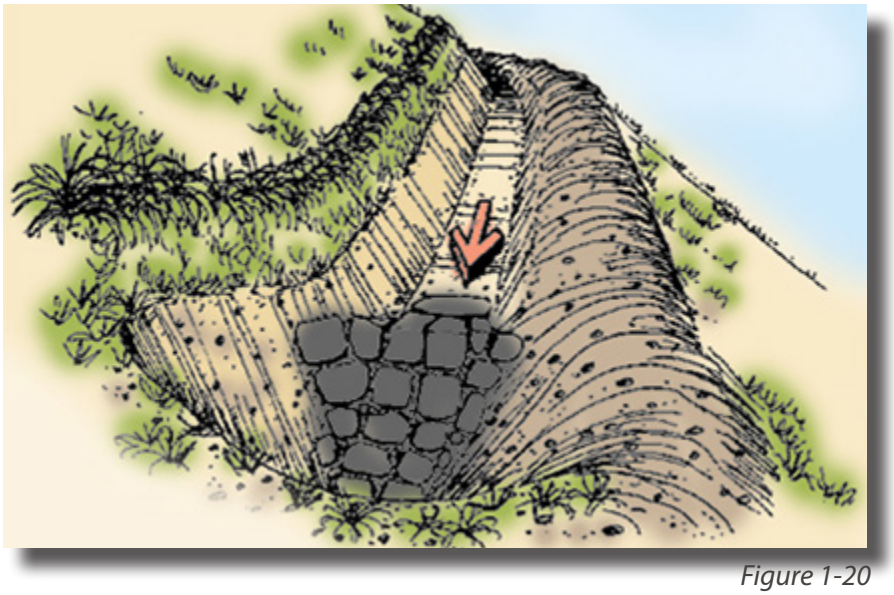


Figure 1-20

Special care should be taken to have the waterways and retention wells completely constructed and well vegetated, if grass lined, before diverting drainage water into them. This can be done by preparing them a season or two in advance or by preparing a temporary drainage site until the permanent one is ready.

Gully Prevention and Control

Gullies form when enough water flows in a concentrated area to remove the protecting vegetation and starts digging in and carrying away topsoil and eventually subsoil. Some gullies form naturally, while others are the result of a farmer's activity, such as redirecting water drainage patterns to protect roads, buildings, or fields. If not controlled, gullies tend to enlarge in both length and width. Both the soil destabilization and the large amounts of water running through them can eventually ruin fields, roads, or buildings located nearby.

When using contour ditching or terracing techniques or carrying out other construction activities requiring the alteration of drainage patterns, gully formation can result if the drainage way is not properly protected with rock or grass lining, with retention wells, or with a well-vegetated area capable of absorbing the water safely.

Whatever the cause of gully formation, control measures should be undertaken as soon as possible to prevent further expansion, more damage, and an even more costly control due to larger size in the future. The most effective control technique is to capture and redirect the source of water responsible. This can be done by means of a gently sloped (1 percent) contour ditch (Figure 1-21). This is appropriate only when a suitable adjacent area is available for drainage or if retention wells can be dug to receive the water. Sometimes large livestock watering tanks are filled with water diverted from gullies.

Figure 1-21

Once water no longer enters the gully from above, the soil is often stabilized enough so revegetation and filling in occur naturally without any further care. The gully should, however, be protected from further damage due to cattle trampling and overgrazing, or cultivation.

Sometimes it is not appropriate to divert incoming water by use of a contour ditch, such as when the gully soils, steep surfaces or climate do not permit natural recovery, or a mere rapid revegetation and refilling is desired. If this is the case, check dams can be placed across the gully at frequent intervals. These can be made of rocks, wood, wire mesh, etc. and serve to reduce the velocity of any water still flowing and to trap soil particles, helping to stabilize the gully so that revegetation can occur. The gully can also be more rapidly re-vegetated by planting trees, shrubs, or grasses, rather than waiting for natural colonization to take place.

Box 1-3. Importance for Volunteers to Consider a Farmer's Context[5]

Volunteers should understand that farmers consider numerous factors when making decisions about soil fertility management. Some of these decisions may have nothing to do with best practices but are dictated by the basic need for survival and the realities of their situation. Examples include the following:

- Farmers may not engage in fallowing due to population increases and shortage of land.
- Farmers may not be able to add manure to their soil due to a decrease in the number of livestock.
- Farmers may have to use crop residues for animal feed due to a shortage of grazing land and, therefore, cannot add much to the soil.
- Farmers may not employ nitrogen-fixing crops for fear of theft of such crops.

Farmers also have their own nomenclature for referring to soils, land forms, water dynamics, etc. that may not fit with what is used in standard technical literature.

As a Volunteer, you should be aware of all of these factors before connecting with farmers and suggesting any new ideas.

Steps to Follow in Designing a Conservation Plan

As in the implementation of any technology, the best results are usually obtained when each situation and pertinent details are carefully examined. Using the *Participatory Analysis for Community Action (PACA) Training Manual* [M0053] and the following steps will be useful in both designing conservation plans and in teaching students about soil conservation.

1. Select a lot and subdivide if necessary.

2. Study the lot and identify problems with respect to erosion, drainage, and drought.

3. Select a suitable drainage site, if necessary.

4. Decide on position of "linea madre".

5. Calculate slope.

6. Select a conservation strategy.

5 For a more detailed discussion, refer to Ellis-Jones, J. and B. Sims. 1995. "An appraisal of soil conservation technologies on hillside farms in Honduras, Mexico and Nicaragua." Project Appraisal 10.2: 125-134. (free access: http://www.tandfonline.com/doi/abs/10.1080/02688867.1995.9726983#.UrR4ztJDuPR)

7. Decide on appropriate distance between structures.

8. Place marker stakes along the "linea madre" at the appropriate intervals.

9. Survey and mark contour lines.

10. Realign stakes along contour lines, if necessary.

11. Carry out your conservation practice.

12. Plant protective barriers, if necessary.

13. Plant desired crop(s) along the contour.

14. Periodically review structures and carry out any needed maintenance practices.

Each of the steps is further outlined below.

1. Select a lot and subdivide if necessary.

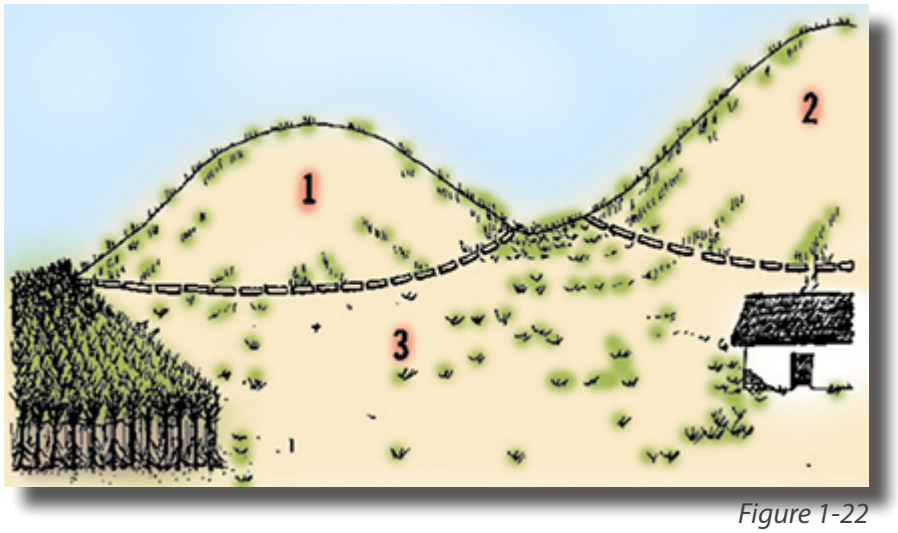


Figure 1-22

This step includes choosing the parcel of land to work on and noting if it should be subdivided into separate management units, each of which should be conserved separately following the rest of the steps. Subdividing the lot into separate units, each of which has a relatively uniform slope, allows for the design of a separate conservation plan for each of the simpler units. This eliminates the difficult task of designing a single plan for a complicated, convoluted area. It should be noted here that most soil conservation techniques are only practical if maintained over a long period. Therefore, the lot selected should be owned by, or permanently available to, the involved farmer.

2. Study the lot and identify problems with respect to erosion, drainage, and drought.

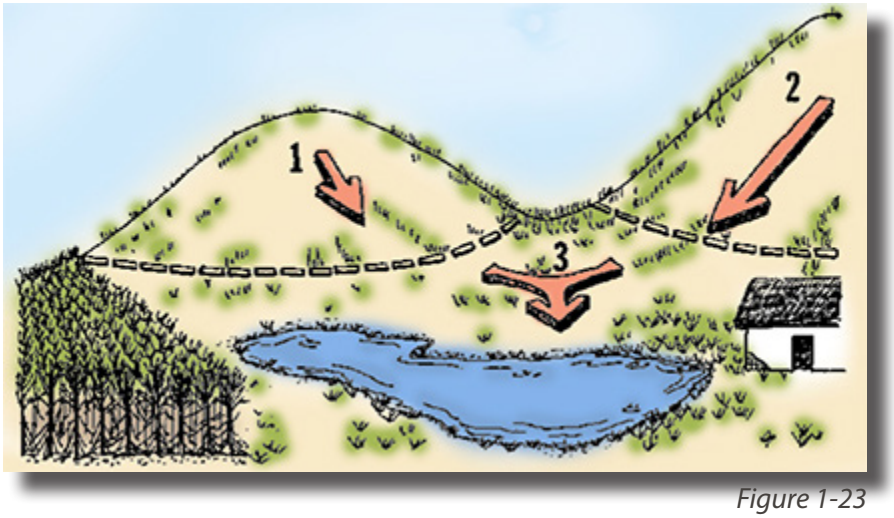


Figure 1-23

This involves asking the farmer about previous years' problems by using a participatory approach. Determine whether flooding or drought are serious problems, the point of entry of runoff water from upper slopes, and sites of serious erosion or drainage problems. This step should also include investigating and recording the types of crops, cultivation method used, fallow periods, pests or diseases, etc.

Example: In the cornfield pictured above, Sections 1 and 2 are characterized by rapid rainfall runoff, causing small gullies to form. This is followed by excessive soil drying between rains. Section 3, on the other hand, is relatively level, but experiences flooding due to poor soil drainage and the runoff received from Sections 1 and 2.

3. Select a suitable drainage site, if necessary.

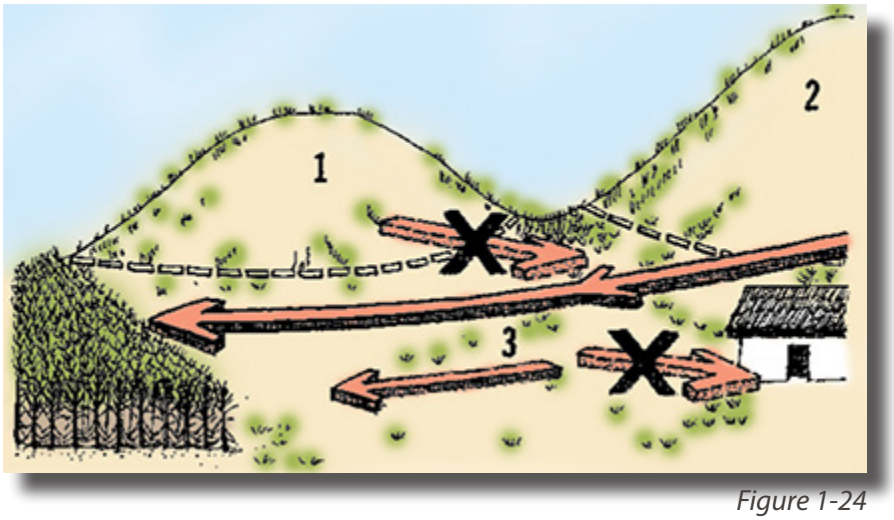


Figure 1-24

This is an often-neglected step, which can result in serious problems if not considered carefully. This may include gully formation, flooded roads, or angry neighbors. If ditches will be constructed to divert excess water from a lot, care must be taken to divert the water to a well-vegetated area, a retention well, or to a grass or rock-lined waterway. In deciding where to divert the water, one should also consider the positions of neighboring fields, roads, or houses in order to avoid flooding these areas. If necessary, the construction of drainage ditches or terraces should be delayed until an adequate site for runoff water can be constructed and thoroughly protected against erosion. Meanwhile, other conservation practices that do not result in concentrations of runoff water, such as the use of contour barriers, maintaining a dense ground cover, etc., can be employed.

4. Decide on position of "linea madre."

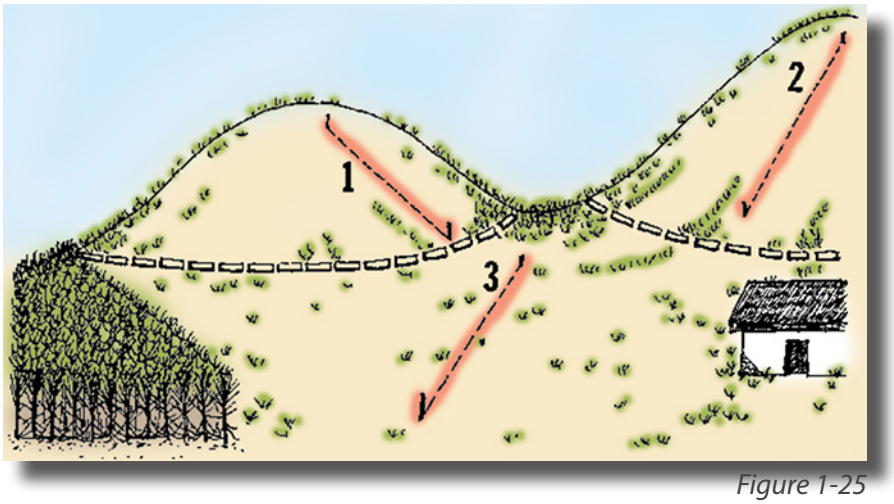


Figure 1-25

This is the imaginary line that best represents the average slope on a unit of land. It will be used as the reference line from which to measure the distance between successive soil conservation structures. It should be positioned to ensure that contour lines are perpendicular to it.

5. Calculate slope.

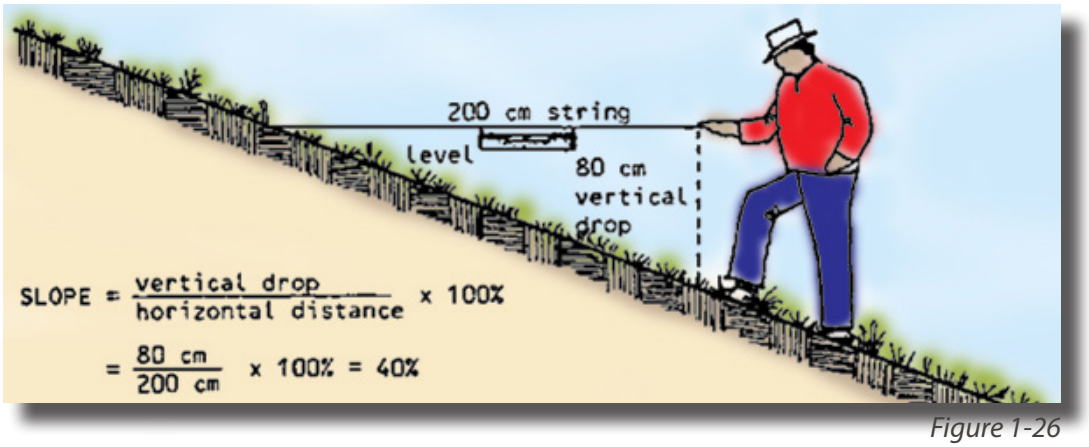


Figure 1-26

The slope of the terrain should be measured at 5–10 randomly selected sites per hectare (2.47 acres) and then averaged. The slope can be measured using a string and a small line level, as illustrated, or by using an A-frame level. The slope of the terrain is important in planning soil conservation strategies. Ideally, flat or gently sloping areas should be used for the production of annual crops, while more steeply sloping areas (35 percent or more) should be used for perennial crops such as fruit trees or forage, and in very steeply sloping areas (50 percent or more) the natural vegetation should be maintained. The slope of the terrain is also used when deciding on the distance between successive contour structures, as described in other sections.

6. Select a conservation strategy.

No strict guidelines are presented here for selecting soil conservation techniques due to the tremendous number of variables influencing the decision. However, the following points should be considered as the Volunteer and the farmer(s) work out the most appropriate design for an area.

1. Identify resources and constraints that will affect the process. These include the availability of labor, rocks, and live barrier plants; presence of water sources for irrigation; the acceptability of a more long-term investment (perennial crop); the presence of cattle during the fallow period; etc.

2. Select complementary soil conservation techniques that are appropriate to the desired cultivation system. Choose as many as possible.

One example would be to plant fruit trees on individual terraces protected by contour infiltration ditches and live barriers of king grass while also planting a green manure crop between the trees and mulch around the tree bases. Another example would be to intercrop corn and beans to form a dense ground cover, construct contour discontinuous narrow terraces with a live barrier of Guatemala grass, plant a green manure crop such as Velvet bean during the fallow season, and plant fruit trees on the terraces.

3. Design all structures along carefully measured contour lines (Usually 0–1 percent slope).

4. Carefully maintain all contour structures, protective barrier plantings, and drainage ways to ensure proper functioning.

5. Review Table 1-6 and Appendix 2.

Table 1-6. Advantages and disadvantages of different soil conservation techniques

Technique	Advantages	Disadvantages
1. Protecting native vegetation	• Avoids erosion and desertification reserve for native flora and fauna	• Often inapplicable due to previous land disturbance • Unavailable for crop production
2. Re-establishing native vegetation	• Re-establishes vegetative canopy, protecting soil and water resources • Restores wildlife habitant • Provides useful natural products: wood forage, medicines, etc.	• Labor cost to plant and maintain • Unless re-establishes naturally, it's unavailable for traditional crop production
3. Perennial crop cultivation systems (pasture, fruit trees, agroforestry systems)	• Avoids annual soil disturbance once established • Low maintenance requirement to produce crop	• Unavailable for annual crop production
4. Minimum tillage or mulching in annual crop cultivation systems	• Protective ground cover reduces erosion and avoids some pest problems • Mulching decreases weed growth • Maintenance of soil fertility, structure, and organic matter content	• Possible pest refuges • Possible weed competition • Labor intensive • By itself, does not control water runoff on sloped land
5. Crop rotation	• Maintenance of soil fertility, structure, and organic matter content • Breaks pest and disease cycles	• By itself, does not control water runoff on sloped land • Acceptable alternative crops must be available

Technique	Advantages	Disadvantages
6. Contour live barriers	• Useful product (forage, fruit, wood) • Decrease water velocity and trap soil particles • Gradually form terraces behind barriers • Little labor and only slight soil disturbance	• Appropriate plant must be available • Possible shading or root competition • Do not stop flow of water • If incomplete germination, ineffective soil traps • May require fencing to keep out cattle • After planting, ineffective during first rains
7. Contour dead barriers (rock walls)	• Removing rocks makes tillage easier • Decrease water velocity and trap soil particles • If sufficient height, form bench terraces as soil fills in • Very little soil disturbance • If planned and constructed during fallow period, function for first rains of growing season	• Labor cost • Only where sufficient rocks • Ineffective if soil fills in level with top • Do not stop flow of water • May require fencing out of cattle
8. Contour planting beds and furrows	• Series of barriers stop water flow • Can be designed to drain or retain water or for furrow irrigation • Avoid compaction of planting surface	• Labor cost • Extensive soil disturbance • Susceptible to erosion on slopes, unless protected by other structures

7. Decide on appropriate distance between structures.

The simplest rule to follow when placing a series of barriers or ditches in a field is to locate one structure with every vertical drop of approximately 4.9 feet (1.5 meters). By standing at the site of one structure and sighting along an extended arm, one can determine the position of the next highest structure.

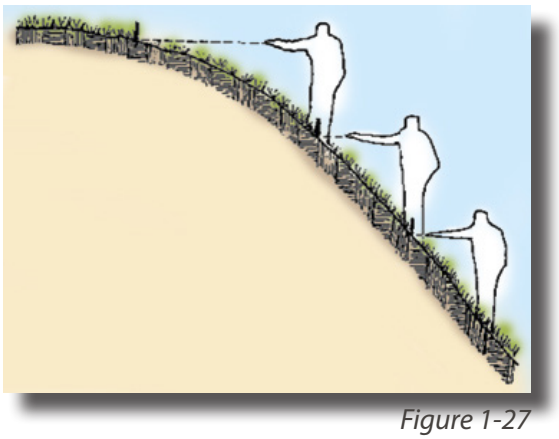


Figure 1-27

Technical tables prescribing distances based on the slope of the terrain should be used whenever possible to ensure an optimum placement of structures. Soil texture, soil structure, and rainfall intensity may also affect the optimum placement distance of structures, but for simplicity, these variables are usually ignored. If the farmer(s) considers the amount of work required to place these structures excessive, then it may be necessary to limit the first season's work to the placement of every other structure, with plans to finish the work later.

8. Place marker stakes along the "linea madre" at the appropriate intervals.

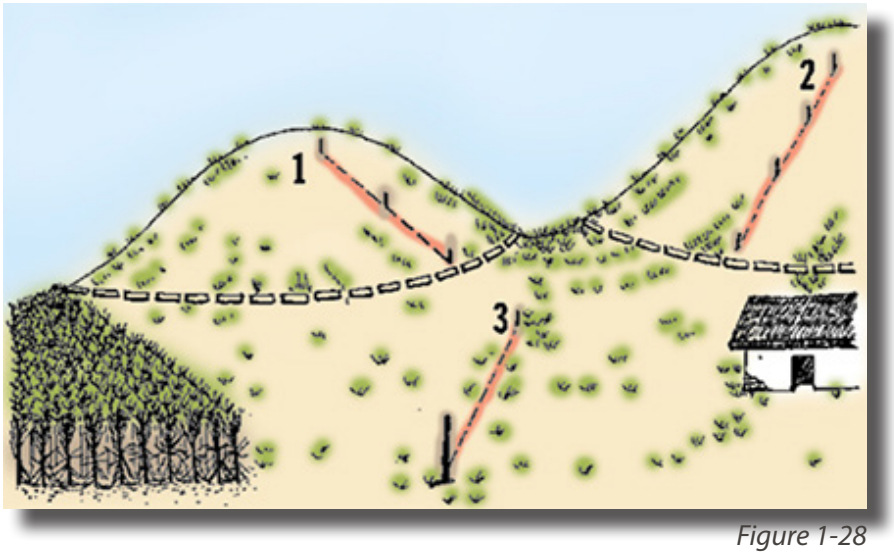


Figure 1-28

The first stake should be placed along the upper edge of the lot or at the highest convenient place where a structure will be located, while subsequent stakes should be placed below.

9. Survey and mark contour lines.

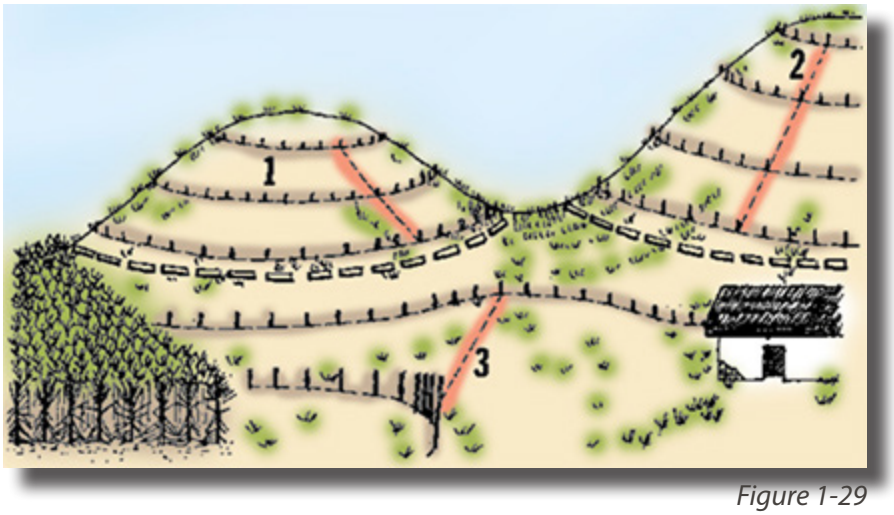


Figure 1-29

This can be done using an A-frame or other type of level. The construction of two types of levels is described in Appendix 4. Care should be taken to carefully calibrate the level and to orient it in the proper direction if surveying lines for drainage ditches.

10. Realign stakes along contour lines, if necessary.

If the contour lines result in an extreme zigzag pattern, which may cause difficulties, for example, in plowing a plot, the lines may be straightened somewhat by slightly moving some of the stakes. It should be noted that realigning stakes means that they no longer lie along measured contour lines and that this will have to be corrected if digging ditches to drain or retain water.

11. Carry out your conservation practice(s).

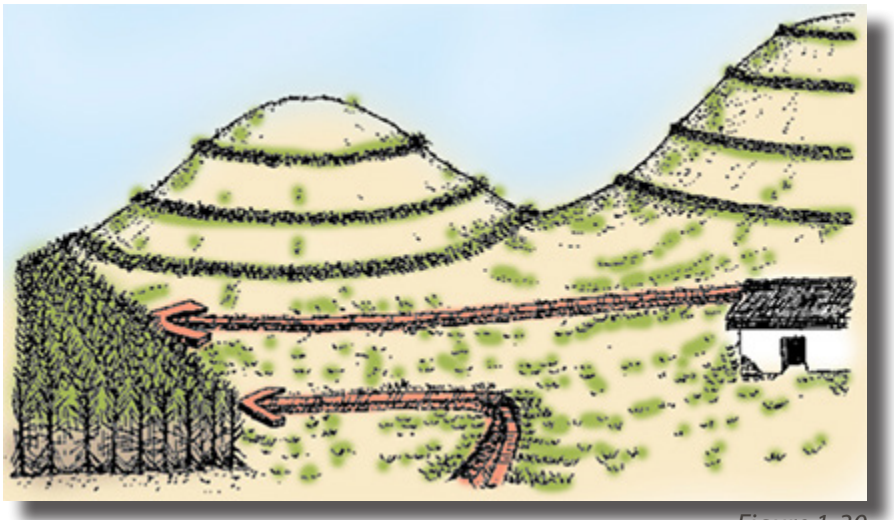


Figure 1-30

These are described in detail in the section on "Soil Conservation Strategies."

12. Plant protective barriers, if necessary.

Figure 1-31

A live barrier planted above barriers, terraces, ditches, and drainages acts as a filter to keep soil particles from filling them in and lessens their maintenance requirements.

13. Plant desired crop(s) along the contour.

Figure 1-32

Planting along the contour with closer spacing within rows and more distance between rows forms a partial live barrier with each crop furrow. Care should be taken to plant well-selected seeds in order to ensure a more complete germination. On irregular terrain with varying slope, successive contour lines will not be parallel. Point rows are used in the wider intervals in order to fill up the land space and still maintain contour-oriented furrows (see Figure 1-33).

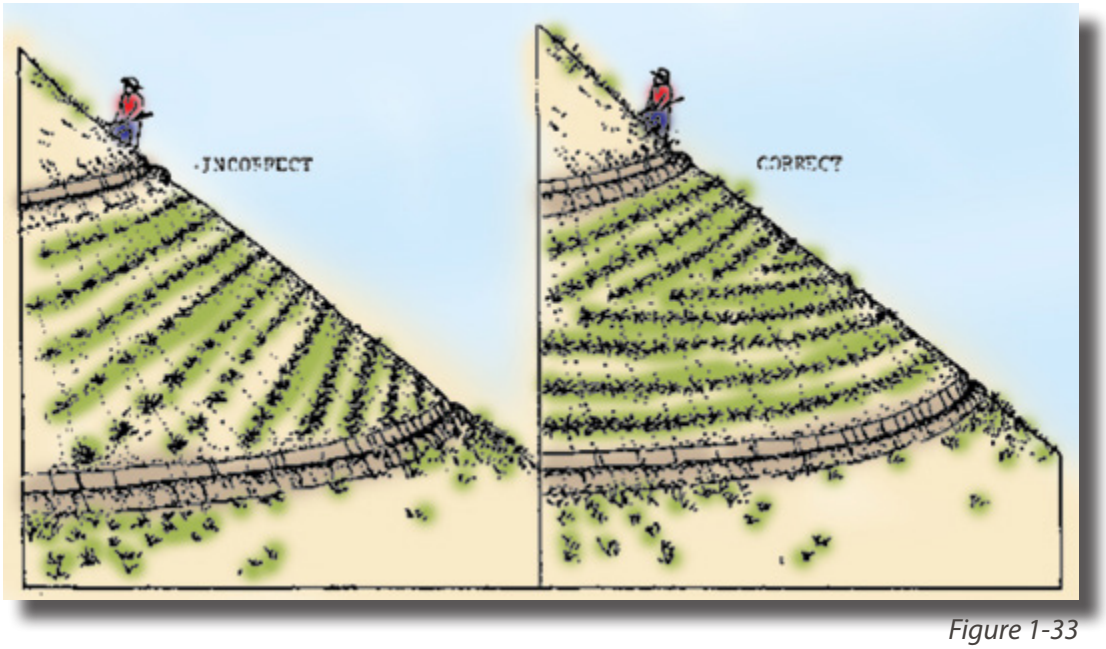


Figure 1-33

14. Periodically review structures and carry out any needed maintenance practices.

Figure 1-34

Common maintenance practices include replanting of open spaces in live barriers and replanting grass on terrace walls.

Introduction to Soil Fertility

Soil fertility is a concept based on the amounts of essential nutrients available to the plants. The plant nutrients involved are classified as macronutrients, such as nitrogen, phosphorous, potassium, calcium, magnesium, and sulphur; or as micronutrients, such as iron, manganese, copper, zinc, boron, and molybdenum. The amount of each of these nutrients is not the only factor in determining whether there are nutrient shortages. Soil pH (acidity) is also important because under certain pH conditions, nutrients form insoluble compounds that are unavailable to be taken up by plant roots. A shortage of any of these elements in the soil can slow crop development and reduce yields, something that Volunteers should consider when working with farmers to improve crop production.

In practice, soil fertility is determined by collecting a soil sample and submitting it for chemical analysis. Since a small sample will be used to infer the characteristics of an entire field, care should be taken to ensure that the sample represents as accurately as possible the conditions present in the plot.

Obtain a sample with a soil probe or a shovel, careful to exclude the surface litter layer and sample at a depth of approximately 1–8 inches (2.5–20.3 centimeters) below the surface. Take subsamples from random positions throughout the entire field (10–20 per hectare) and mix thoroughly in a bucket or bag. From this mix, air dry, label, and submit a 1–2 pound (.45–.9 kilogram) sample to a laboratory for analysis. Subdivide a highly variable field into uniform sections and treat these separately, as they may have very different soil characteristics.

Samples may be analyzed with portable field test kits, if available, but it is also advisable to familiarize farmers with any laboratory facilities available to them. The most common soil analyses performed are those for nitrogen, phosphorous, potassium, and pH, which generally are most important in limiting crop yields. If crops do not appear to respond to changes in these factors, then a deficiency of another nutrient may be involved and a more detailed analysis can be carried out.

Strategy of Fertilizers

Positive, sustainable impact and "do no harm" are core principles of Peace Corps development work that should provide a framework for every decision to promote and disseminate technologies or practices to improve local agriculture and food security. When considering whether to promote use of inorganic fertilizers in smallholder agriculture, the answer may not always be clear. Under the right conditions, the right fertilizer can significantly increase productivity (i.e., yield or value of crop per unit area), particularly on poor and degraded soils. This can, in turn, have a positive impact on the environment, reducing pressure to convert forests and other fragile lands to agricultural uses. It will increase biomass production, with

the additional organic matter supplying and helping to retain soil nutrients and moisture and helping to increase soil organic matter content.

For most smallholder farmers in developing countries, however, use of any fertilizer is often a complicated economic decision. Inorganic fertilizer can be an expensive investment. With few or no services available to test a farmer's soil, it is nearly impossible to determine what soil nutrients are lacking and what fertilizer would be most beneficial. In addition, even if known, the right fertilizers are often in limited supply or not available at all when application is optimal. There is the additional uncertainty of unstable costs (of inputs) and lack of guaranteed returns on investment. Also, there are negative environmental concerns that add an ethical element to any decision. Production and transportation of the often-imported nitrogen-based fertilizers requires non-renewable energy (from fossil fuels). Phosphorous is a finite resource in ever-greater demand and supplies that, at some point in time, will eventually be exhausted. Inorganic fertilizers, when overused or applied incorrectly, can enter surface and groundwaters, contaminate potable water supplies, and lead to eutrophication of water bodies. Likewise, there can also be a buildup in the soils of salts and heavy metals, such as cadmium, as well as a release of nitrous oxide.

For many developing countries where the Peace Corps is engaged in food security work, the environmental costs of using inorganic fertilizers are not currently considered significant in light of the more immediate need for food. In Sub-Saharan Africa, where most of these activities are taking place, inorganic fertilizer use is very low, with the average amount being applied each year at 22 pounds (10 kilograms) per hectare or less. This is well below what is needed to replace the nitrogen, potassium, and calcium that are removed with the harvests. Available supplies of animal manures and crop residues that can be used to organically fertilize and mulch fields are limited and very often are well below what is needed to have a significant impact on production. Therefore, encouraging correct use of inorganic fertilizer, where and when feasible, can make both sense and cents. However, for efficient nutrient utilization, inorganic fertilizer should be used as part of a site-specific integrated soil fertility management strategy that also includes: 1) use of organic matter (manures, compost, mulch, biochar, etc.), 2) water harvesting, and 3) control of soil erosion. These complementary activities will help ensure that maximum benefits are derived from each of the component practices and that environmental risks are minimized.

Inorganic Fertilizers

Inorganic Fertilizers

The most commonly encountered fertilizers are in granular form and contain compounds of nitrogen, phosphorous, potassium, or a mixture of these. The type of fertilizer and the amount to be used generally are given as recommendations accompanying soil analysis results. In applying such fertilizers, it is important to calculate from the given recommendation

the quantity that must be applied in each furrow or at each plant to avoid under- or over-application.

The timing of fertilizer applications is also important. For example, in corn, a formula containing both phosphorous and nitrogen is usually recommended at planting time. Meanwhile, one month after planting the corn, a formula of only nitrogen, in the form of urea, is usually recommended. Since fertilizer recommendations vary widely based on the soils and the crop to be planted, specifics concerning their use are not discussed here.

Volunteers should familiarize themselves with the fertilization practices in use throughout their regions in order to determine if changes in the types, amounts, and/or timing of fertilizer applications would be beneficial.

Organic Fertilizers

The use of organic fertilizers is another method of correcting soil nutrient deficiencies. Although it is more labor intensive than chemical fertilization, it has the advantages of being locally produced and more readily available; maintaining soil humidity; improving soil organic matter content, structure, and texture; adding a better balance of micronutrients; and improving the soil's capacity to hold nutrients. Organic fertilizer refers to a number of types of organic matter that can be incorporated into soils or left as a mulch on the surface. This may be as simple as incorporating crop residues or manure, or as complex as planting a green manure crop, making compost, or raising earthworms to produce materials that will be incorporated into the soil later.

A traditional practice in many areas is the burning of residues left when initially clearing land or those left after a harvest. Although some nutrients are returned to the soil in the ashes, much of the organic matter and nitrogen present are lost to the air. This loss of organic matter affects all of the aforementioned soil properties.

Manures and Crop Residues

The incorporation of crop residues or animal manure is a means of utilizing often wasted by-products of the agricultural process. They are relatively simple operations, requiring only the labor to collect and spread manure or crop residues before carrying out the normal tillage operations.

Green Manure Crops

Green manure crops are nitrogen-fixing plants that can be grown for a period and then turned into the soil as a source of nitrogen and organic matter. If cultivated for seed production

and only turned into soil after dried, they contain little nitrogen and provide mostly organic matter. Table 2-1 lists a variety of possible green manure crops, all different types of legumes.

In crowded areas, where there is pressure to produce as much as possible on every cleared land space, it is often difficult to convince farmers to take land out of food production in order to plant a green manure crop. Fortunately, there are alternatives that allow for the production of green manures without affecting the normal crop production cycle. Some species, such as gandul (pigeon pea), rice bean, and others (especially if planted sparsely) can be grown in intercropping systems with other crops. In these cases, the green manure crop can be useful as a ground cover or living mulch that reduces rainfall impact and, thereby, soil erosion. It can also be effective in reducing weed growth and providing useful organic matter, seeds, or forage (Figure 2-1).

Figure 2-1

Some species, such as velvet bean, are such aggressively climbing, densely foliaged plants, that they are best grown alone. These can be planted during fallow years and then incorporated into the soil. Velvet bean and other drought-tolerant specie can even be planted near the end of the growing season, allowed to grow during the dry season, finally to be incorporated into the soil prior to the next planting season.

Figure 2-2

Tree species, such as leucaena, madre de cacao, and gualiqueme, can be planted along the edges or in contour strips in the middle of fields, providing a source of leaf material for green manure or forage and firewood (as shown in Figure 2-2).

Table 2-1. Some Suggested Green Manure Crops

Common Name(s)	Scientific Name	Other Uses	Cultivation	Environment	Comments
Bean, Frijol	Phaseolus vulgaris	Food- pods, seeds	Traditional methods	Many varieties exist for almost all areas	Already commonly cultivated, but often residues not incorporated
Butterfly Pea, Frijol Mariposa	Clitoria ternata	Food- young pods	2–3 seeds spaced 20–25 centimeters (cm) by 50–100 cm	Warm, sunny, well-drained areas, 380–4,200 millimeters rain, wide pH tolerance, 0–1,600 meters elevation	Perennial, often poor germination, some disease problems in humid areas
Canavalia Jackbean, Canavalia Roja, Swordbean	Canavalia ensiformis	Food- pods, seeds, forage	1 seed 50 cm by 50–100 cm (50–70 kilograms (kg)/ hectare)	Warm, temperate to hot tropical rainforest areas, sun or shade, 700–4,200 millimeters rain, 0-1,800 meters elevation	Climbing annual; usually produces seed in 3–4 months; toxic before cooking; mature seeds must be boiled, changing water and peeling seed coat
Clover	Trifolium spp.	Forage	From seed	Developed in temperature climates, possible value in tropical areas	

Common Name(s)	Scientific Name	Other Uses	Cultivation	Environment	Comments
Cowpea	Vigna unguiculata	Food- seeds, forage	For seed: 2 seeds 10–15 cm by 40 cm (25–45 kg/ hectare) For forage: 2 seeds 8–10 cm by 30–40 cm	Warm climate, 0–900 meters elevation, moderately drought tolerant, various soils	Annual, fairly erect, susceptible to insect damage
Crown vetch	Securigera varia	Forage	From seed	Developed in temperature climates promising for cool highland tropics	Toxic to horses
Gandul, Pigeon Pea	Cajanus cajan	Food- seeds, forage, shade-living fences	For seed: 3 seeds 30 cm by 30–40 cm (15–45 kg/ hectare) For forage: 1 seed 5 cmby 30–40 cm	Warm climates, drought tolerant, various soils	Woody, erect perennial (5 years), difficult to chop when full grown, 1.5–4 meters tall
Gualiqueme, Pita	Erythrina spp.	Ornamental forage, firewood	From seed		Fast growing tree, resprouts from base when cut
Kudzu	Pueraria spp.	Forage	From seed	Grows well under a wide range of environmental conditions, although greatest growth achieved where winters are mild, summer temperatures rise above 80 F, and rainfall is abundant (101+ cm [39 inches]). Kudzu can grow in nearly any type of soil	Very aggressive climbing vine, problem weed in some areas

Common Name(s)	Scientific Name	Other Uses	Cultivation	Environment	Comments
Lablab Bean, Dolichos	Lablab purpureus	Food- pod, seeds, leaves, sprouts	2 seeds 10–15 cm by 50–60 cm (50–70 kg/ hectare)	Many varieties exist for almost all climates, all elevations	Perennial (2–3 years)
Leucaena	Leucaena leucocephala	Forage, firewood	From seed	Hot areas, drought tolerant, lower elevations (up to 500–1,000 meters)	Fast-growing tree, resprouts from base when cut
Madre de Cacao Madriago	Gliricidia sepium	Forage	From seed or stakes	Hot areas, 0–1,600 meters elevation, 1,500–2,300 mm rain	Fast-growing tree, resprouts from base when cut
Rice Bean, Frijol Arroz	Vigna umbellata	Food- seeds, pods, leaves, seedlings, forage	3 seeds, 20 cm by 50 cm (60–80 kg/ hectare)	Hot, humid areas, 0–1,500 meters elevation	Mature seeds in as little as 60 days
Tepary Bean	Phaseolus acutifolius	Food- seeds, forage	1–2 seeds, 8 cm by 50–90 cm Seed production: 11–17 kg/ hectare; hay production: 60 kg/ hectare	Arid and semiarid regions	Grows poorly in humid areas, salt sensitive, susceptible to insect damage but disease-resistant, annual, semi-erect, 50 cm tall
Velvet Bean, Frijol terciopelo	Mucuna pruriens	Food- pods, leaves, toasted seeds are like coffee, forage	2 seeds 40 cm by 50–100 cm (10–45 kg/ hectare)	Drought tolerant, 0–2,000 meters elevation, 380–3,100 mm rain, soil variable	Trailing or climbing vine, produces great amounts of foliage, can smother weeds, variable life span (up to 6–8 months to produce seed, use staking when growing for seed)

Sources: NAS (1979), Duke (1981)

Composting

Composting is a very labor intensive technique that involves mixing plant residues, manure, soil, and water.

Decomposition takes place over a period of 1–4 months, reducing the mix to rich humus to be incorporated into the soil. Because of the bulkiness of the material and the labor involved, it is most practical in small, intensively worked vegetable plots, but it can also be used as a fertilizer in large fields of any crop if labor is available.

A compost pile can be composed of almost any organic materials: weeds, banana stalks, sawdust, coffee pulp, corn or bean residues, etc. Manure from cows, horses, chickens or rabbits is usually used as a nitrogen source. Ashes, eggshells, and sometimes chemical fertilizers may also be added. Composting can be done with a careful eye on the chemical composition of the ingredients in order to provide an optimum ratio of the elements necessary for the bacterial and fungal decomposers, or by just throwing a little of everything in. Some farmers feel more comfortable with the casual, less exact approach, while others may be more intrigued by a more scientific attitude toward the process.

Among the types of compost piles are the square aboveground compost pile, the underground compost pile, the volcano compost pile, and the contour compost ditch.

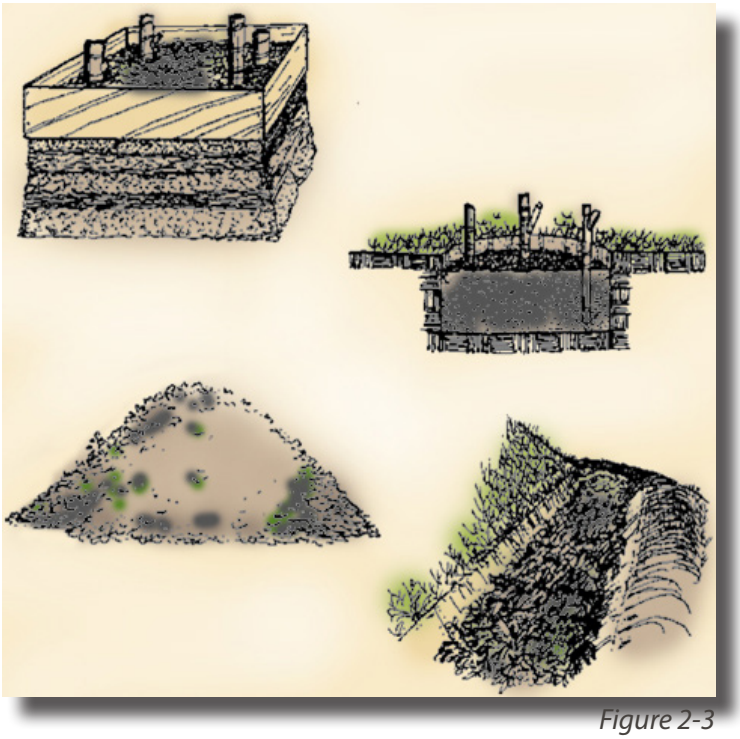


Figure 2-3

The square aboveground compost pile is tightly compacted into a wooden frame and is often composed of three 12-inch (30.5 centimeters) layers. Each of the layers is made up of 9 inches (22.9 centimeters) of plant materials (both fresh and dry), 2 inches (5 centimeters) of manure, and 1 inch (2.5 centimeters) of black soil. Each layer is thoroughly compacted and saturated with water during construction. Posts are placed vertically in the pile (one per 3.28 feet or 1 meter) to be removed after construction to serve as air vents. These piles are generally turned once a month and are ready to use in 3-4 months.

The underground compost pile is similar, but is constructed inside a hole dug in the ground 19.7–39.4 inches (50–100 centimeters deep). This can be very effective in arid zones or during the dry season, as it reduces the amount of evaporation from the compost.

Another type of compost pile is the volcano compost pile, which is simply a mound composed of the same materials (plant matter, manure, soil, and water). This type of compost pile can be used to decompose materials much more rapidly (1–2 months) if it is turned and mixed frequently (every 2–3 days). The contour-ditch compost method simply involves filling contour ditches with crop residues, manure, and soil. This method can be very effective on a large scale, leaving the materials undisturbed to gradually decompose over the course of a year. Drainage ditches should not be filled with compost during rainy periods. Contour retention ditches can be filled, however, as the accumulated compost serves as a spongy retaining material. The water collected also accelerates the decomposition process.

Composting with Earthworms

Another method of improving soil chemical and physical properties is the raising of earthworms and the subsequent incorporation of both the worms and the rich soil they are raised in. Earthworms can be raised in a mixture of the same materials used in composting, but in this case, they are not compacted. They are also often enclosed in a box or tub to prevent them from escaping. If a variety such as "Red Wiggler" (Coqueta Roja) is available, it may be much more active and reproduce much faster than other native types of earthworms. The earthworms ingest organic matter, digest it, and leave behind mineral rich feces, which provide nutrients for plant growth. Also, by physically passing through the soil, earthworms increase soil aeration and drainage.

For a more thorough discussion of composting and of composting with earthworms, see *Worms Eat My Garbage. How To Set Up and Maintain a Worm Composting System*, by M. Appelhof. (Kalamazoo, Mich.: Flower Press, 1982).

Extension Methodology

The technical aspects of solving problems associated with hillside farmland are much more simple and straightforward than the extension work aspects. Even though there are many variables that affect land-use decisions, there are many more that affect the receptivity of farmers in an area to an individual Peace Corps Volunteer's promotional efforts. The possibilities available to a Volunteer are almost endless. Presented here are some sample work activities, guidelines for evaluating work, motivational techniques, and types of groups with which one may be involved.

Volunteers should find this material useful in designing and carrying out a more realistic and successful work plan. For additional references on the extension process in rural areas, see The *Peace Corp Agricultural Extension* manual [M0018].

Box 2-1. Timetable of Events Associated with a "Typical" Two-Year Peace Corps Volunteer Service

First 3–6 months:

1. Settle in, find, and fix up living quarters and meet people and make friends.
2. Work on learning local customs and language.
3. Get acquainted with (official) counterpart, work zone, communities, climate, topography, crops, technology, and problems.
4. Carefully review the *Peace Corps Agricultural Extension* manual [M0018].
5. Carefully review the *Participatory Analysis for Community Action (PACA) Training Manual* [M0053] and conduct a community assessment.
6. Identify at least one local community as a target area.
7. If possible, plant demonstration lot, perhaps in the form of a vegetable garden in your own yard, with interested collaborator or as a school project. Use live barriers, contour ditches, contour planting beds, organic compost, etc.
8. Become familiar with the host agency, its resources, and its policies, and meet fellow Volunteers.
9. Develop a reputation as being interested by attending host agency and community meetings, visiting farmers, and keeping informed of seasonal agricultural activities. Help out farmers in areas other than soil conservation (pest control, fertilizer applications, cooperative management, etc.).
10. Formulate ideas about best potential work strategies.
11. Look for interested collaborators (i.e., beneficiaries) to try out soil conservation techniques.
12. Incorporate some tools which take into account societal roles into your participatory analysis.

Second 3–6 months:

1. Maintain a reputation as an interested, responsible Volunteer.

2. Discuss specific possibilities for soil conservation work with program staff. Begin promotional efforts, such as introductory lectures, simple demonstrations (See Appendix 5), field trips to visit other farmers, etc.

3. Select at least one collaborator from each of the communities targeted and help them carry out some conservation practices on their own land.

4. Encourage these initial collaborators to help seek out and teach other interested farmers.

Third 3–6 months:

1. Keep demonstration lots well maintained; use them to motivate and to teach others to start more demonstration lots.

2. Keep records to measure success of demonstration lots; publicize successes in the communities involved and at host agency meetings.

3. Make sure host agency extentionists, collaborators, and other interested farmers understand techniques used; plan more formal courses, demonstrations, or field trips.

4. Constantly be on the lookout for new collaborators and have the initial collaborators help organize interested farmers into groups to receive visits and demonstrations at regularly scheduled times. Encourage initial collaborators to work as volunteer extentionists with other interested farmers.

Fourth 3–6 months:

1. Work with a larger number of collaborators.

2. Organize farmers so that future Volunteers will already have distinct groups to visit.

3. Make sure farmers and other host agency extensionists are well trained to be able to continue designing and building soil conservation structures.

4. Publicize work based on records kept and publicize at agency and community meetings, at local, regional, or national fairs, and through the media (radio, newspaper, etc.).

5. Assist with training of incoming Peace Corps Volunteers.

Depending on the area, the receptivity of the people, the number of growing seasons per year, etc., this may already be the end of the two-year period. If work has proceeded rapidly, all this may have taken as little as one year. If any time remains, it can be spent trying additional soil conservation techniques (remember that different techniques reinforce each other when combined); helping develop the farmers into more stable, better organized groups; giving more formal training courses for both farmers and extentionists; expanding the work to other communities; or working on another aspect of agricultural development, such as youth organizations, improving marketing, crop diversification, etc.

Guidelines for Evaluating Extension Work

Guidelines for Evaluating Soil Conservation Techniques Used

If records are kept, then a comparison of budgets and crop yields can be made (See Appendix 3). This type of record can be very important in convincing farmers or other Volunteers to try similar techniques in another area. Records can also be used to evaluate which techniques are most appropriate or which are inappropriate to the area. Remember, however, that many of the benefits of using soil conservation techniques are long-term and may not show a dramatic improvement when using short-term observations to evaluate the techniques.

Guidelines for Evaluating the Extension Methodology Used

Again, records should be kept following the growth of a program. This is often measured in terms of the number of people or land area involved in the program. Volunteers should realize that a large program is not necessarily more desirable than a slow-to-start, steadily growing one. Finding farmers genuinely interested in carrying out soil conservation practices is difficult (especially identifying the initial farmer). It is reasonable to expect slow acceptance of the techniques at first. Each farmer adopting soil conservation techniques may lead to one or two additional farmers adopting the techniques during the next planting season. Assuming two additional highly motivated new collaborators for every current collaborator, the following growth sequence can be generated:

1	(+2) = 3	(+6) = 9	(+18) = 27	(+54) = 81	(+162) = 243
1st planting season	2nd planting season	3rd planting season	4th planting season	5th planting season	6th planting season

This growth sequence may take place anywhere from 2–6 years, depending on the climate and the crops involved.

If there is only one planting season per year (an arid zone without irrigation or crops such as coffee or fruit trees), after two years the Volunteer may have just three collaborators. It is

important that these three people be well trained and highly motivated and that other local Volunteers are convinced of the value of the work so that they keep expanding it in the area.

In this case, since such a small number of collaborators are involved, the Volunteer should attempt to visit several communities so each one can initiate this growth sequence of adopting soil conservation techniques at the same time. For example, if this can be carried out in four communities, then 12 collaborators, rather than just three, are involved.

If there are two planting seasons per year (moderate climate where a system such as successive corn and bean plantings are practiced), after two years, the Volunteer may be at the point where 9–27 collaborators are involved. If working in three separate communities, 27–81 people could be involved. Any of these is enough so that time will be saved teaching in groups. Then teaching groups can be the basis for organizing interested farmers into agricultural committees or cooperatives at a future time. These groups will also form a nucleus of people for future Volunteers to visit, reducing much of the time spent in initially being introduced to a community and discovering interested farmers. This larger involvement also merits bringing in outsiders for field trips to see the variety of work being done and its acceptability by the community. This helps motivate innovative farmers, making them feel they are doing something important and worthy of respect, and motivates the visitors to try the techniques in other areas. At this time, the program can also serve as a model for other Volunteers to follow.

If there are three or four planting seasons per year (year-round cultivation is possible because of climate or availability of irrigation water), after two years the Volunteer may have 27, 81, or 243 collaborators, depending on the speed in getting started. Enough collaborators are now involved to make the formation of groups essential if attention is to be given to all, especially if working with more than one community. These large groups can be powerful forces, making it much easier to attract government aid in the form of courses or loans, and in meriting regional or national publicity for soil conservation techniques. The area can now serve as a good model for other agricultural Volunteers or development agencies. The group-oriented nature may involve changing the work strategy and focusing more on training people in management and organization to stabilize and strengthen the groups, rather than strictly focusing on training in agricultural techniques.

To ensure sustainability, the work must be collaborative from the beginning. You will be learning from the farmers and sharing your knowledge. Behavior change comes slowly, but it is an essential piece to ensure that improved practices are maintained.

From this growth sequence, one can see that even though growth starts very slow, if it can be maintained at a steady rate, it is soon growing so fast that one Volunteer can hardly keep up with it. Essential to the process, however, is quality and success, especially in the initial period, in order for the techniques to appear acceptable and attractive to farmers.

Ch 3: Extension Techniques

Several methods are available to those Volunteers attempting to generate farmers' interest in new techniques. Some of the most common are informal discussions, lectures, videos, classroom demonstrations, demonstration lots, field trips, visits from farmers already using the techniques, financial incentives, and soil conservation courses.

Informal discussions with farmers can be one of the most effective techniques, especially in more isolated communities where people may be unaccustomed to receiving courses, attending meetings, or receiving visits from Volunteers. Informal discussions provide an opportunity to make friends, to have people understand what to expect of the extension program, and to discuss ideas in an informal setting. Friends made in this manner often turn out to be the first interested collaborators in an area.

Presentations that are more formal, such as lectures, videos, and classroom demonstrations (see Appendix 5), allow for the presentation of more information to more people and the use of visual aids to make some of the ideas clearer. A disadvantage is that they require people to attend a meeting at a fixed time, something that may be uncustomary for many. These types of presentations are probably most effective when several individuals have already expressed an interest during informal discussions. In communities where people are not accustomed to receiving focal presentations, the format and content of the lecture, video, or demonstration should be designed carefully to ensure that those attending understand how this will relate to their own farm work.

Demonstration lots are small plantings, carefully prepared and cared for, that demonstrate some or all of the techniques that are to be promoted in an area. "Seeing is believing" and that is the main advantage of this technique. People are given a concrete example, so when a Volunteer talks about digging ditches in the middle of a cornfield, planting in contour curves, or using organic fertilizer, farmers will have a clearer concept of what these terms are describing. They also provide a local trial to evaluate the appropriateness of the techniques under local conditions.

Field trips to, or visits from, farmers already using soil conservation techniques provide an opportunity to evaluate what is being done in other areas and to consider their suitability for the new area. These are especially valuable if there is a chance to discuss the new techniques directly with the farmers involved. This will permit a more thorough consideration of time and labor involved and the rewards to be expected. Agricultural Volunteers should encourage their collaborators to seek out and share their experiences with other farmers in the area. Volunteers might even consider making a "moral contract" with collaborators, requiring them to teach two additional farmers, who in turn will each promise to teach two more farmers, and so on. In this way, the number of farmers learning and using the techniques increases more rapidly with time. The Volunteer should be aware that if the model area or farmer has received any special attention or aid to carry out the work, this might be interpreted as a prerequisite to the success of the technique.

Financial incentives (credit, seed, fertilizer, food for work, etc.) are available from many national and international agencies interested in rural development projects. These often are available only for groups of farmers. They can be used to attract participants to a project designed, for example, to bring people together for formal classroom sessions where new techniques are described, followed by farmers carrying out the practices on their own land. In this process, the involved farmers receive benefits from increased production and a longer useful life of their fields. In Appendix 3, an extension program is described in which 50 farmers were involved in such a project. If carried out throughout a region or country, these types of projects can benefit the economy because of greater self-sufficiency in production and can reduce migration to urban areas and avoid often-destabilizing political pressures for rapid land reform measures. This method has the advantage of attracting a larger number of people to be trained during the extension program and the immediate achievement of economic benefits to a larger number of people. A possible disadvantage of this strategy is that it may overlook the importance of future acceptance of soil conservation techniques by those farmers not involved initially. If the same motivating benefits are not available to other farmers, they may not feel that the soil conservation work by itself is worthwhile. Depending on the receptivity and the subsequent extension methodology followed, however, this may not present a problem. In fact, the immediate high visibility of such a program may allow a great increase in the effectiveness of a Peace Corps Volunteer during his or her two years of service. The high visibility of such a large project could also be important in providing a site for field trips to motivate or train other farmers and Volunteers, and a basis for publicizing the success of soil conservation techniques on a regional, national, or international level.

Soil conservation courses allow Volunteers to teach a variety of techniques to farmers, more than they may be able to learn by doing their own fieldwork. It should be remembered, however, that many people are unaccustomed to learning in a classroom format, and that the courses should involve as much practical fieldwork as possible. Courses are probably most effective in training extension workers, once several farmers in an area have already tried some soil conservation techniques on their own fields and seem receptive to learning more[6].

Working with Groups

As an extension program gets under way in a community and starts growing, it becomes more and more necessary for the Volunteers to work with groups, as time may not always be available for individual visits.

If working in communities with no organized groups, Volunteers are faced with the task of initiating groups with which to work. It is common for community members to be resistant to the idea of joining such a group. For many reasons (a tradition of working alone, local feuds or jealousies, suspicion of unwanted economic or political commitments, etc.), this may

6 See http://www.meas-extension.org/tip-sheets/participatory-methods-and-approaches for more on extension approaches.

be one of the Volunteer's most difficult tasks. Dealing with and overcoming this reluctance is an individual matter and each Volunteer works things out uniquely. It takes time and communication to develop a relationship that both the community members and the Volunteer are comfortable with. Other agricultural Volunteers, nurses, or schoolteachers who have had experience working with similar community groups may have useful suggestions concerning such matters.

Although presenting new information to farmers is more efficient on a group than on an individual basis, this may not be true for actual fieldwork. The Volunteer must evaluate each community to decide if it is more appropriate to carry out demonstrations on individual- or group-tended lots. In group-cultivated lots, the work and risks are shared, lessening the burden of any individual. However, sometimes farmers are less conscientious about caring for a crop where they don't enjoy individual ownership. In such cases, it may be most appropriate for the Volunteer to present new information or techniques at a central location, such as a school, a small parcel of land made available to the Volunteer for this purpose, or by rotating among the individual parcels of the group members. After the group presentation, the Volunteer should, whenever possible, discuss or visit each individual's parcel to ensure that the technique will be put into practice correctly.

Organized groups of farmers can also be very important in the continued spread of the new techniques after a Volunteer leaves. They increase communication among farmers, they serve as support groups for innovative farmers, they are more likely to attract the attention of other extension programs and, in some cases, they manage credit funds, which make it easier for farmers to implement certain technologies. Volunteers should familiarize themselves with the different types of groups so they have a better understanding of how groups may facilitate, or possibly inhibit, the continuance of their promotional effort.

Agriculture committees are often informal assemblages of people drawn to meetings by a common interest in agricultural innovations. These committees are very flexible and allow for the admission of new members or formation of new committees upon demand. This can be a big advantage when working in a new area, as the success of the program will probably attract more and more interested persons. This flexibility also leads to the danger of dissolving rapidly if interest wanes, especially if dominated by only one or two enthusiastic members. However, the members of these committees can be very important resources as local Volunteers since very often they are attending solely based on interest and a desire to learn, without any other reward. These committees can also be a good starting point for the organization of an agricultural cooperative, if desired.

Cooperatives are more formal groups, generally organized around a set of bylaws or a constitution, requiring members to fulfill certain responsibilities (pay dues, attend meetings or workdays) and granting them certain privileges (credit, buying and/or selling at favorable prices, right to farm a certain portion of land). Because of their formal nature, cooperatives

are likely to be more permanent organizations than agricultural committees. However, the formality often means cooperatives are less flexible about admitting new members. Many times cooperatives receive preferential treatment from governmental agencies when soliciting training courses, credit, or other types of assistance.

There are several types of cooperatives, differing in the nature of the rights they grant and the responsibilities they require of the members. Production cooperatives involve the members working together in the production process, such as farming the same piece of land. Credit cooperatives manage a common fund that is used to loan members money, an alternative to more expensive and often unavailable bank loans. Buying and selling co-ops pool all the farmers buying orders, buying in bulk for cheaper prices, and pool the farmers' produce to sell at higher prices or to lessen transportation costs.

Soil conservation Volunteers may also be involved in working with other types of groups, such as schools, youth groups, homemakers groups, etc. Regardless of the type of group an agricultural Volunteer works with, some basic concepts must be considered. First, groups should be goal-oriented or purposeful, providing some advantage to their members, such as an incentive to spend their time with the group. Second, the group must have a structure, organization, plan of activities, and disciplinary code that permit the attainment of its goals. Third, care must be taken in planning, promoting, and realizing all group-oriented activities to avoid disillusion among members and abandoning of the group. This may result from joining a group without understanding its stated goal or joining a group incapable of attaining its stated goal because of flaws in the design of its structure, organization, plan of activities, or disciplinary code. When these concepts are kept in mind, then the group is much more likely to serve its members in a productive, self-sustaining fashion. Once confident of the usefulness and power of their own group, community members will be much more motivated to work within the group framework to improve their own situation.

Ch 4: Conclusion

This guide attempts to provide agricultural Volunteers with an understanding of some techniques that have been found helpful in improving hillside-farming systems. Hopefully, each Volunteer can find one or several techniques that are appropriate for any specific work area. Clearly, it is not the role of this guide, just as it is not the role of the Volunteer, to dictate the techniques to be used in any given situation. Rather, agricultural Volunteers and farmers should realize the realm of possible techniques available to them, enabling them to formulate their own plans according to the many variables (climate, topography, labor, markets, etc.) that determine the appropriateness of any given farming practice for an area.

Furthermore, it is hoped that hillside farms are not to be regarded as "things to be fixed once and for all" with a set of soil conservation techniques. Farms, like individuals and communities, never reach an ideal state of development; rather, they are dynamic units that must adjust over time to a changing a climate of environmental, human, economic, and political factors. All of these factors require that new practices constantly be tested and evaluated. If agricultural Volunteers can communicate to farmers the importance of testing and evaluating new techniques, such as the ones included in this guide and many others, then both will be better prepared to address problems facing the farmers now and in the future.

The technologies described in this guide are all simple options available to small-scale hillside farmers in the use of their land. It is hoped that by using these practices, better yields may be sustained for more years on each cultivated plot of land. In addition to the increase in crop production, the introduction of soil conservation techniques may facilitate the promotion and realization of more long-term effects of area-wide conservation programs; such as the management of watersheds to maintain a reliable, clean, drinking water supply and the protection of undisturbed lands as reservoirs of native flora and fauna.

Bibliography

Agpada, A., et. al. *Manual of Reforestation and Erosion Control for the Philippines*. W. Germany: German Agency for Technical Cooperation Ltd. Eschborn, 1975.

Appelhof, M. *Worms Eat My Garbage. How To Set Up and Maintain a Worm Composting System*. Kalamazoo, Mich.: Flower Press, 1982.

Atangana, A., D. Khasa, S. Chang, and A. Degrande. *Tropical Agroforestry*. New York: Springer, 2014.

Bunch, R. *Two Ears of Corn: A Guide to People-Centered Agricultural Improvement, 2nd Edition*. Oklahoma City: World Neighbors, 1985.

Duke, JA. *Handbook of Legumes of World Economic Importance*. New York: Plenum Press. 1981.

Ellis-Jones, J, and B Sims. *An appraisal of soil conservation technologies on hillside farms in Honduras, Mexico and Nicaragua*. Project Appraisal 10.2 (1995): 125-134.

Greenland, DJ and R. Lal (eds.) *Soil Conservation and Management in the Humid Tropics*. New York: John Wiley and Sons, 1977.

Hudson, N. *Soil Conservation, 3rd ed*. London: BT Batsford, 1995.

Kunkle, SH and JL Thames (eds). *Guidelines for Watershed Management. Conservation Guide #1*. Rome: FAO, 1977.

Leonard, D. *Soils, Crops, and Fertilizer Use: A Guide for Peace Corps Volunteers*. Peace Corps Program and Training Journal Reprint Series No. 8. Washington, D.C.: Peace Corps, 1969.

Michaelson, T. *Manual de Conservación de Suelos pare Tierras de Ladera. Ordenación Integrada de Cuencas Hidrográficas*. Proyecto PNUD/FAO/HOND/77/006. Tegucigalpa, Honduras, 1980 (out of print).

Morgan, R. and P. Charles. S*oil Erosion and Conservation*. London: Wiley. 2009.

National Academy of Sciences. *Tropical Legumes, Resources for the Future*. Washington, D.C., 1979.

National Academy of Sciences. *Firewood Crops: Shrub and Tree Species for Energy Production (2 vol.)*. Washington, D.C., 1983.

The Peace Corps. *Participatory Analysis for Community Action (PACA) Training Manual*. [M0053]

The Peace Corps. *Agricultural Extension*. [M0018]

Bibliography

The Peace Corps. *Soil and Water Conservation for Small Farm Development in the Tropics*. [R0084]

Sheng, TC and HR Stennett. "*Forestry Development and Watershed Management in the Upland Regions*," Jamaica, Lecture Notes: Watershed Management and Soil Conservation Training Course. United Nations Development Programme, FAO, Kingston, 1975 (out of print).

Suarez de Castro, F. "*Conservación de Suelos*." San Jose, Costa Rica: Instituto Interamericano de Ciencias Agrícolas, 1980 (out of print).

Tracy, F and R Perez. "*Conservación de Suelos. Folleto de Campo: Distanciamientos y Dimensiones de Obras Físicas*." Proyecto Manejo de Recursos Naturales, SAN/AID #5220168. Tegucigalpa, Honduras. 1986.

Tracy, F and R Perez. *Manual Practico de Conservación de Suelos*. Proyecto Manejo de Recursos Naturales. SAN/AID #522-0168. Tegucigalpa, Honduras. 1986.

United States Department of Agriculture. Soil Conservation Service. *A Manual on Conservation of Soil and Water*. Agriculture Handbook No.61, Washington, D.C., 1954.

Vickery, D and J Vickery. *Intensive Vegetable Gardening for Profit and Self-Sufficiency*. Peace Corps Information Collection and Exchange. Reprint R-25. Washington, D.C.: Peace Corps, 1981.

Appendix 1: English-Spanish Vocabulary List

English	Spanish
A-frame level	nivel tipo "A"
bench terrace	terraza de banco
check dam	barrera
compost	abono organic
compost pile	abonera
contour barrier	berrera al contorno
contour furrow	surco al contorno
cover crop	cultivo de cobertura
crop residues	rastrojos, residues
dead barrier	barrera muerta
desertification	desertificación, desertización
discontinuous narrow terrace (orchard terrace)	acequia de ladera, terraza de huerta, terraza angosta
drainage	desagua o drenaje
drop box	caja disipadora
earthworm	lombriz de tierra
earthworm house	lombricero
eroded land	tierra erosionada, sierra cansada
erosion	erosion
fertilizer	fertilizante, abono
grass-lined drainage canal	canal de desague engramado
green manure	abono verde
gully	cárcava
hillside	ladera
hillside ditch (channel terrace)	zanja o acequia de ladera
individual terrace	terraza individual
infiltration	infiltración
line level	nivel de cuerda o de apoundañil
live barrier	barrera viva
manure	estiercol
minimum tillage	labranza minima
mixed barrier	barrera mixta
mulch	cobertura
planting bed	cama o arriate
point row	surco muerto

Appendix 1: English-Spanish Vocabulary List

English	Spanish
retention well	pozo de retención
riser (terrace bank)	talud
rock-lined drainage canal	canal de desague empedrado
rock wall	muro de piedra
runoff	escurrimiento, agua de escorrentia
slash and burn	roza y quema
slope	pendiente, desnivel
stormwater drain (uppermost of series of contour ditches)	cabecera
windbreak	barrera rompeviento

Appendix 2: Dichotomous Key to the Selection of Soil Conservation Practices

IF: percent	THEN GO TO or Note Practice:
1. a. Slope less than 12 percent or greater than 60 percent	2
b. Slope between 12 percent and 60 percent	3
2. a. Slope less than 12 percent	Live barriers and agronomic measures*
b. Slope greater than 60 percent	Reforestation
3. a. Slope between 12 percent and 50 percent	4
b. Slope between 50 percent and 60 percent	Perennial crops using discontinuous narrow terraces
4. a. Terrain with little or no rocks	5
b. Terrain with abundant rocks	Rock wall barriers and agronomic measures*
5. a. Annual crops (basic grains, vegetables tubers, flowers) or bananas	6
b. The majority of the fruit trees (citrus, coffee, cacao, etc.)	Individual terraces with discontinuous narrow terraces or hillside ditches
6. a. Deep soil (greater than 3.3 feet or 1 meter)	7
b. Shallow soil (less than 19.6 inches or 50 centimeters)	8
7. a. Non-irrigated	8
b. Irrigated	Continuous bench terraces and agronomic measures*
8. a. Slope between 12 percent and 30 percent, and soil greater than 19.6 inches or 50 centimeters	Discontinuous narrow terraces depth with agronomic measures*
b. Slope between 12–50 percent, or soil depth less than 19.6 inches or 50 centimeters	Hillside ditches with agronomic measures

** Agronomic measures refer to other land management practices, such as contour plowing and planting, mulching, etc. which may be appropriate to the area.*

Source: Tracy and Perez (1986)

Appendix 3: Results of an Extension Project: Profitability of Modern Agricultural Techniques

Many nontraditional agricultural techniques require a greater investment in labor and/or fertilizers, seeds, pesticides, etc. than the traditional techniques they are designed to replace. The extra labor and expenses incurred discourage many farmers from changing their traditional methods.

In order to illustrate the changes that a small family farm operation might experience, data are presented here to represent average expenses and earnings of 50 farmers. The data were collected the year before and the first year in which techniques of soil conservation, fertilizer use, improved corn seed varieties, and chemical pest control were introduced to a group of local farmers by a Peace Corps Volunteer.

The farms involved in this project were all small [1 manzana (mz)=.68 hectares], with slopes ranging from 10–50 percent. They were planted with corn and beans, the traditional crops in this area. Because of the nature of this group, these data are probably not applicable to other cultivation systems, such as vegetables or fruit trees, but they do provide insight into questions that may be important to Volunteers working with other systems.

Table A-3-1. Sample Farm Expenses and Earnings on a Small Honduran Farm

	Year 1		Year 2	
I. Expenses				
	Unit	Cost	Unit	Cost
A. Land preparation				
Soil conservation practices			40 days at 5.00	200.00
Plowing		20.00		
Subtotal		20.00		
Subtotal (excluding labor provided by family)		**20.00**		
B. Corn Crop (first planting season)				
1. Cultural practices				
Planting (including fertilizer and pesticide application)	2 days	10.00	8 days	40.00
Weeding	16 days	80.00	16 days	80.00
Fertilizing			2 days	10.00
Weeding	16 days	80.00	16 days	80.00
Folding over mature ears	12 days	60.00	12 days	60.00
Harvesting	12 days	60.00	20 days	100.00

Appendix 3: Results of an Extension Project: Profitability of Modern Agricultural Techniques

	Year 1		Year 2	
Husking	10 days	50.00	20 days	100.00
Transport (field to house)	2 days + 2 mules	30.00	5 days + 2 mules	75.00
Shelling	10 days	50.00	20 days	100.00
2. Products				
Seed	30 pounds at 0.20/pound	6.00	30 pounds at 0.50/pound	15.00
Fertilizer (18-46-0)			2 qq at 38.00 qq	76.00
Fertilizer (urea)			2 qq at 28.00qq	56.00
Insecticide (volaton)			15 pounds at 0.80/pound	12.00
Subtotal		446.00		804.00
Subtotal excluding labor provided by family		**86.00**		**239.00**
C. Bean Crop				
1. Cultural practices				
Weeding (pre-planting)	16 days	80.00	16 days	80.00
Planting	4 days	20.00	4 days	20.00
Weeding	16 days	80.00	16 days	80.00
Harvest	12 days	60.00	12 days	60.00
2. Products				
Seed	40 pounds at 0.40/pound	16.00	40 pounds at 0.40/pound	16.00
Subtotal		256.00		256.00
Subtotal excluding labor provided by family		**16.00**		**16.00**
Total		702.00		1,280.00
Total excluding labor provided by family		122.00		275.00
II. Earnings				
	Unit	Cost	Unit	Cost
A. Corn	12 qq at 12.50–25.00/ qq	150.00–300.00	27qq at 12.50–25.00/ qq	462.50–925.00

Appendix 3: Results of an Extension Project: Profitability of Modern Agricultural Techniques

	Year 1		Year 2	
B. Beans	10 qq at 30.00/qq	300.00	11 qq at 30.00/qq	330.00
Total		**450.00–600.00**		**792.50–1255.00**
III. Net Earnings		(-252.00)–(-102.00)		(-487.50)–(-25.00)
Net earnings excluding labor provided by family		328.00–478.00		517.50–980.00

All costs and expenses are given are in Honduras currency, the Lempira (L.)

The expense accounts reveal several points that should be considered by Volunteers when advising farmers:

- These farms are heavily dependent on family labor. (Note net losses when all labor costs are included). Therefore, designing a conservation plan that can be carried out without hiring out additional labor is important.
- The market price available to farmers determines whether the extra expenses are profitable in the short run. Due to seasonal variations in grain prices, profits are much higher if grains can be stored and sold when prices rise (in this case approximately 6–8 months after time of peak harvest).
- Once the soil conservation practices are in place, however, future years' labor expenses will decrease and a greater likelihood of sustained yields increases the profitability of the modern techniques in the end.
- The use of organic fertilizers may reduce the amount of inorganic fertilizer needed and avoid some expenses.
- Limiting the first year's work to a smaller plot can greatly reduce the risk incurred and can be helpful in promoting the techniques in new areas.

Appendix 4: Two Simple Levels for Use in Surveying Contour Lines

In many areas, sophisticated surveying levels are not available to farmers interested in designing soil conservation structures. Even where they are available, it is often more practical for the farmer to build a cheap, simple, effective level for use in surveying contour lines. Although less accurate than more sophisticated levels, the two levels presented here, when properly constructed and used, are sufficiently accurate for work on small hillside farms that require the measurements of 0- or 1-percent slope described in this guide.

A-frame Level

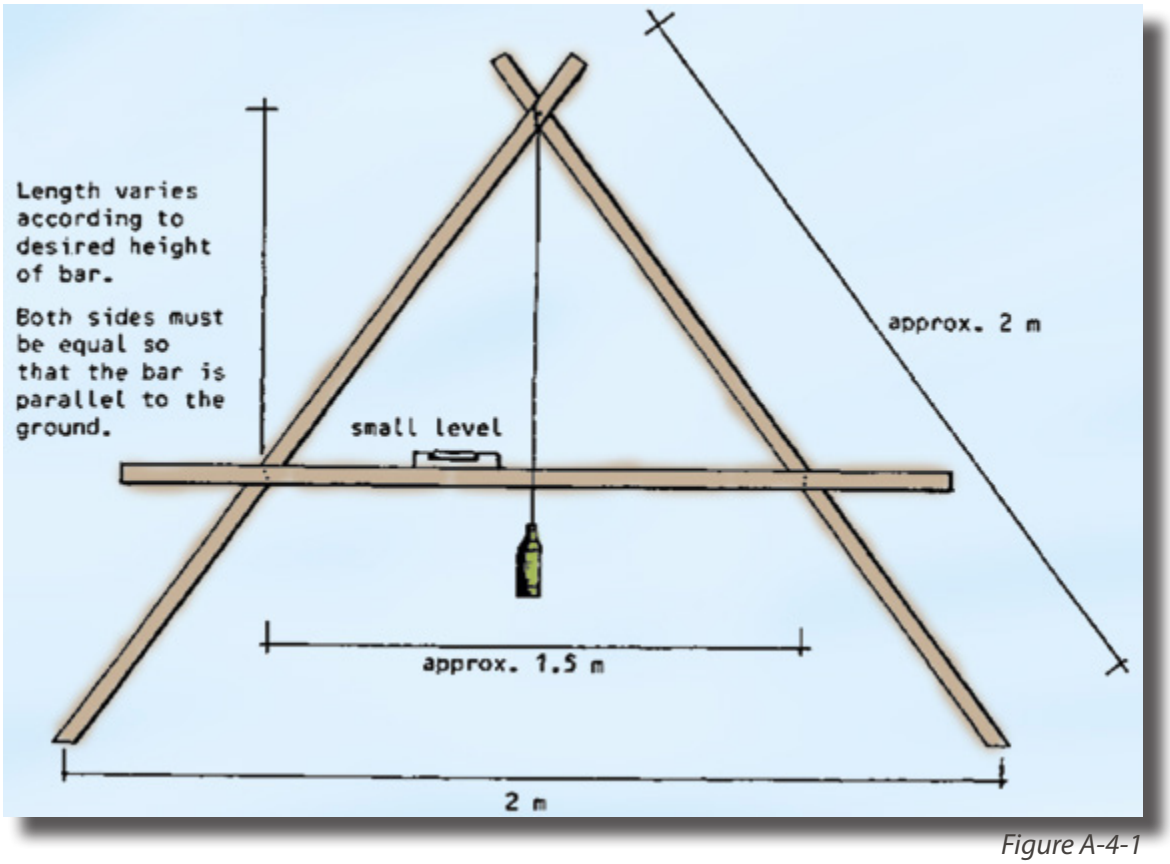


Figure A-4-1

Construction

The materials required are three straight boards or sticks, three nails or screws, a thin string, and a screw-capped glass bottle or uniform-shaped rock. A small line level is very convenient and makes use much easier on windy days.

Important points to consider in building the A-frame level:

- The symmetry of the level is important (two legs should be the same length and the crossbar should be positioned identically on the legs so that it is parallel to the ground).

Appendix 4: Two Simple Levels for Use in Surveying Contour Lines

- The dimensions of the level are not important, but if constructed much larger than the one pictured, they should be assembled with screws so they can be disassembled for transportation. Measuring an exact distance between the legs makes calibrating the 1-percent contour position easier.
- The plumb bob must be attached so it does not deflect the string to either side. If a screw cap bottle is used, it should be hung by a hole made exactly in the center of the cap. If a rock is used, it is important that a very uniformly shaped rock be chosen.

Calibration

The level should be calibrated every day before use, as warping of the wood can greatly change the results.

Calibration of 0 Percent:

1. The level should be positioned with both feet on firm surfaces but with one end obviously higher than the other.

2. The level is gently rocked, allowing the string with the plumb bob to gently strike the cross bar.

3. When the plumb bob stops swaying side to side and the string strikes the cross bar at the same point repeatedly (5–10 times), mark this position in pencil on the cross bar.

4. Reverse the position of the level so that the other foot is now at the higher point. Care must be taken to position the feet of the level in exactly the same points as before.

5. Repeat Steps 2 and 3, obtaining a second mark on the other side of the center of the cross bar.

6. The 0-percent position of the level is exactly between the two marks obtained in this trial. This position can be marked by measuring with a ruler or paper (one-half the distance between the two marks). Now when the feet of the level are even, the string will strike the cross bar at the 0-percent position, which is used to survey contour lines for barriers, terraces, or ditches that are to be used for retention, rather than diversion of water.

7. Once calibrated, a small carpenter's or line level can be fastened to the cross bar to facilitate use on windy days.

Calibration of 1 Percent:

1. Position the level so the feet are on the same level and the string strikes the cross bar at the 0-percent position. Both feet should be on firm surfaces.

2. Raise one foot by the distance required to position the level at a 1-percent slope. For example, if the distance between the feet is 6.7 feet (2 meters), then a .79-inch (2-centimeter) tall object or .79-inch (2-centimeter) tall stack of coins should be placed under one foot (.79 inch/78.7 inches=.01 = 1 percent).

3. Rock the level gently. Now the string strikes the 1-percent slope position. Mark this position on the crossbar.

4. Since this type of contour line will be used to construct structures to divert water, an arrow should be placed pointing toward the lower foot to indicate the direction of water flow.

5. As in the previous calibration, if desired, a small level can be fastened to the cross bar.

Use of the A-frame Level

The A-frame level is used to survey contour lines by placing stakes at the position of the feet when the level gives the desired reading. Stakes should all be placed on the same side of the level, all upslope or all downslope, in order to avoid errors. When not being used, the level should be stored in a dry, shady place.

Line Level

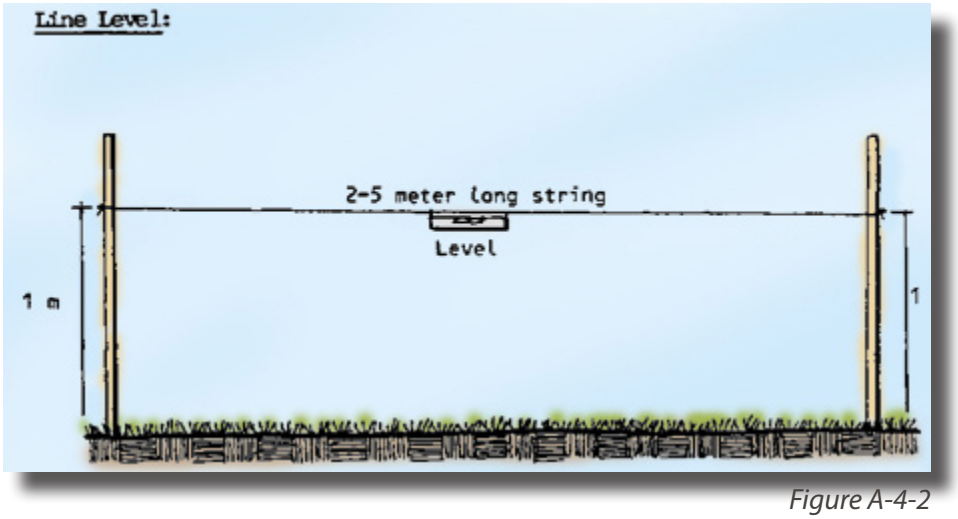


Figure A-4-2

Appendix 4: Two Simple Levels for Use in Surveying Contour Lines

Construction

The materials required are two straight boards or sticks, a string of desired length, and a line level.

Calibration

The level should be calibrated every day before using, as bending of the hooks on the line level or warping or chipping of the sticks can greatly change the results.

Calibration of 0 Percent:

1. Slots are cut in each stick at the same distance from one end.

2. The string is tied firmly to each stick so that it cannot slip out of the slots.

3. Hook the line level on the string and find a place on firm ground that gives a level reading.

4. Reverse the direction of the line level on the string while maintaining the position of the sticks. If the reading changes, the hooks of the line level must be adjusted slightly by bending them.

5. Repeat Steps 3 and 4 until the line level gives identical readings upon reversal.

Calibration of 1 Percent:

1. Repeat the steps as in the calibration of 0 percent. However, this time the slots on the sticks should be placed so that a 1-percent drop occurs over the distance of the string. (Example: If the string measures 6.7 feet or 2 meters, then the slot on one stick should be .79 inches or 2 centimeters higher than on the other).

2. Remember that the stick that has the slot located higher up actually represents the lower ground surface when the reading of the string is level. Remember to mark the sticks so no confusion as to the direction of water flow will arise when surveying contour lines.

Use

This type of level is easiest to use with at least three people, two holding the sticks and the third reading the line level and placing stakes. When not in use, the line level should be protected so the glass vial and hooks are not damaged.

Appendix 5: Some Demonstrations Useful in Promoting New Techniques

One of the main problems faced by agricultural Volunteers is gaining credibility in a community. People are often unwilling to invest time or money to try new techniques that they do not understand, solely based on the word of an outsider. The following demonstrations can help farmers understand more about their soils and how they might benefit by changing some of their traditional agricultural practices.

The Erosive Power of Raindrop Impact

Figure A-5-1

As water is dropped on the soil next to a piece of white paper, soil particles are dislodged and splash onto the paper. When done over a mulch-protected soil, this demonstration results in no dislodging of soil particles. This illustrates the value of a permanent ground cover or mulch in the prevention of soil erosion.

The Advantage of Contour Cultivation Practices over Traditional Methods

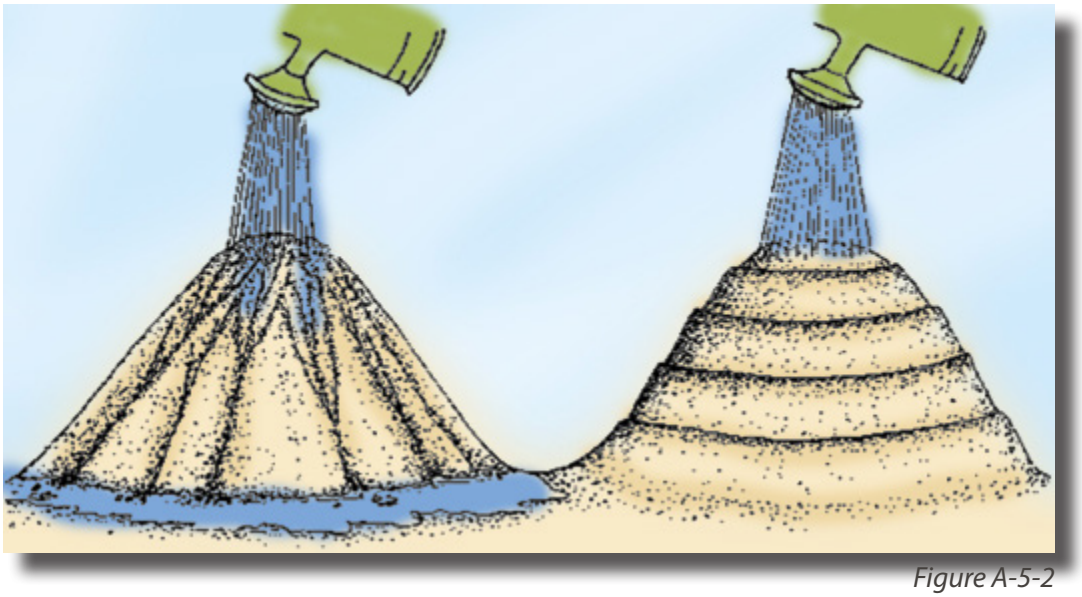


Figure A-5-2

Form two mounds of soil and scratch contour furrows on one and furrows straight up and down on the other. When watered, the mound with contour furrows should erode less than the other mound (Figure A-5-2).

Appendix 5: Some Demonstrations Useful in Promoting New Techniques

This demonstration can be used to stress the importance of working the land along the contour. A trial run should be made before the actual demonstration to determine the appropriate watering intensity.

Demonstrating the Particulate Makeup of Soils

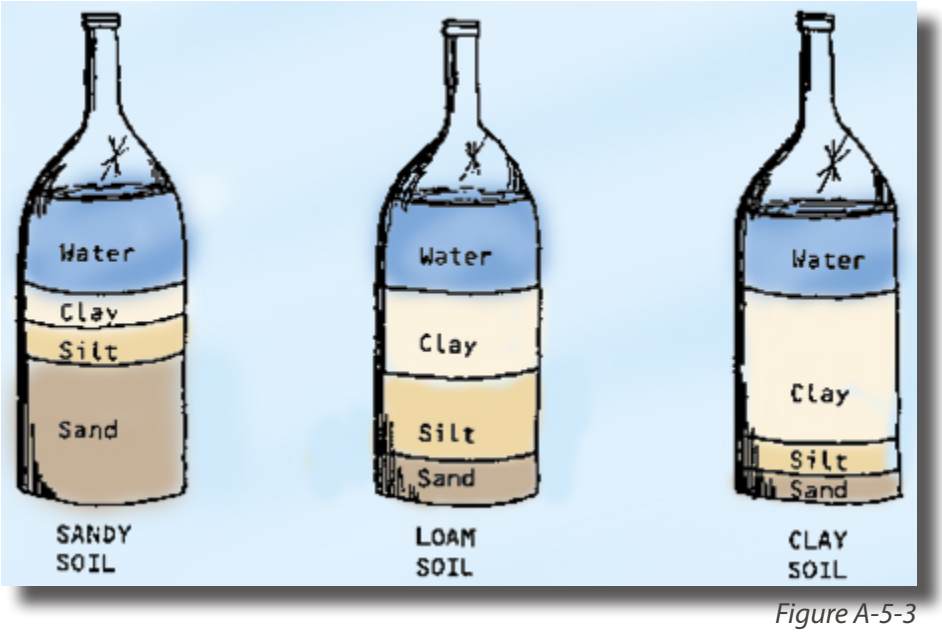


Figure A-5-3

Place soil in a bottle, add water, shake, and set on a stable level surface. The heavier sand-sized particles will settle out first, followed by silt-sized and then clay-sized particles. This demonstration illustrates the particulate nature of soils and can be used to help farmers understand what soil texture means and how it can be important in affecting the drainage or erodability of a soil. The bottles should be allowed to remain undisturbed for a full day in order for the finer, clay-sized particles to settle out.

Demonstrating Soil Profiles

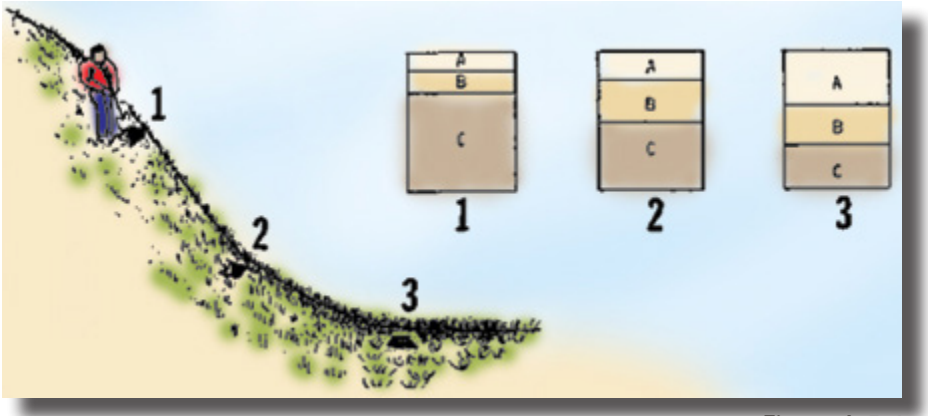


Figure A-5-4

Appendix 5: Some Demonstrations Useful in Promoting New Techniques

By digging soil pits at the spots indicated in different parts of a field, the results of past erosion can be seen. The much thinner layers of the more fertile A and B horizons on the more steeply sloped areas can be helpful in explaining the need to introduce soil conservation measures.

Growth Trials in Soils of Varying Fertility

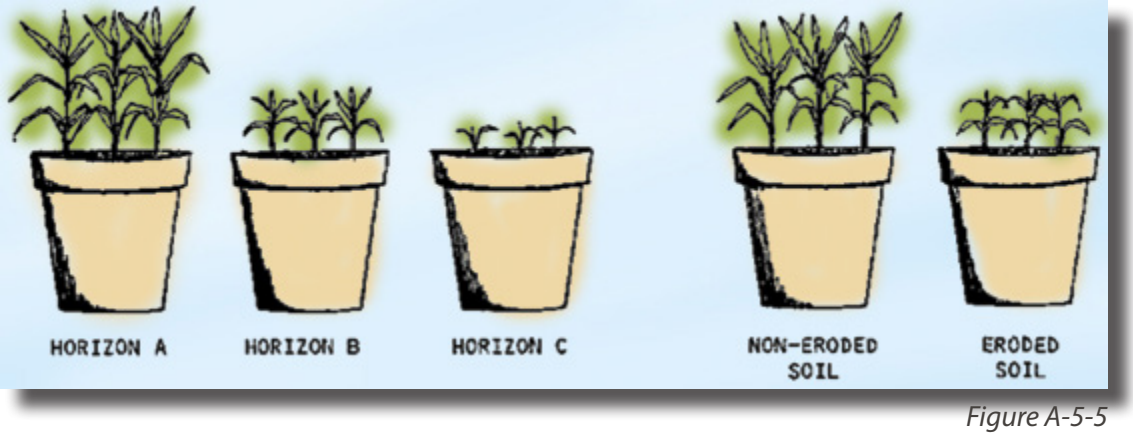


Figure A-5-5

Planting of 3–5 corn seeds in cans containing soils from different horizons or from eroded and non-eroded parts of the same field can demonstrate the difference in fertility between upper and lower soil horizons and the value of protecting the upper soil horizon from erosion. This demonstration requires three to six weeks to show best results.

Growth Trials Using Inorganic and Organic Fertilizers

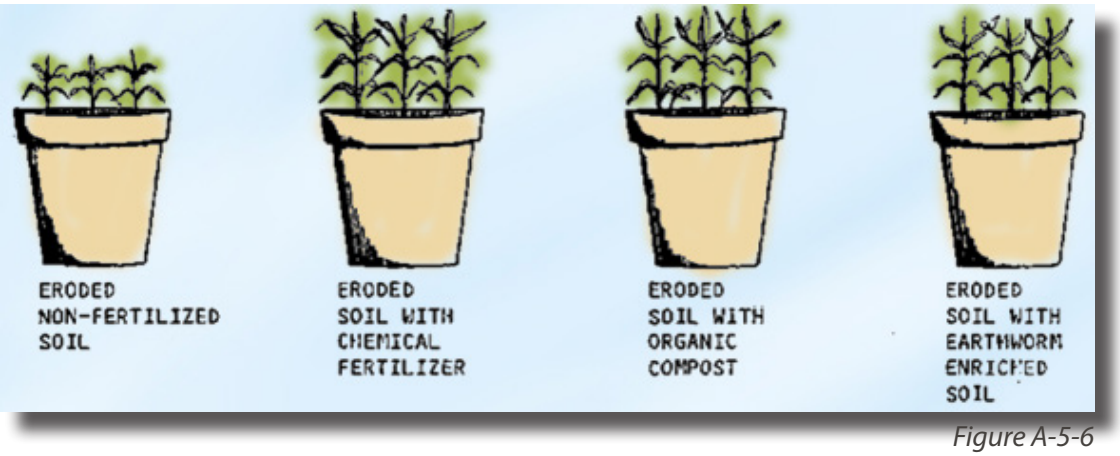


Figure A-5-6

Similar to Figure A-5-5, this demonstration can be used to show the benefits of using different techniques to maintain or increase soil fertility. Again, three to six weeks are required for best results.

Growth trials such as the ones shown here can be carried out to show an unlimited number of comparisons. It might also be valuable to try mulched soil, repeatedly burned soil, waterlogged soil, another crop which could be grown to maturity (beans, radishes, carrots), etc.

Appendix 6: Resources on Environmentally Adaptive Agriculture

InPaC-S: Integração Participativa de Conhecimento sobre Indicadores de Qualidade do Sol – Guia Metodologico (Participatory Knowledge Integration about Indicators of Soil Quality – Methodological Guide) (http://www.worldagroforestry.org/newsroom/highlights/new-book-breaks-new-ground-soil-conservation).The main objective of the InPaC-S methodology is to combine knowledge from farmers, extension professionals, and researchers about soil quality, thus generating a "hybrid" knowledge base that promotes the adoption of good agricultural practices.