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UNDERSTANDING SOIL

CONSERVATION TECHNIQUES

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PREFACE

This paper is one of a series published by Volunteers in Technical Assistance to provide an introduction to specific state-of-the-art technologies of interest to people in developing countries. The papers are intended to be used as guidelines to help people choose thechnologies that are suitable to their situations. They are not intended to provide construction or implementation details. People are urged to contact VITA or similar organizations for further information and technical assistance if they find that a particular technology seems to meet their needs.

The papers in the series were written, reviewed, and illustrated almost entirely by VITA volunteer technical experts on a purely voluntary basis. Some 500 volunteers were involved in the production of the first 100 titles issued, contributing approximately 5,000 hours of their time. VITA staff included Suzanne Brooks handling typesetting and layout and Margaret Crouch as editor and project manager.

Co-author Fred Weber, a pioneer in the community forestry concepts presented here, has advised projects for over 20 years. He wrote the original edition of the VITA publication Reforestation in Arid Lands, from which much of this paper is drawn, based on a training manual he prepared for Peace Corps volunteers in Niger. Carol Stoney collaborated with Mr. Weber on the revisions for the new edition of Reforestation.. Dr. Edward Pytlik teaches appropriate technology at West Virginia University. Frederick J. Holman, a landscape architect, illustrated both the book and the additional material in this paper.

VITA is a private, nonprofit organization that supports people working on technical problems in developing countries. VITA offers information and assistance aimed at helping individuals and groups to select and implement technologies appropriate to their situations. VITA maintains an international Inquiry Service, a specialized documentation center, and a computerized roster of volunteer technical consultants; manages long-term field projects; and publishes a variety of technical manuals and papers.

UNDERSTANDING SOIL CONSERVATION TECHNIQUES

by Fred Weber, Carol Stoney, and Dr. Edward Pytlik

I. INTRODUCTION

Soil conservation efforts protect the soil from the two primary forces of erosion, wind and water. A wide assortment of different soil conservation techniques are being used today. Windbreaks and dune stabilization, for example, are effective methods of halting wind erosion. Terracing, planting trees and other vegetation in contour strips or along contour ridges, and gully control plantings are techniques used in combination with physical control measures to reduce soil erosion from water. Conservation tilling refers to a variety of methods used to control both wind erosion.

Some of these methods are based on traditional practices that have been carried out by local people for generations. Others are relatively new, "invented" by technicians working with local farmers or pastoralists and still being adapted to varying site conditions. The methods described here provide a practical guide for use in the field, rather than extensive coverage of background information, theory, and reference sources. The Reference List and Information Source List should be consulted for further documentation.

The techniques described here can contribute to the increased productivity and sustainability of land

use systems. Most can be implemented by rural households or communities using locally available materials. Nearly all of the techniques involve the establishment of vegetation cover, primarily trees and shrubs. Some also involve physical soil conservation methods as well, such as contour ridges, terraces, or walls. This approach is intended to increase awareness of ways in which vegetative methods can be used in combination with physical methods.

Trees and shrubs play a critically important conservation role. They can reduce soil surface temperatures, increase infiltration and retention of soil moisture, provide organic matter, pump nutrients, fix nitrogen, reduce erosion from water and wind, form live fences, and provide shade, all of which create better growing conditions for crops and grasses. In addition, certain tree species may provide food (fruit, leaves, edible seeds, etc.) not only for people but also for livestock, fuel, building materials, and other important products.

Soil conservation project planning should not take a cookbook approach. Rather, the project design should be adapted to specific site conditions and current land use patterns. Species trials are required to meet site requirements. Demonstration sites using more varied species, including more indigenous species, are needed so that future selection can be made on the basis of what

has worked.

The material in this technical paper is drawn largely from Reforestation in Arid Lands (Weber and Stoney, 1986), which provides a comprehensive review of reforestation methods including project design, site and species selection, soil preparation, nursery management, and many of the conservation techniques presented here. Additional material, on physical methods to control erosion, were provided by Dr. Pytlik.

II. CONTROLLING WIND EROSION

Windbreaks

Windbreaks are strips of trees and other vegetation that slow the flow of the wind, reducing wind erosion, evaporation, and wind damage to crops. They are sometimes referred to as shelterbelts, although this term usually implies a wider strip of vegetation, which incorporates more rows of trees and shrubs than are usually found in a windbreak.

Windbreaks have an especially high potential in farming areas where cereal crops such as millet and sorghum are grown. The most successful windbreak projects to date are those found on enclosed farm lands and in some demonstration or pilot projects under government or private

control. The major obstacle to windbreak establishment in other areas has been the difficulty and high cost of protecting the trees against animal grazing. Some large-scale successes have been achieved in areas where donors, government agencies, and local people have worked closely together.

Highly impressive results have been observed at a CARE project in the Majjia Valley in Niger, where crop yields from fields protected by windbreaks are consistently higher than those from unprotected fields. Studies indicate that total yields are approximately 20 percent higher, even after accounting for losses from land that has been taken out of crop production to provide space for the windbreaks (Dennison, 1986).

The effectiveness of a windbreak depends on how efficiently the wall of vegetation blocks the wind and confines the wind's turbulence to the zones close to the windbreak. A vegetation density of, 60 to 80 percent seems to work best in arid zones. A barrier dense enough to block wind passage completely will cause turbulence close to the ground, loosening soil particles that can then be picked up by the wind. As well as removing needed topsoil, wind that is carrying soil particles causes damage to crops through the abrasive effect of the sediment on plant tissues.

A row of trees that provides less complete wind reduction will also ensure that the effects of the wind
are felt farther away. Gaps or openings in the windbreak should be avoided as much as possible. Wind
is funneled through gaps in the tree rows, concentrating its force and speed, so that the final effect can
be very damaging.

<WINDBREAK>

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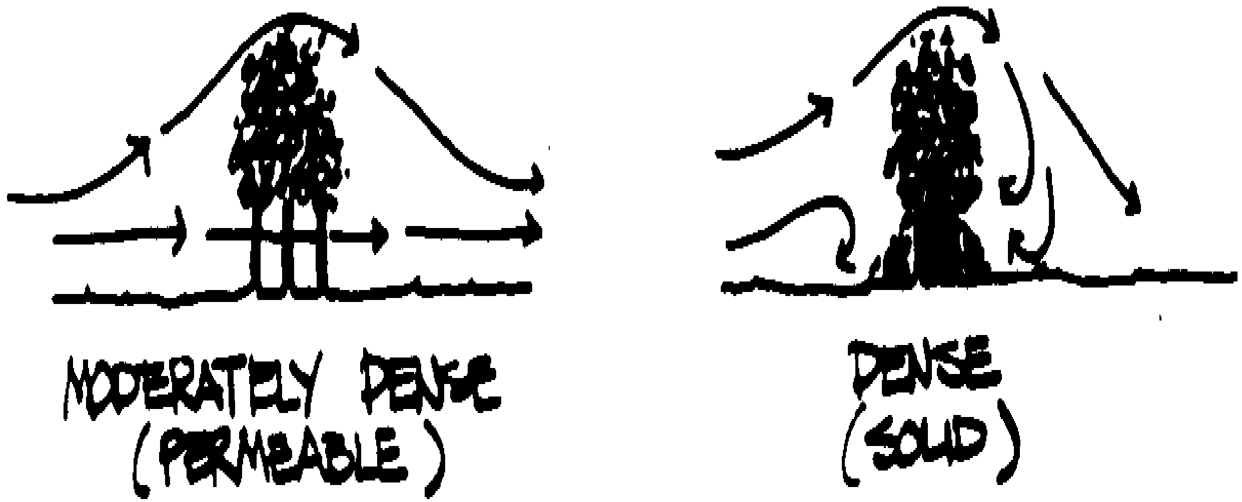

Windbreaks can furnish protection for downwind areas up to 10 times the height of the trees, provided
the windbreak consists of at least two rows of plants of different heights.

Large trees should be chosen for one row (see A, below). Fast-growing species can be mixed with slower growing, longer-lived trees, depending on local preference. Row B should be composed of shorter species, chosen if possible for their by-products, and rows C and D are auxiliary rows. These are planted with lower, bushier trees, shrubs, and grasses. A well chosen vegetation mix for windbreak composition will not only provide protection from the wind, but will yield secondary products as well. The windbreak trees themselves, if properly harvested, can also provide significant quantities of fuelwood and poles without jeopardizing their primary function.

<WINDBREAK>

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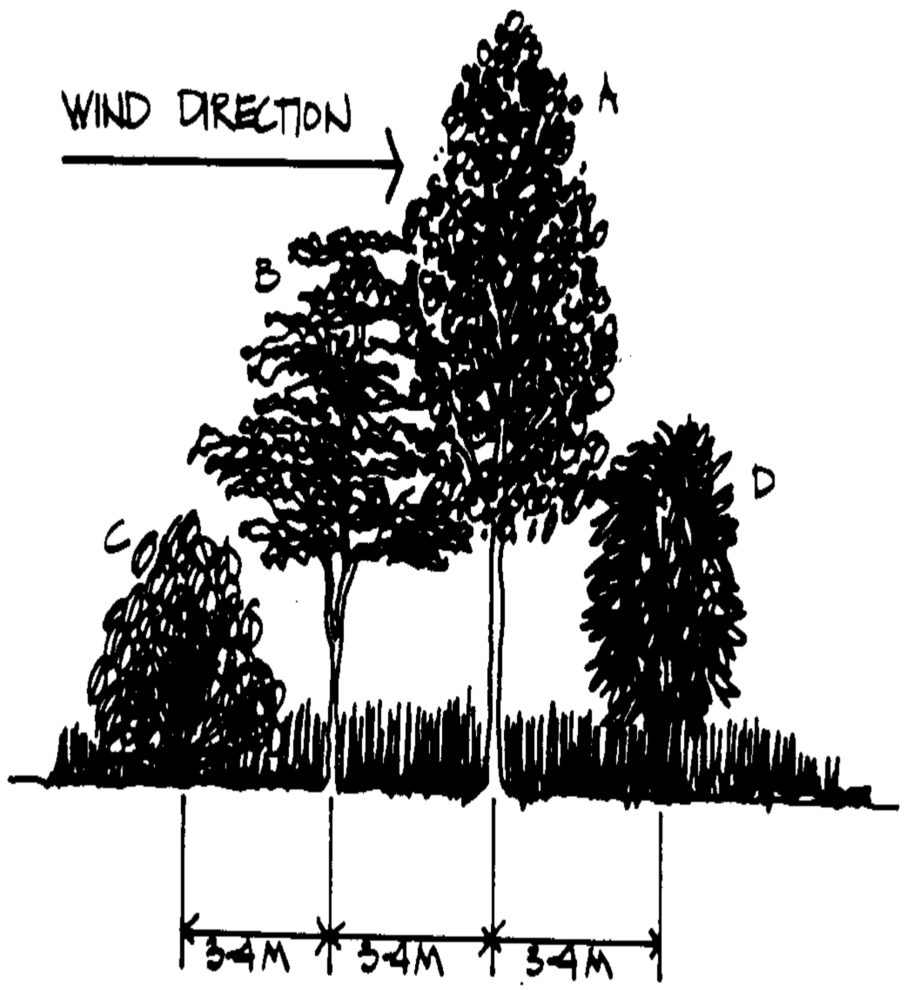

This windbreak is protecting the cropland from high winds, which would carry away topsoil and make the land useless for farming.

Windbreaks and shelterbelts can be laid out to include roads, trails, or driveways for livestock. In this

way, animals and people can benefit from a shaded passageway that otherwise would be very hot. Any path through the windbreak should be at an oblique angle rather than perpendicular to the tree rows. This will allow people and livestock to move through the windbreak without opening a gap for the wind to roar through.

<WINDBREAK>

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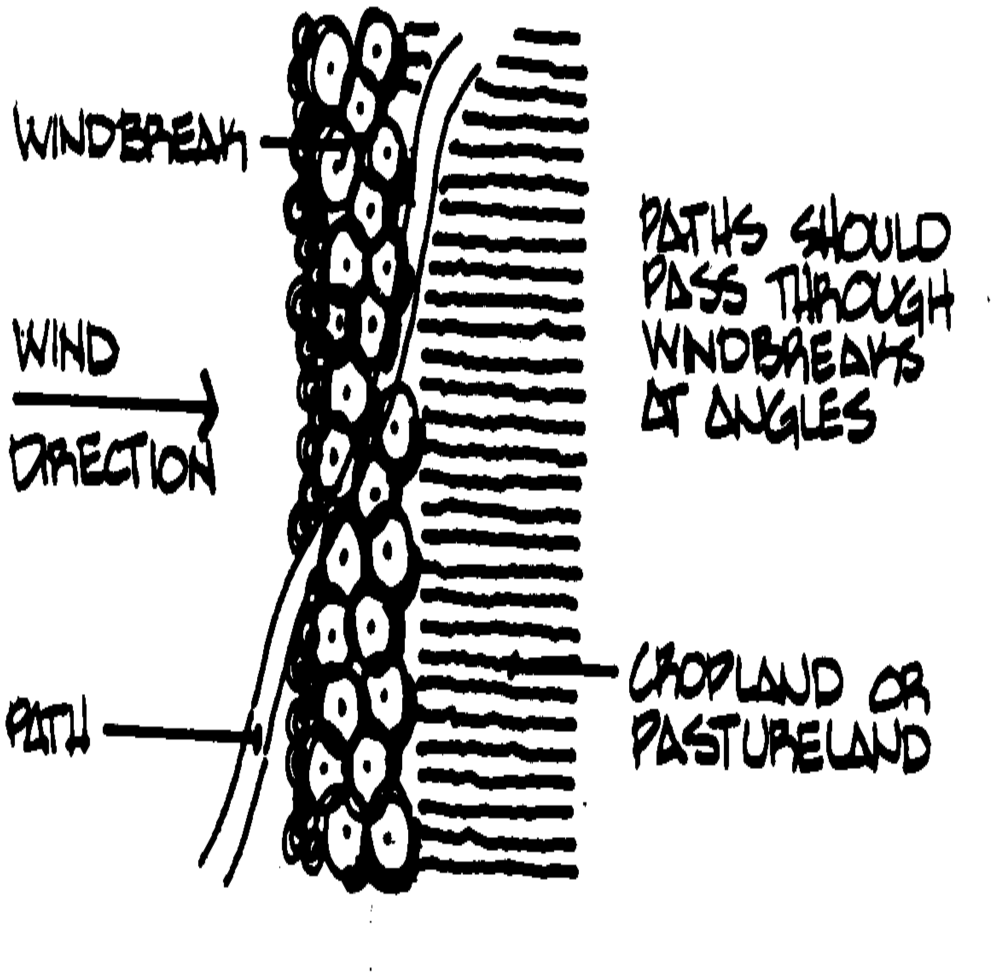

Some other points to consider about windbreaks:

o Species chosen should obviously be suited to the soil and climate where they will be grown.
Local species are preferred Good selections can be made from species protected by law.
Use species local residents themselves have chosen and value.

o The most efficient windbreaks are those with one or two rows of low-growing shrubs or trees on the outside and two or three rows of taller trees on the inside.

o The utility of wider shelterbelts can be enhanced by the selection of multiple use
species for the middle rows. Species that provide locally consumed fruits and medicines should definitely be considered.

o Frequently a combination of planting methods is highly practical when establishing
windbreaks. In other words, a combination of nursery transplants, live fencing, cuttings, and stumps can be used depending on planting times in the area.

o Preparation and protection of the site involved are possibly more important for
windbreaks than for regular plantations. During the rainy season when crops are being cultivated, the fields are effectively protected from livestock, however, after the
harvest the animals are often allowed to browse the crop residues left in the fields. Keeping livestock away from the windbreaks during this time is difficult, and
fencing a long narrow strip of land is costly.

o Where complex land ownership patterns exist, it may not be possible to establish
continuous straight tree rows across individual fields and parcels. In this case windbreaks may be staggered so that they conform with established boundaries

**such as
borders of fields, roads, trails, stream, and other natural or man-made features. Staggered
windbreaks also provide the most effective protection around towns and villages, where
they are laid out in a pattern of overlapping blocks.**

<SHELTERBELTS>

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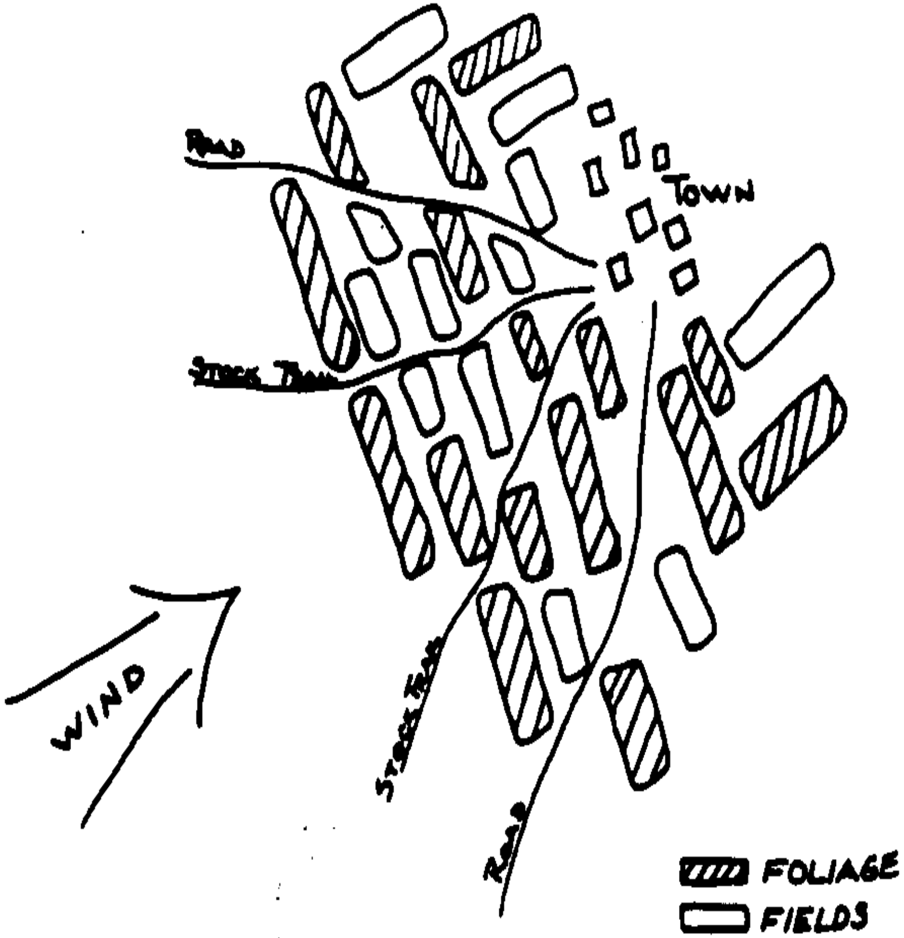

Shelterbelts

o Another possible planting pattern is to line farm fields with wide windbreaks and to
Plant dispersed trees inside the field.

o Many nurseries in arid zones could benefit from the establishment of a windbreak to
protect the seedlings from drying winds. The nursery windbreak also serves as a demonstration to visitors to the nursery. If the nursery is very small, however,

a tall windbreak might cast too much shade on the seedlings.

<SAND STABILIZATION>

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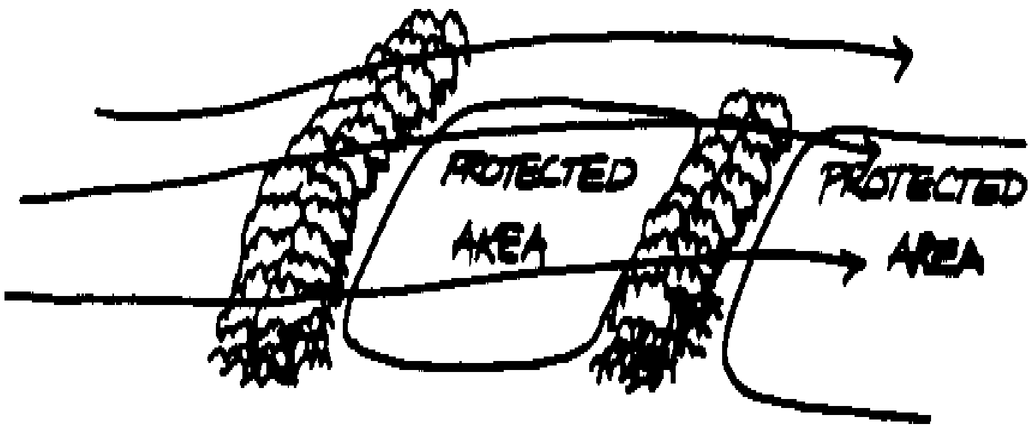

Sand Stablization

Sand stabilization is an important aspect of revegetation and conservation activities in many arid and coastal areas. Shifting and blowing sand causes great damage to farmland, buildings, installations, and roads. Entire settlements can be threatened by the movement of shifting dunes.

The best protection against drifting or blowing sand is to prevent the sand from

being picked up by the wind and becoming airborne. Conservation of existing grass and other vegetation cover is necessary to hold the sand in place. Even a small disturbance such as a footpath can start the process of erosion on fragile dunes. Once airborne, drifting sand can be made to settle, nevertheless, and can be kept from further shifting.

The first step is to determine why the natural vegetation has not recolonized the area that is being eroded. Various options that will remove any constraints to natural vegetation should then be considered. Often the problem is being caused by animals. Under these circumstances, little if anything will be gained by planting trees, unless access is first controlled.

There are basically two approaches to dune fixation: biological and physical. The best ultimate results are obtained when the open area where sand is picked up can be permanently covered by vegetation.
Biological methods include:

o Fencing off the area to protect it from animals, so that the vegetation can regenerate naturally.

o Establishing hedge rows of species that can be successfully regenerated from cuttings even in areas where annual rainfall does not exceed 300-400mm. Freshly

cut
branches can be partially buried in rows of shallow trenches.

o Direct seeding, particularly of grasses, but also of woody plants such as vines,
shrubs, and trees.

Often before grasses and other ground cover can be reestablished, however, the movement of the sand
must be halted. Physical dune stabilization measures include:

o Wind-baffles (palisades), which are constructed of a variety of materials, generally
whatever is locally available.

o "Fore-dunes," which consist of sand or soil ridges set at right angles to the major
winds. They can be 1 to 5 meters high and stretch over hundreds of meters in
length. Heavy construction equipment is required for large-scale efforts.

o Mechanical surface stabilization, which is accomplished by covering exposed areas
to reduce further erosion. Plastic sheeting, nets, cloth, or some other fiber
are used.

o Chemical surface stabilization, which involves spraying a binder (rubber, oil, or
plastic base) on the surface to bind particles together. Grass seeds and mulch can

also be mixed with the binder and sprayed on the area to be protected.

Preference should be given to biological control measures whenever possible. However, some physical construction is often needed for initial plant establishment. Usually some type of low-cost materials are available locally. This barrier can take many forms and be made of a variety of materials.

<WINDBREAK FENCES USED FOR SAND STABILIZATION>

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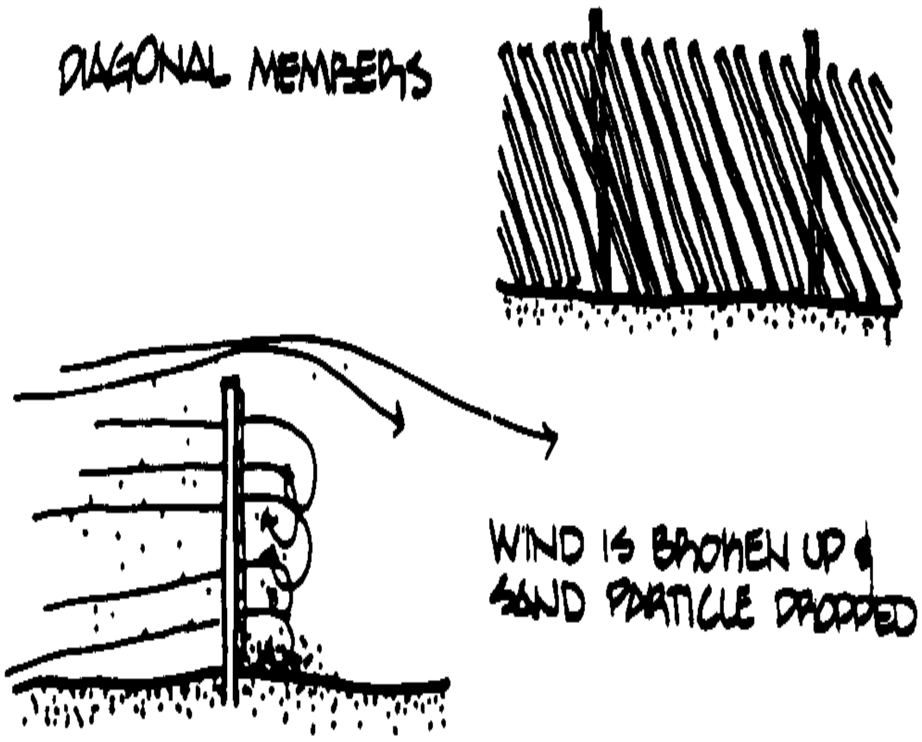

Windbreak fences used for sand stabilization

Stems and poles (3-8cm in diameter and up to 2m long) can be used to construct a diamond pattern of criss-cross rows across areas of open sand. Branches can be staked out in dense rows, or fences can be woven from branches to construct the palisade. By breaking the force of the wind, the palisades keep the exposed sand from being picked up, and the sediment load already carried by

the wind is deposited in or behind the barrier. Sand will become entrapped in such rows, and ridges will gradually form. Plant growth then becomes possible in the protected areas behind the ridges.

Fenced in squares and other sand traps can also be constructed of materials as basic as bundles of grain stalks or other crop residues. Additional possibilities include palm fronds, sticks, branches, cardboard, or any material that is reasonably sturdy, easily available, and low cost. Some of the problems that may be encountered in maintaining the barriers include damage from animals and termites that are attracted to them for food. Where sand accumulations are heavy, the barriers may have to be raised or added to periodically.

<TYPICAL WIND BARRIER PATTERN>

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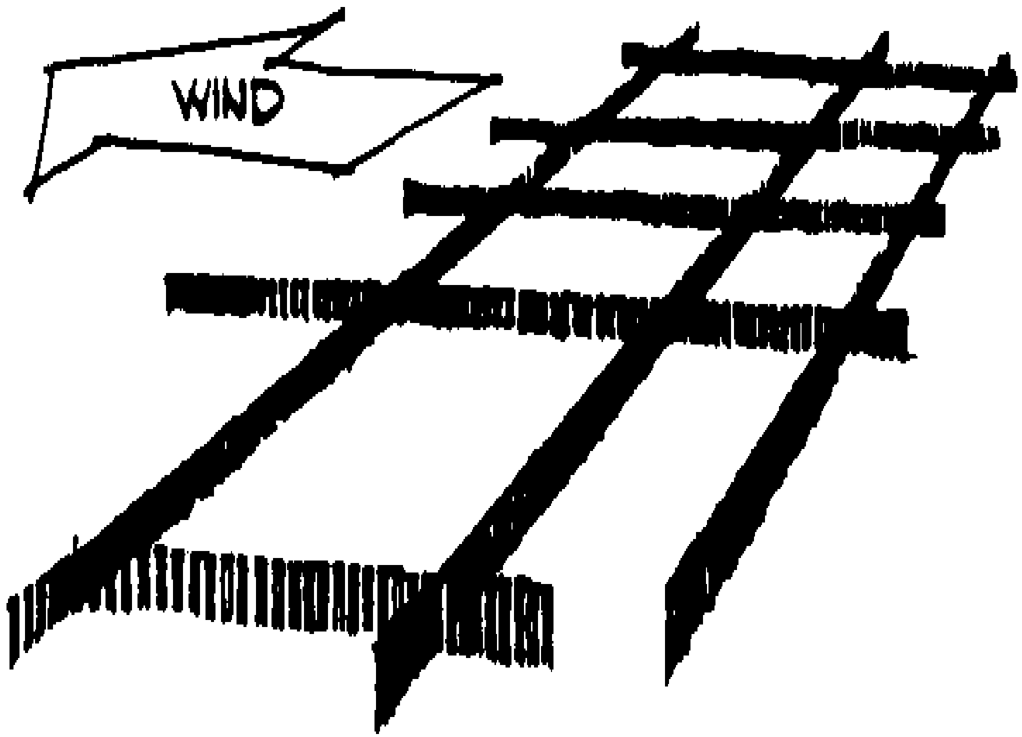

Typical Wind Barrier Pattern

Before beginning a sand or dune stabilization project, planners should consider the following:

o Dune fixation is not an appropriate conservation investment if the area that is being threat
ened by shifting sands has no inherent value. Unless some benefit will accrue in terms of

protection of farmland, homes, or other property, the cost is prohibitive. Furthermore, those who will gain the most from the project should also be willing to exert the most effort, particularly in terms of sustaining and protecting the vegetation cover.

<DETAILS OF PALISADE NETWORK>

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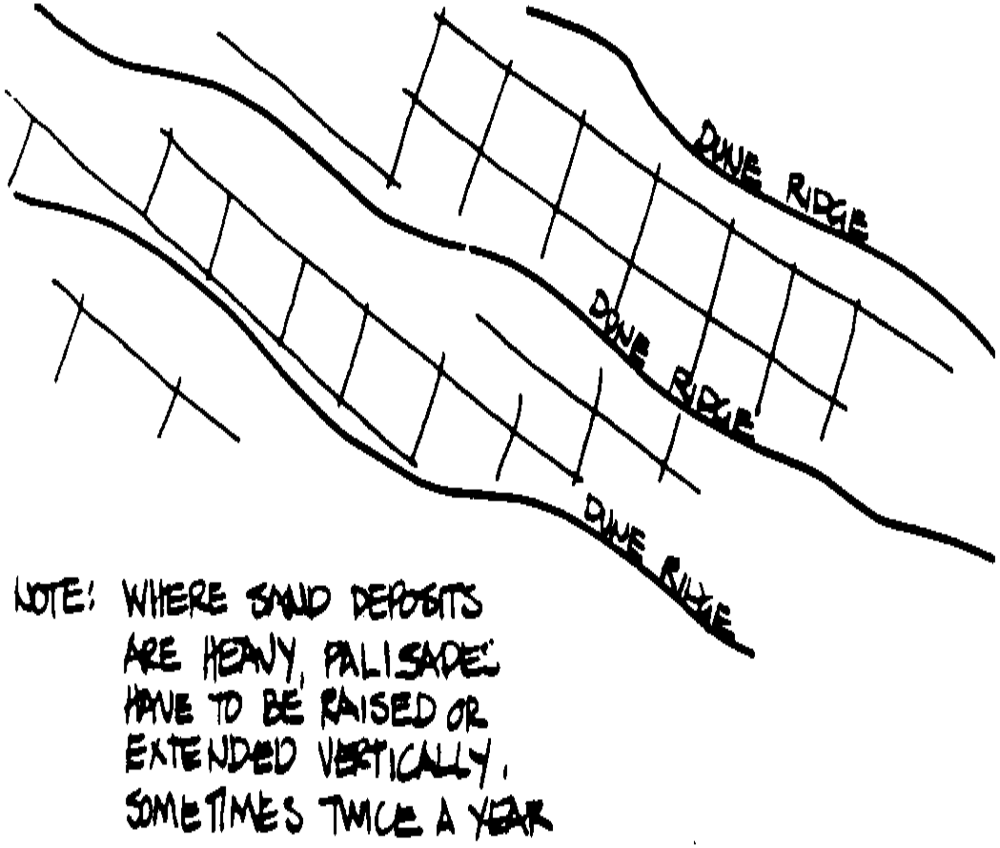

Details of Palisade Network

o Dune fixation projects should not be undertaken without first carefully evaluating traditional and current land use attitudes, especially those governing grazing and wood cutting. If these are incompatible with the restrictions needed to protect the vegetation, then changes in land use policies and practices must take place before dune fixation activities are

initiated.

o The shifting of live dunes is influenced by a complex set of variables, and may change with the seasons. It is worthwhile to observe and measure dune movements for a period of 12 months before starting stabilization activities.

<DUNE STABILIZATION>

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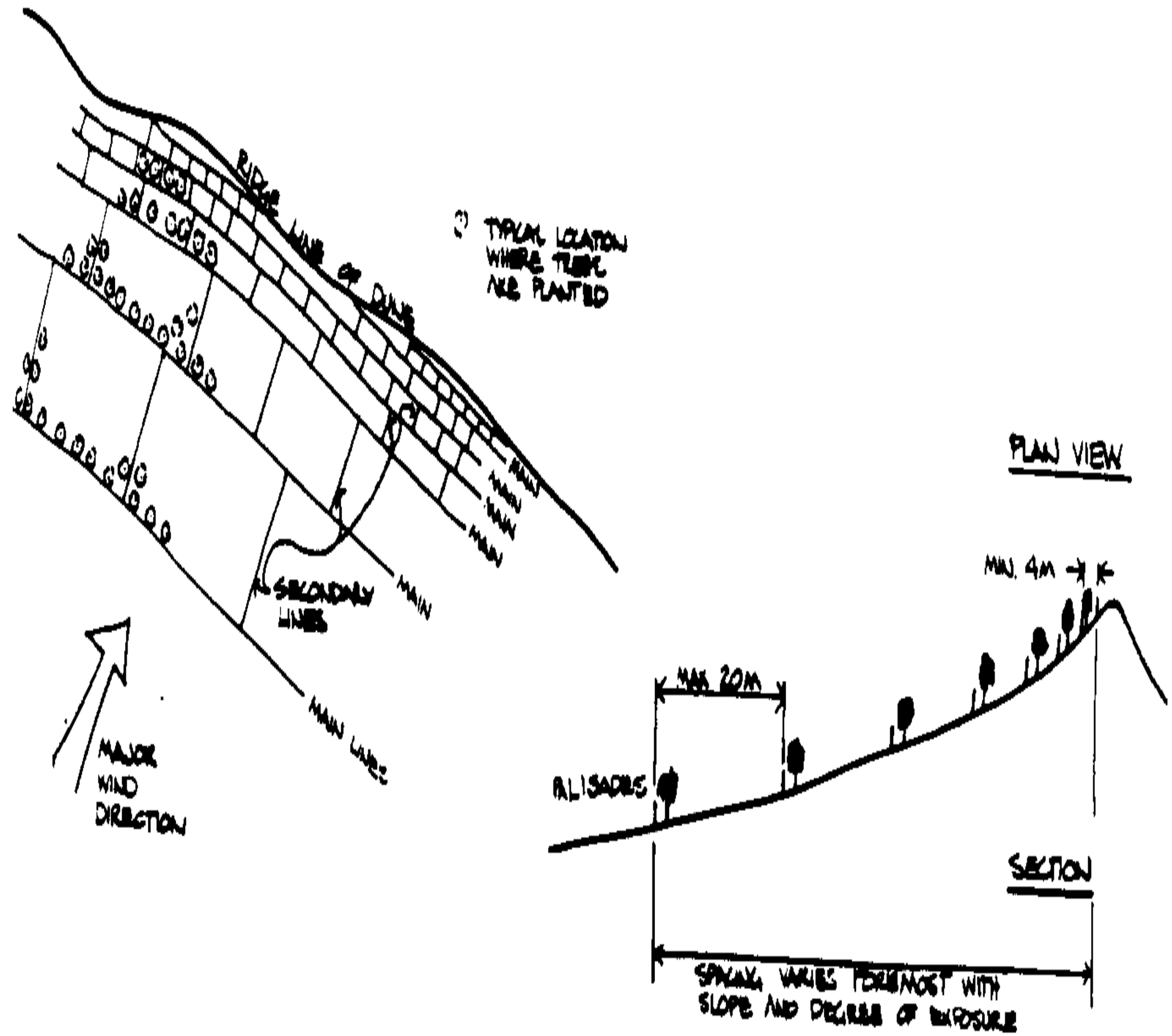

Dune Stabilization

o Except under extreme desert conditions, it is more effective to stabilize the zone of

origin of the shifting sand, rather than concentrating efforts on the areas where the sand is being deposited. It is important, therefore, to determine the location from which the sand is being removed by the wind.

o Project sites that are close to or within actual desert zones will require more intensive efforts to stabilize shifting dunes. Maintenance inputs will also be higher.

o The more exposed a specific location is to the wind (near the crest of large dunes, or in saddles between ridges), the more difficult it is to establish vegetation. Physical protection is often needed. If it is not possible to use physical control measures, however, the area can still sometimes be stabilized after the top has been lost to wind erosion.

o Locally occurring trees and shrubs have great resiliency. In species selection, the indigenous vegetation should receive priority over exotics, particularly for large-scale projects.

III. CONTROLLING WATER EROSION

Contour Strips

The most likely, logical place to use trees and shrubs to halt erosion caused by

water is across slopes, particularly where hillside cultivation is practiced. Properly maintained trees and shrubs, planted in combination with grasses and other vegetation, can effectively control surface runoff, thereby reducing soil losses. One successful technique involves establishing parallel vegetation bands along contour lines.

These contour strips will reduce runoff from the slopes above if they are designed and maintained to ensure a dense, multi-layered permanent ground cover. The ground surface is protected by successive layers of litter, grasses, other ground plants, bushes, and trees. A dense vegetation belt will not only stop or slow down runoff, but will also trap soil particles suspended in the water that have been removed from the more exposed areas between the strips.

<CONTOUR STRIPS>

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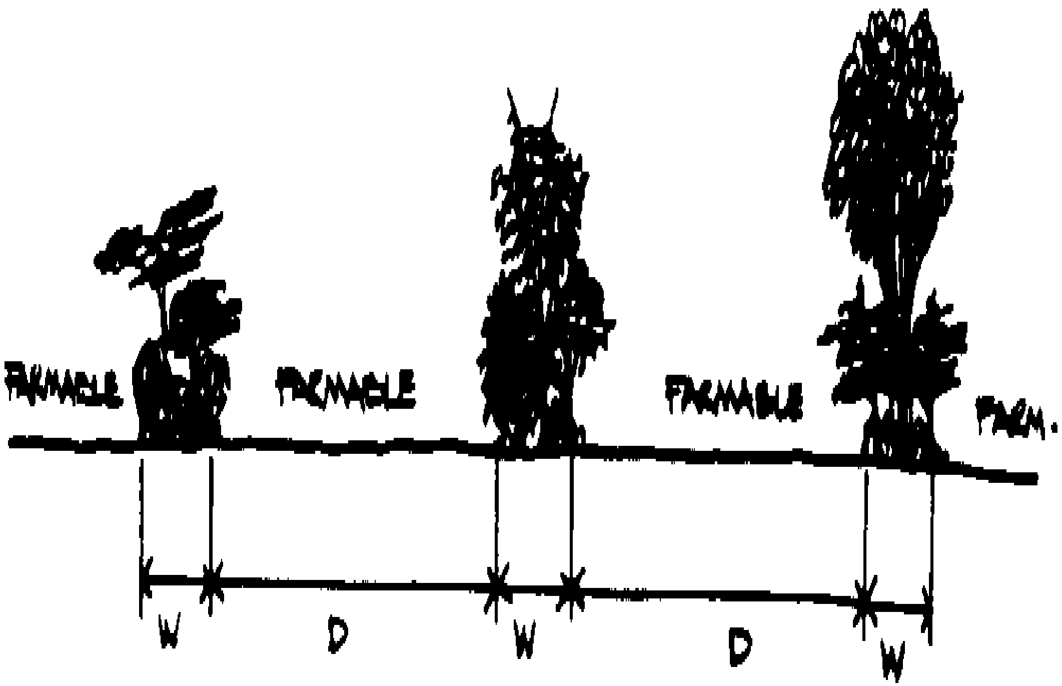

D=Distance between contour strips
W=Width of the band of vegetation in the contour strip

Correct dimensioning of the D and W variables indicated in the illustration above is important. Many factors affect the spacing of the strips, but the degree of slope is the most important. If previous efforts

to establish contour strips in the area are available for study, these sites should be observed for evidence of erosion to determine if the dimensions are in proportion. Conservation services may also have tables or formulas appropriate for local site conditions. If no information of this kind is available, dimensions can be calculated using the following table as a rough indication of spacing in arid and semi-arid areas:

Slope (degrees)	W (meters)	D (meters)
0	2	50
5	4	47
10	5	43
20	8	38
30	10	33
40	13	28
50	17	24
60	20	20

Basis: 0-600mm mean annual precipitation

**In areas with rainfall between 600-1,000mm: increase W by 20%
decrease D by 10%**

**In areas with rainfall more than 1,000mm: increase W by 50%
decrease D by 20%**

Revegetation efforts on these strips can be approached in many ways. To simply establish some groundcover, scarification of the ground along the contour may be sufficient site preparation. Furrows can be dug by hand or by using a harrow or disc blade. More intensive effort may consist of additional seedbed preparation, for instance, loosening up the soil surface and raking along the contour. Direct seeding of desirable trees and shrubs may be feasible for some species. Other trees can be established by cuttings. The most direct, but also most costly, method of establishing contour strips is by planting nursery raised seedlings.

The primary consideration for species selection should be local preference, because the contour strips take a certain percentage of the land out of cultivation, even though they are intended to increase productivity of the total area. Many different species can be used, often in combination. Fruit trees are frequently a high priority on farmland. In other areas, trees that produce poles for construction, rafters, and fences may be preferred.

Particular attention should be given to vegetation layers nearer the ground surface. Fodder plants, such as Guinea, napier, clover, or elephant grasses, may be of interest for feeding to penned livestock.
Perennial bean species, produced on small woody shrubs for human consumption,

may appeal to the local inhabitants. Contour strips can be a good location for introducing new species on a small-scale, experimental basis as well.

Terracing

For centuries, farmers living in hilly and mountainous regions of the world have been terracing their hillsides as a means to prevent soil erosion. Terraces are simply channels cut into hillsides, embankments built onto hillsides, or a combination of the two constructed across the slope of the land. They have proven to be the most effective mechanical means of erosion control on slopes planted in continuous row crops. As much as 85 percent of the sediment eroded from a field can be trapped by terracing.

There are four basic terracing designs. In the level bench design the terraces are parallel with the horizon, whereas in the sloping bench design the terraces are leveled so that their planting surfaces have a slight downward angle. The reverse slope or step terracing design has terraces that have planting surfaces that angle upward slightly. The fourth terracing design, used primarily in conjunction with flood irrigation, has terraces that are parallel with the horizon and have a built up outer edge to prevent water runoff down the hill.

<FOUR TERRACING METHODS>

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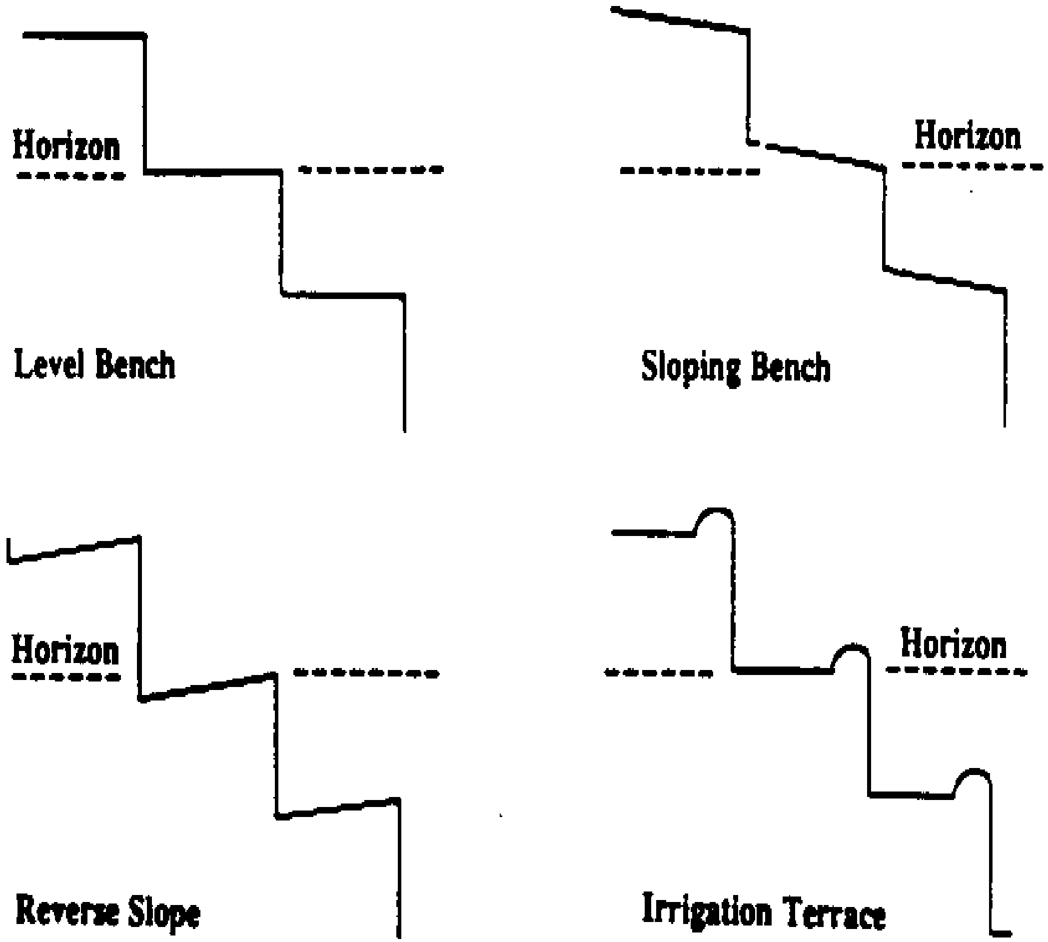

Four Terracing Methods

Trees Along Contour Ridges

For information on the various applicable soil conservation measures that involve construction of contour ridges or terraces, or excavation of infiltration ditches, a number of texts are available. The Centre Technique Forestier Tropical (CTFT), the Centro Agronomico Tropical de Investigacion y Ensenanza (CATIE), the International Council for Research in Agroforestry (ICRAF), and the United Nations Food and Agriculture Organization (FAO) have all published handbooks and technical materials on the subject. In addition, many of the bilateral donor organization have developed standard texts on the subject during the past decade. Construction designs and extension materials have been developed specifically for certain countries, among them Honduras, Kenya, Burkina Faso, and the Philippines.
There is still relatively little information available, however, that deals with the effective combination of biological and physical erosion control measures. Vegetation, especially trees and shurbs, can play a vital role in increasing the effectiveness of soil and water conservation efforts. Properly established and managed woody plants can reduce maintenance and costs on hillside erosion control projects as well.

The following sketch shows where trees and shrubs can make an important

contribution to physical ridge or ditch formations along the contour lines of sloping surfaces.

<GRADUALLY DEVELOPING BENCH TERRACES>

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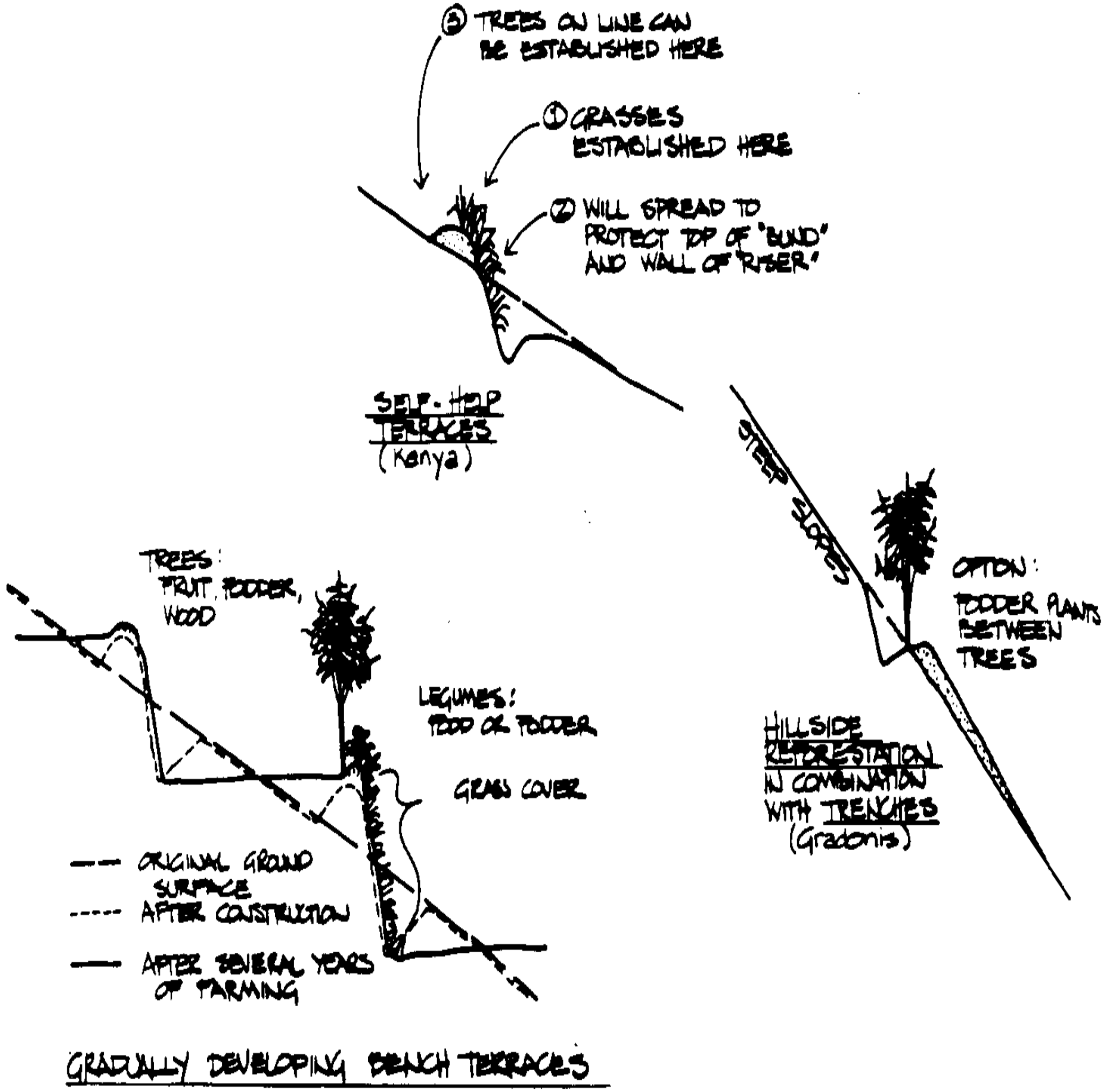

Gully Reclamation

Permanent vegetation, especially shrubs and trees, can reduce bank or channel bottom erosion as long as the flow of water is not too powerful. Vegetation can also help stabilize mechanical protection materials, such as large rocks positioned along banks or bottom (rip-rap), wire mesh baskets filled with rocks (gabions), or bales of straw or branches staked in place to reduce water velocities.

Gullies present special problems, because they often occur on steep slopes, and even brief peak flows can cause serious damage. Gully erosion is difficult to reverse once it has gotten started, and it can quickly destroy valuable agricultural land.

To prevent the formation of gullies along waterways, the banks should be lined with trees and shrubs. Trees, shrubs, and other vegetation can be established within the gullies to control further erosion and to help rebuild the soil layers that have been removed. Improperly placed trees can, however, have the undesired effect of narrowing the channel and increasing the speed of stream flow. The following sketch shows how to combine vegetation with mechanical gully erosion control methods for optimal results.

<GULLY CONTROL: COMBINING PHYSICAL AND VEGETATIVE METHODS>

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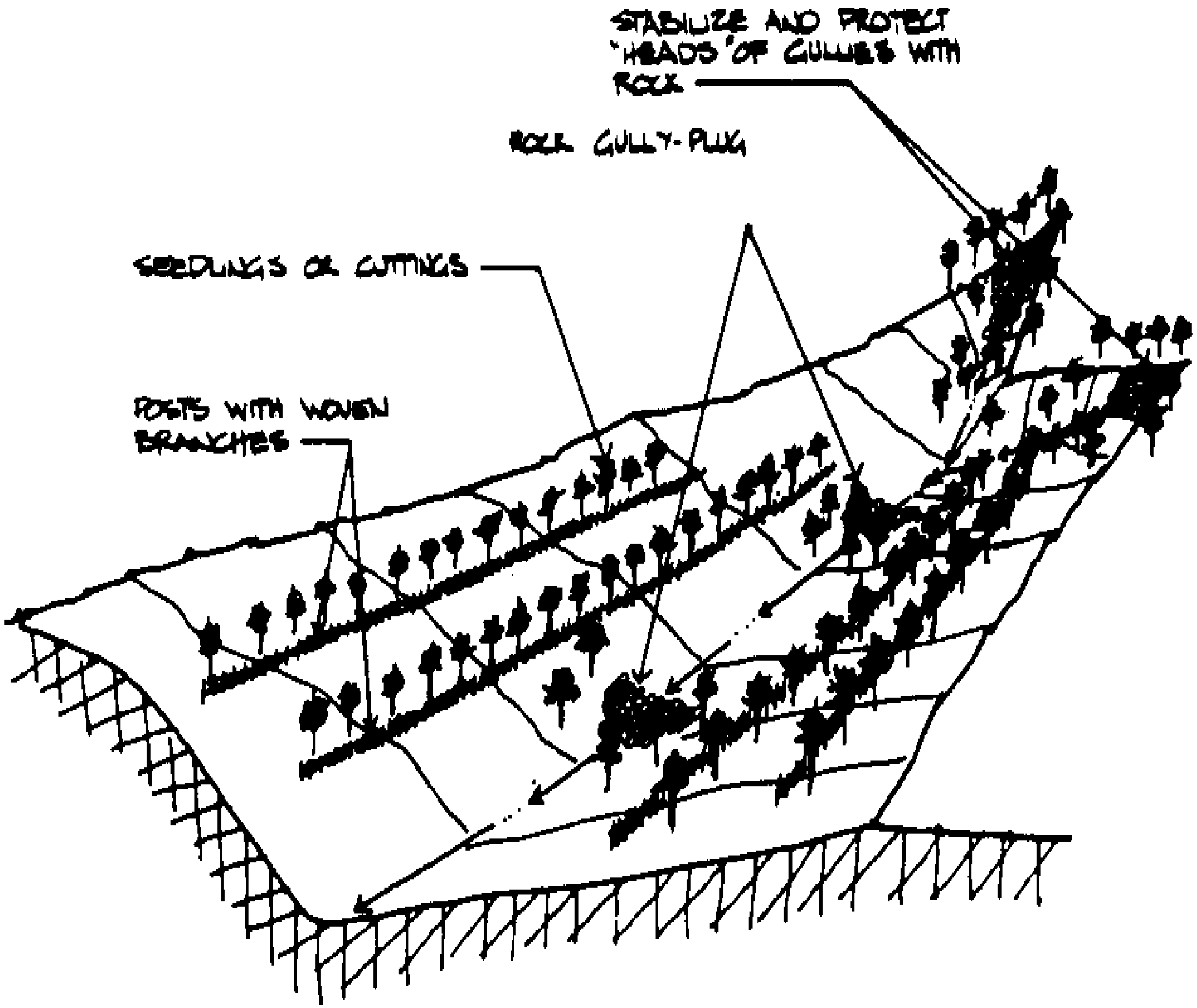

Gully Control: Combining physical and vegetative methods

IV. CONSERVATION TILLING

Conservation tilling is a general term that includes a number of tilling methods, used alone or in combination, to conrol erosion caused by both wind and water. The methods have in common the goal of disturbing the surface of the soil--as by plowing--as little as possible.

In general, the dominant factor in determining the effectiveness of conservation tillage practices is the amount and distribution of crop residue left on the soil surface. However, the amount of crop residue mixed into the soil during tilling, the type of soil, size and location of untilled residue strips, contour ridging, and surface roughness are all important factors contributing to soil loss prevention.
Wind erosion control can be established by developing vegetative and non-vegetative land cover, reducing field lengths along the prevailing wind direciton, roughening or clodding the land, and terracing slopes and hilltops where converging winds increase velocity and shear stress.

Crop residue and mulches help to reduce both water runoff and the amount of sediment contained in the runoff. Ground roughness and clods created through tilling increase water absorption and reduce water runoff velocity. Ridging on the contour also substantially reduces runoff velocity and soil loss.

Low-till and no-till farming practices combined with residue mulch cover and

contour planting can reduce the soil loss ratio of a field from .63 in conventional across-slope plowing and planting to .12 in the first year of implementation and to .04 by the end of the fourth year. Examples of no-till farming systems include the following:

1. Sod-planting--in which maize, for example, is grown in combination with cool-season perennial grasses.

2. Sod-strip planting--in which six rows of maize are alternated with 8m parallel strips of established grasses across the general slope of the land. Each year 1 1/4 rows of maize is advanced down the slope and the upper border is reseeded to a mixture of grass and legumes.

3. Complete pasture renovation--sod-planted maize method extended into entire fields where erosion is too severe to permit conventional tillage.

4. Interseeding legumes and/or grasses into established grass.

5. Planting in winter cover crops.

6. Planting in crop residues.

7. Multi-cropping systems--maximizes production by providing three crops in two years or five crops in four years.

<CONTOUR PLOWING AND PLANTING>

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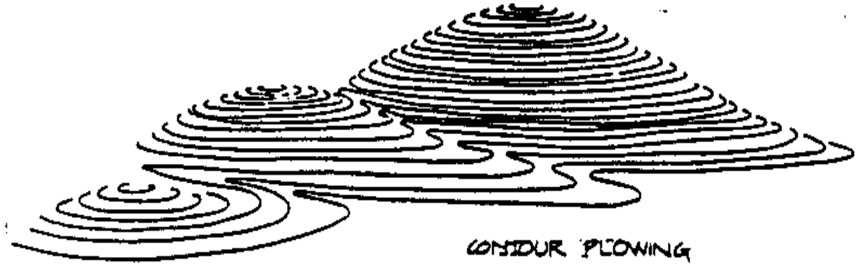

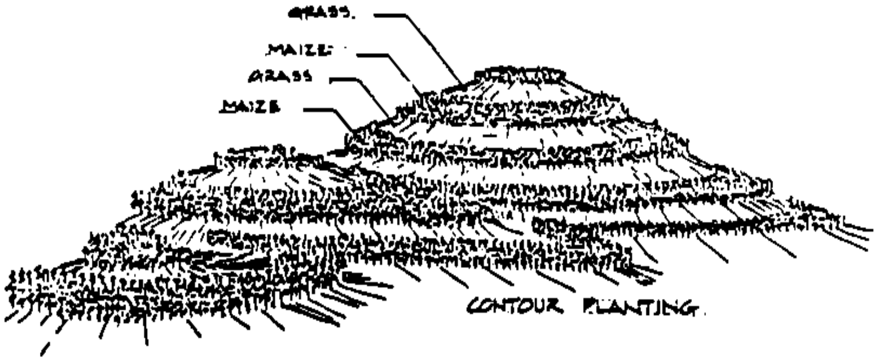

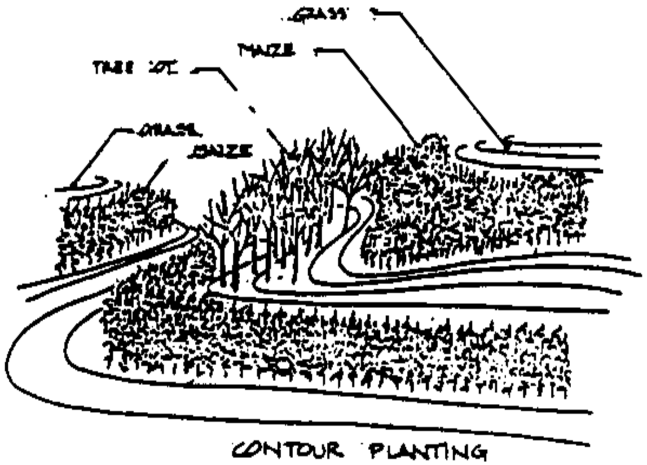

Contour plowing and planting are more popular than terracing because of their lower production and

maintenance costs (both real money and time). In the contour system, both the plowing and planting are done across the slope and follow the natural contour of the land. Contour strip cropping is an even ore efficient means of soil erosion, but this efficiency is offset by a loss of the major crop yield. However, the alternating forage crop compensates somewhat for this loss.

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