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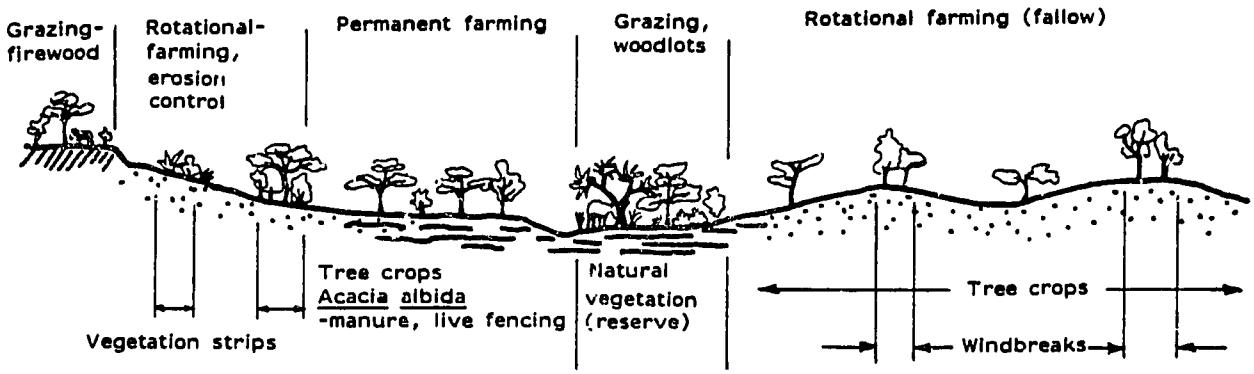
SOIL CONSERVATION TECHNICAL SHEETS

Fred Weber
Marilyn W. Hoskins



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University of Idaho
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U.S.A.

SOIL CONSERVATION TECHNICAL SHEETS

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INTRODUCTION

During a soil conservation seminar for technicians from CILSS countries[1] begun in 1979, a series of hand-outs was prepared, briefly describing various conservation techniques that may be useful in various local situations. At the end of the course (1981), these sheets were assembled and distributed to the participants with some extra copies transmitted to technical agencies and donor organizations interested in this general subject. Subsequently, requests, still continuing, for additional copies in both English and French have exhausted the original supply.

To provide additional copies, the United States Department of Agriculture (USDA), in collaboration with the United States Agency for International Development (USAID), has asked the authors of the original text to prepare a second version. Under the overall direction of the University of Idaho's Forestry, Wildlife and Range Experiment Station, the original format has been expanded and updated to better serve training, information and extension needs of field technicians across the Sahel.

Valuable assistance and cooperation from the following people and agencies contributed to the preparation of this edition:

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1 Cape Verde Islands, Chad, the Gambia, Mali, Mauritania, Niger, Upper Volta and Senegal.

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SDPT/Bamako

Depending on the nature of the basic problem at the different sites, soil conservation activities aim to reduce or reverse:

1. declining farm soil fertility (farm land);
2. deteriorating natural vegetation (open areas);
3. wind or water erosion (both farm land and open areas).

Many activities can be undertaken to improve conditions. Most are described in various texts. The following pages summarize essential information for some of the more common methods. Range of application, design criteria, and location of previous experience are outlined and combined with data on local participation, possible production benefits, etc.

In choosing one or a combination of efforts, it is of critical importance to know the nature and extent of the present problem and the priorities of the local population, as well as the effect the various soil, water or vegetation conservation activities will have on the people and their environment.

Socio-political and economic factors, just as physical factors, limit the choice of appropriate technical solutions. Requirements for availability and control over land, labor, benefits, extension and local organization differ in various types of soil conservation activities. If, for example, (1) farmers are unsure of their continued access to land, if (2) labor is in short supply during planting season or after harvest, if (3) benefits are delayed in an area where farmers are too poor to

wait, if (4) extension services are limited, or if (5) the community is not traditionally

organized for group activities, then either technologies must be chosen which do not require these factors, or the project design must somehow overcome the specific handicap. Failure of so many efforts has revolved around selecting technologies and designing activities without also considering the non-physical environmental factors.

It is essential to look at all five socio-economic and political requirements of a potential activity. Requirements need to be discussed with residents and involved local field agents to verify that the technology chosen is not only suitable technically but has the potential for successful implementation.

TABLE OF ACRONYMS

AFR/DR/SDP	African Bureau/Development Resources/Special Development Programs
CARE	Cooperative for American Relief Everywhere (a non-profit organization through which donors supply goods and services for relief, rehabilitation, and reconstruction)
CILSS	Comité Permanent Interétats de Lutte contre la Sécheresse dans le Sahel (Permanent Interstate Committee for Drought Control in the Sahel)
CTFT	Centre Technique Forestier Tropical
FAO	Food and Agriculture Organization (United Nations)
ICRAF	International Center for Research in Agroforestry (Nairobi)
IRAT	Institut de Recherches Agronomiques Tropicales et des Cultures Vivriéres (GERDAT) Groupement d'Etudes et de Recherches pour le Developpement de l'Agronomie Tropicale
NAS	National Academy of Science
OMVG	Organisation de Mise en Valeur du fleuve Gambie
OMVS	Organisation de Mise en Valeur du fleuve Senegal
SCS	Soil Conservation Service
SDPT/Bamako	Sahel Development Programming and Training
SODEVA	Société de Developpement et de Vulgarisation Agricole
USAID	United States Agency for International Development
USDA	United States Department of Agriculture

GLOSSARY

agroforestry - a system of land use incorporating trees and animal raising with cropraising and other agricultural practices.

baffles - structural element such as wall built to deflect, check or slow the flow of water.

berms - ridges of soil, level or near-level to hold back water or reduce erosion by runoff.

biomass - any live matter in a given environmental system. Here: total of vegetative matter on any given surface.

"dead" fence ("zeriba") - rows of cut (thorny) branches, piled up high enough to keep animals out.

demarcating land - establishing boundaries of land parcels.

"diamond ditches" - a series of gradient ditches and ridges criss-crossing a slope and dividing the surface into rhombohedral units.

draws - small, "v" shaped valley.

fore-dune system - a series of stabilized dunes or other barriers located windward of areas to be protected.

gabions - rocks placed inside wire-mesh cages.

gradonis - small, half-moon shaped ridges of soil placed around individual, recently planted trees to concentrate and retain runoff in root areas.

infiltration ditches - trenches dug to allow water to accumulate and seep into soil.

laterite - a material formed by leaching and consolidation of soils occurring under specific climatic conditions in the tropics.

leguminous species - a group of plants (Leguminosae) bearing legumes or pods.

live fencing - shrubs or trees planted closely together and trimmed to produce a barrier to keep grazing animals out of farm fields, gardens or compounds.

low elevation check structures - structures placed across flowline of channel less than 1.5 m high.

manioc fields - manioc = cassava. Plots of land where cassava is cultivated.

millet soils - loose, sandy, well-drained soils.

riprap - rock courses placed along stream banks or bottoms to prevent erosion or slowdown the flow of water.

rivulets - very small channel formed by runoff accumulating in a localized depression.

scarified - soil: to loosen surface by scraping, scratching action. Seeds: to break, cut or remove part of the shell surrounding the seed to allow moisture to enter the seed shell, thus hastening germination.

semipervious - halfway between pervious and impervious (restricting passage, impermeable).

soil inocculant - a material containing parts of active microbiologic soilforming (vegetal) matter assuring transfer and establishment of microorganisms beneficial to tree growth.

swales - gentle undulation in a slope where runoff concentrates and begins to form a small, intermittent channel.

weir (of the dam) - opening in a structure (wall, dike, dam) through which water passes.

weir section - surface area of opening in a structure designed to accommodate over-flow.

1.0 METHODS OF INCREASING ORGANIC MATTER

In terms of conservation and protection of renewable natural resources in the Sahel (soil, water, natural vegetation, wildlife) the most important problem is the continuous decline of yields of traditional farm soils. The overriding factor causing yields to decline is the depletion of organic matter which is the carrying agent for plant nutrients and moisture. Immediate action(s) can be taken to increase the organic content. Adding vegetation residue (leaves, crop residue, manure, etc.) increases the microbiologic activities in the soil and produces humus which will act as a sponge to retain more moisture and increase the supply of chemical nutrients to the plants.

Any action that increases the amount of vegetal matter or manure to the soil helps. Place and leave organic matter on the surface or incorporate it into topsoil layers. Providing a more temperate microclimate by reducing soil surface temperatures, for instance, also is critical on hot and arid sites, since this greatly facilitates biologic soil activity, especially humus formation.

1.1 ACACIA ALBIDA

Narrative Description

Introduction, reintroduction or protection of Acacia albida seedlings in worn-out farm fields is very desirable. Acacia albida occurs naturally throughout arid and semi-arid portions of Africa. Although the precise nature of this tree's benefits are not completely understood, crops such as millet, sorghum, or peanuts do much better under and near Acacia albida than in open fields. The presence of Acacia albida can make a decided difference as to whether a field can be cropped continuously without degenerating, or whether soil fertility declines to a point where extended fallow periods are necessary to restore fertility.

Areas of Applicability

Acacia albida is most successfully grown in areas receiving below 800 mm of rainfall (In areas with more rainfall, tree crops usually apply. See 1.2 Tree Crops.).

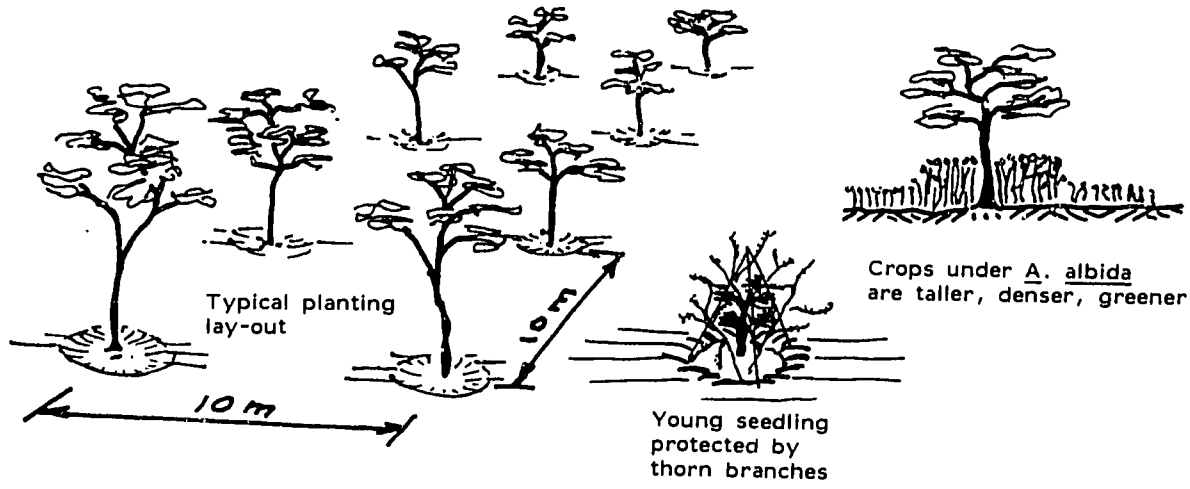
Mostly sandy, well-drained, typical "millet soils" are preferable. However, Acacia albida also have been successfully introduced in intermittently flooded river plains on clayey soils.

This species is especially valuable on overused, traditional dryland farm areas near villages or individual compounds.

Restricting Conditions

Do not plant Acacia albida where natural reproduction is found; protect existing young trees instead. Where mechanized soil preparation is used, trees must be in line. One constraint: Acacia albida attract birds which eat the cereal crops. Therefore, farmers may be reluctant in some areas to have additional trees in or near their fields.

Planting Acacia albida is not a reforestation effort. Use the species only in farm fields, especially where crop yields have been regressing. Species other than Acacia albida can also play a significant conservation role on agricultural land (see 1.2, Tree Crops).



Design Guidelines

Trees can be raised in nurseries during three to four months. Plant 10 m by 10 m; an ultimate density of 40 to 60/ha is recommended. Some direct seeding trials have yielded encouraging results. Always carefully select seeds from large, well-formed parent trees.

Notes on Local Participation

Land: Guaranteed long-term land-use right is essential in interesting residents in planting and protecting a tree which will not grow or change field conditions quickly.

Labor: Added labor may be needed the first year during the busy planting season, but this technique does not require long planting efforts. Surveillance, however, is needed year-round for 3 to 6 years to protect the trees from animals which traditionally browse in fields after harvest. Trees may be protected individually or access to the area may be limited, but either way labor investment is required.

Benefits: If animals access for browsing is changed, farmers may lose valued manure, fodder or other benefits from herders. If the farmers stay after harvest to protect trees they may lose off-season employment. Benefits to soil may take years to realize.

Extension: Farmers already value *Acacia albida*; thus, consciousness-raising may not be necessary. Planting stock, proper organization, timing of production, transport and distribution of seedlings are critical where planting is to be done.

Organization: This can be an individual or family voluntary activity. Outside support may be needed to back up local efforts to protect trees.

Combination With Other Conservation Activities

Especially where land pressure is extreme, combine with windbreaks and live fencing (3.1.1 and 3.1.2). Planting *Acacia albida* along berms (3.2.1.4) also is possible. On slight slopes of heavier soils, *Acacia albida* growth will benefit from "mini-catchments" (4.1).

Possible Production Benefits

Pods for supplemental livestock feed. Limited amount of branches for thorn fences. Above all: crop production under fully grown *Acacia albida* is significantly and consistently higher than in unprotected areas. Studies have shown yield increases in the range of 30% to 60%.

Inputs Required

Plants (seedlings) - where sufficient water is available, seedlings can be grown in family or village nurseries (Upper Volta). Proper planting techniques and timing are very important.

Major, continuous protection is required for at least three years against free-grazing animals.

Location of Previous Experience

Earliest efforts (1930) undertaken in Senegal; several additional campaigns have occurred since then. The latest efforts were jointly carried out by Forest Service and SODEVA (Parastatal organization for agricultural extension).

Positive results were also recorded in Niger (excellent results in Maradi area; direct seeding success near Matameye, with seeds being distributed by sheep and goats).

Good results were also experienced in Chad, between N'Djamena and Bongor (CARE project).

Literature References

Various CTFT articles.

Felker, P. (1978). State of the Art: Acacia albida. Paper prepared under contract AID/afr-C-1361 for USAID. Univ. of Cal., Riverside. 133 p.

CARE Project Evaluation (Chad), CARE, New York.

CARE Acacia albida Training Manual. CARE, New York.

1.2 TREE CROPS

Narrative Description

Apart from Acacia albida (1.1), many other indigenous tree species mix well with farming activities, particularly the raising of staple crops.

While the primary function of Acacia albida is to improve soil conditions, trees covered in this section furnish directly, in one form or another, products of considerable value to the local economy. Their use and management, integrated into farming or grazing systems, has been practised by the rural population for a long time. The full economic and ecologic values of this management formula has recently been receiving more attention from development agencies on national as well as international levels.

Different trees, depending on the region, grow in a park-type farm landscape. Fruit, branches and other portions of these trees provide important food, forage or tertiary products for the local population (tannin, gum, etc.). In many areas, young trees (natural regeneration) are now scarce because of intensive farming, grazing, burning, etc. It is possible to reintroduce many of these species by planting seedlings into farm fields and then protecting them for the first critical three to six years.

Different activities of this kind are described and promoted under the term "Agro-forestry."

Areas of Applicability

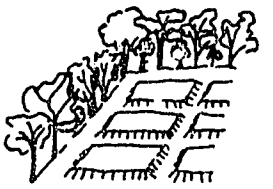
Trees can be introduced in farm fields as far north as land is being cultivated. They are especially valuable in heavily farmed areas

that have been cleared extensively or in other areas where remnant natural vegetation has been eliminated. They are also important on wind- or water-eroded locations.

Restricting Conditions

Apart from lack of moisture, the biggest problem is protection from free-grazing animals.

Trees around houses, compounds, fruit tree plot. Shade trees, mangoes, citrus



Trees along edges of a vegetable garden. Citrus prosopis, Guava, A. scorpioides

Trees in farm fields; intercropping: Karite, Nere, Tamarind, Baobab

Design Guidelines

Space trees so they do not interfere unduly with farming operations, yet provide adequate ground cover and production benefits. Depending on species and cropping patterns, spacing between trees can vary between 5 and 10 meters. Between 60 and 100 mature trees per hectare is the norm. Some species can be established by direct seeding.

Combining trees with cropping and grazing is possible in almost all ecologic zones of the Sahel. Distribution by species is normally along the following general pattern:

Below 250 mm: Acacia raddiana or Balanites aegyptiaca in connection with grazing.

250-500 mm: Acacia senegal in rotation with forage production (and controlled grazing) and--on favorable sites--intermittent millet and sorghum cropping.

350-800 mm: Acacia albida mainly in combination with staple cereal crops (see 1.1).

600-900 mm: Parkia biglobosa, Nere. Ideal agroforestry species much appreciated for its pods.

700-1000 mm: Butyrospermum parkii. Shea nut tree; of great traditional as well as modern economic value.

Site specific: Borassus aethiopum - food and wood; Tamarind - food; Doum Palm - food and mat weaving; Baobab - food; Prosopis africana - utility, wood, high grade charcoal. Fruit trees (mainly Mangoes).

The major problem in establishing stands of these species in farm fields is protection during the first critical years (3 to 5) against grazing damage, fires, and uncontrolled cutting.

The location of each tree should be carefully selected. Planting efforts should include construction of mini-catchment around each tree.

Notes on Local Participation

Land: Long-term land use rights must be guaranteed, or at least rights to fruits or tree products. Trees may compete with crops for land area.

Labor: Additional labor is required during the busy agricultural season for planting. Labor is also required for protection and maintenance year-round during first 3 to 5 years. Trees may be individually protected or access to area limited.

Benefits: If access to animals is changed, farmers may lose valued manure or fodder or other benefits offered by herders. If farmer stays to protect trees he may lose off-season employment. Tree products may take years before benefits materialize.

Extension: Many trees are valued by farmers, but the idea of planting trees may need to be introduced. Planting stock may be required, which involves planning, organization, proper timing, transport, and distribution.

Organization: Activities may be organized by individual family or by community groups, depending upon land availability and/or typical organizational pattern in the community.

Combination With Other Conservation Activities

Ideal in combination with Windbreaks (3.1.1), Live Fencing (3.1.2). Can also be combined with berm or terrace efforts (3.2.1.4-5). This activity should be included wherever other farm/soil improvement efforts are carried out.

Possible Production Benefits

Many of these tree species provide valuable products: food (leaves, fruit, oil); also fibre and pharmaceutical products. They may also provide branches, sticks, and leaves for mats, as well as thatch for roofing, etc.

Inputs Required

Same as *Acacia albida* (1.1).

Location of Previous Experience

Upper Volta (Yatenga), Niger (Gaya), Senegal (M'Biddi).

Literature Reference

Reforestation in Arid Lands (Peace Corps/VITA), several ICRAF publications.

Delwaulle, J-C. (1978). Plantations Forestiéres en Afrique Tropicale Sèche. CTFT, Nogent-s-Marne, France. 177 p.

Catinot, R. (1974). Contribution du Forestier. Rev. Bois et Forêts des Tropiques No. 155. 13 p.

1.3 COVER CROPS

Narrative Description

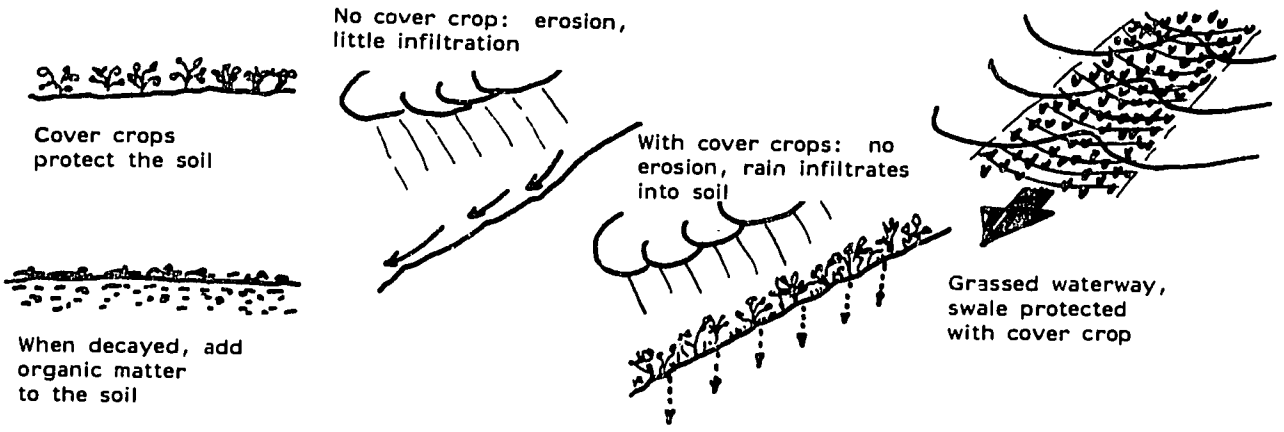
The term Cover Crops refers to the cultivation of crops for the primary purpose of providing ground cover to control erosion and/or add organic matter to degraded farmland.

Areas of Applicability

Cover crops may be applied as far north as land is being cultivated and in special rangeland project areas. There are no restrictions on slopes other than avoiding unsuitable cultivation practices causing heavy erosion losses. Most likely sites and conditions occur where the organic content of farm soils has been declining.

Restricting Conditions

Lack of moisture, uncontrolled grazing, and, to a lesser extent, fire restrict cover crop growth.



Design Guidelines

Leguminous species are best, but one may use plants that cover ground rapidly, are drought resistant and have residues which decompose well: Niebe, Sirathro, Alysicarpus ssp., Dolichos lab lab.

Notes on Local Participation

Land: Guaranteed medium-term land use rights are important.

Labor: Added labor is required both during busy planting season and for plowing under debris after harvest.

Benefits: Short-term fodder or secondary products may be produced, but benefits to soil are visible only after several years.

Extension: Information (perhaps demonstrations) and seeds are needed.

Organization: Can be an individual or family voluntary activity.

Combination With Other Conservation Activities

Should be an integral part of general Farm Management efforts (1.4). Also can be carried out in Vegetation Strips (3.2.1.2).

Possible Production Benefits

Excellent source for livestock feed, additional (intermittent) grazing, supplemental crop production (beans), etc.

Inputs Required

Seed, farm labor, grazing control.

Location of Previous Experience

Numerous experiments (research, IRAT, Bambey, etc.). Most recent efforts: FAO regional program, Niger, Mali, Upper Volta. Contact national livestock services.

Literature Reference

Standard agricultural textbooks.

Secretariat d' état aux affaires etrangérès (1972). Mémento de l' Agronome. Paris. 1153 p.

1.4 FARM MANAGEMENT

Narrative Description

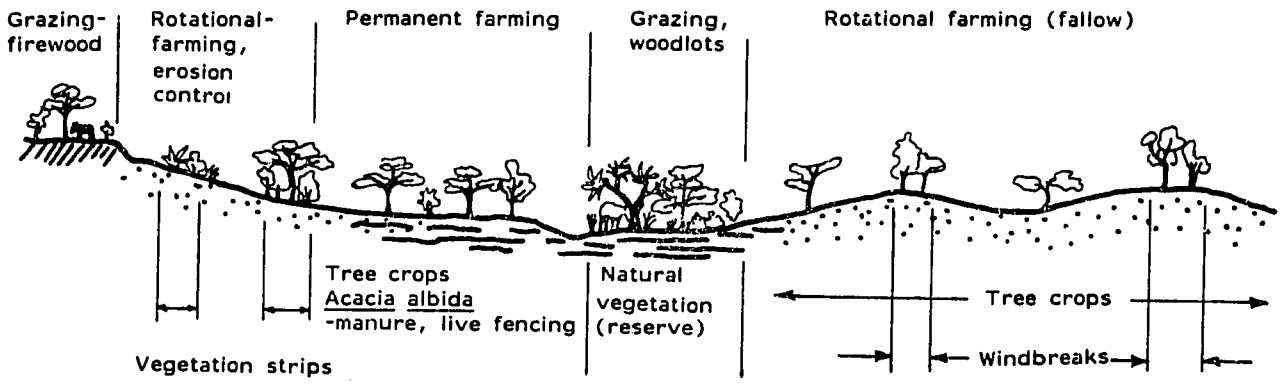
Available farmland is used according to a plan which includes provisions for the restoration and protection of the soil, the available water as well as the surrounding or residual natural vegetation. Optimal farm management may include crop rotation, tree crops, cover crops, use of manure and compost, rotational grazing, etc.

Areas of Applicability

No rainfall limits apply, but note that excessive or careless cultivation below 450 mm may produce irreversible damage to soils and ground cover.

Cultivating slopes greater than 15 percent may, depending on soils, create special water erosion problems.

Farm management techniques are especially useful where land pressures have been rising rapidly and in areas which are intensively farmed.



Design Guidelines

An overall, village-wide resource use plan must be developed showing soil capability, production options, use restrictions and potential degradation hazards and procedures leading to optimal use of the

available natural resources. Within the limits given in this plan, develop the combination of activities and interventions that best protect and improve soil fertility and that prevent erosion losses.

Notes on Local Participation

Land: Guaranteed medium to long-term land use rights are important.

Labor: Added labor requirements depend upon activities selected.

Benefits: Some short-term benefits may be realized, but planning will focus on long range benefits. The selected activity may require limiting access to animals and people, thus losing current use of benefits.

Extension: Collaboration of farmers requires agents with technical skills and sensitivity. Residents must see feasibility and desirability of long-term plan, especially when land use is changed.

Organization: Can be organized by farm family or by community, depending on traditional organizational and leadership patterns.

Combination With Other Conservation Activities

Farm management incorporates many individual conservation and restoration techniques.

Possible Production Benefits

Assures best possible resource use for highest, long-range production benefits of staple and secondary crops, as well as cash crops.

Location of Previous Experience

These techniques have been tested through many pilot activities, demonstration projects, farmer-training centers, at, for example, Maradi, Niger, and through Senegal's local resource planning efforts.

Inputs Required

Dialogue with individual farmers, local commitment, planning, decision-making. For physical inputs, see individual components.

Literature Reference

Senegal: "Reforme Administrative."

Several USAID reports, project documents on "farming systems." Also check international Institute of Tropical Agriculture, Ibadan, Nigeria, research activities and reports.

1.5 MANURE, COMPOST, RESIDUE

Narrative Description

Organic matter is of vital importance to soil productivity. In semi-arid, hot areas, organic matter cannot maintain itself from one season to the next. It is important that during each growing season, a fresh supply of leaves, litter, manure, etc., is added. Under natural vegetation cover, this occurs naturally. This process can be enhanced by adding organic matter, either by reestablishing vegetation (trees or cover crops) or adding manure, compost, etc.

Areas of Applicability

The lower limit of these techniques is around 600 mm mean annual precipitation, unless specially favorable moisture conditions prevail or can be developed. There is practically no upper rainfall limit.

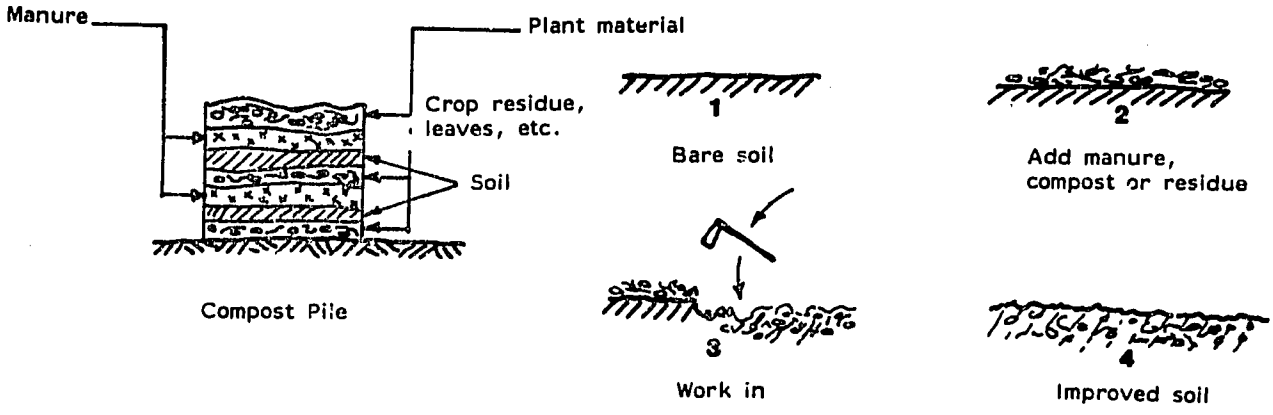
Decreasing benefits occur on slopes steeper than 30 percent.

Most soft, non-woody vegetative matter, weeds, plant residue, can be composted.

Most likely sites and conditions occur where animals are penned, where sufficient water is available for proper composting and where organic substances can be worked into topsoil. The techniques are especially viable on small surfaces, i.e., irrigated gardens, fields near houses.

Restricting Conditions

Heat, intermittent dryness, lack of vegetal matter or manure restrict effectiveness.



Design Guidelines, Criteria

Manure: Spread on farmland, gardens, etc.; work into topsoil, but respect minimum tillage principles (especially on dry, sandy sites).

Compost: Prepare at least two heaps, one for build-up, one for processing. Use proper layer-sequence: vegetation refuse, soil inocculant, manure (or chemical fertilizer where available).

Plant Residue: If nothing else, leave lying on the surface. It is better to work it into (turn into) topsoil. Heavier material (i.e., stalks) should be cut before incorporating into soil (disking).

Notes on Local Participation

Land: Medium-term land-use rights must be guaranteed.

Labor: Additional labor is required at several times throughout the year, and its availability is crucial to selected activity success. For making compost, the task of carrying water may be very time consuming.

Benefits: The benefits may be difficult to see until after the second year. Traditional uses of agricultural byproducts may be lost.

Extension: Most men and women farmers know the value of manure to soil, but many have never seen composting. They may need to see demonstrations to be convinced of the worth of required extra labor.

Organization: Farm family on a voluntary basis.

Combination With Other Conservation Activities

Combine with vegetable gardens, tree crops (1.2), cover crops (1.3).

Possible Production Benefits

The importance of adding organic matter to topsoil cannot be overstressed. More organic matter and more moisture remains after each rain.

Location of Previous Experience

Many pilot and demonstration farms and gardens, Farmers Training Centers, Agricultural Education Centers, etc.

Inputs Required

Compost: labor, material for bins, watering, spreading, incorporating into topsoil.

Manure: collecting, storing, spreading, incorporating into topsoil.

Residue: incorporating into topsoil, disking, harrowing, plowing.

Literature Reference

Many extension pamphlets, texts on agricultural training, farming practices, etc.

2.0 REVEGETATION

All land in the Sahel (with the exception of areas with live dunes or bare rock outcrops) was once covered with different forms of vegetation: grasses, forbs, shrubs, trees. Much of the surface area is now cropland. This has reduced natural ground cover, exposing the soil surface to solar radiation (higher temperatures) and wind.

Areas outside of farm fields also have less vegetation compared to only 20 to 30 years ago. Although a considerable loss of vegetation may be attributed to decreased rainfall, much of the deterioration of the natural vegetation is caused by burns, over-grazing and over-cutting, mainly for firewood, or to clear more land for farming.

The need to restore vegetation on the non-farm areas has increased. More wood and better grazing conditions are required (production aspect). Beyond those considerations, denser vegetation cover is needed to protect adjacent land, reduce wind erosion and to retain rainfall and runoff (protection, conservation aspect).

Properly restored and managed, vegetation on these open areas can produce and protect at the same time. Reestablishing or increasing vegetation is the first step. Several techniques can be used.

Vegetation can be established (regardless of the technique used) only if the conditions which presently prevent plant growth are removed. Before revegetation efforts can succeed, it is of primary importance first to properly identify the conditions which presently inhibit growth, and second, to correct them.

2.1 ACCESS AND USE CONTROL

Narrative Description

Access and use control involves a series of efforts to reduce or, in extreme cases, to eliminate, all use and access to a specific site.

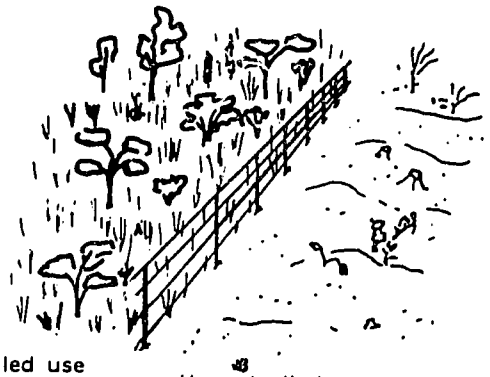
Areas of Applicability

Experience has shown that in many areas natural revegetation will grow back simply by temporarily eliminating grazing, cutting and other uses. Rainfall, soils, and slopes do determine how rapidly natural vegetation can reestablish itself, but generally do not pose any specific limits. Even on extremely dry sites (around Nouakchott, for instance), natural vegetation reestablishes itself where properly protected.

Most likely locations and conditions are heavily overused or extremely degraded sites, near rapidly growing population centers, around large livestock wells, or where live dunes threaten houses, installations, or valuable farmland.

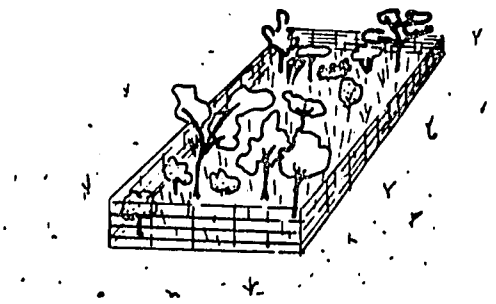
Restricting Conditions

Lack of incentives, commitment of the population, and capabilities of agencies restrict the effectiveness of this method. Limits also occur in areas where natural vegetation has disappeared to such an extent that natural seed sources are no longer available. In such cases, reseeding and planting will be necessary.



Controlled use

Uncontrolled use



Eliminating access is often all that is needed to reestablish vegetation

Design Guidelines

The ultimate objective is optimal, sustained use of an area's natural resources potential. Use control and restriction frequently increase the available resource "capital." Once an area has been reconstituted through use control alone or in combination with other efforts, the land and its cover can be used and harvested again; but on a rational, limited basis only. The extent of harvest will determine the future potential. Overuse may well destroy the resource base (capital) again. Relatively little use may further build up this base, but there are limits. Under-use may result in waste, or at least incomplete use of nature's growth and regeneration potential.

Notes on Local Participation

Land: Future control of the products of the land must be assured for medium to long-term to those who forego land use in the short term. Both local residents and outsiders must be considered in areas with transient herders.

Labor: Sometimes some sort of fence construction and maintenance is required, and frequently people are needed to control access to land or to control movement of animals.

Benefits: Future benefits must be obvious to those giving up current use. There must also be options available or developed to replace products lost to present users.

Extension: In some areas residents have voluntarily limited use of selected land; in other regions, traditions of open access make this concept difficult to accept or enforce and require careful extension inputs from sensitive agents. Demonstration plots and visits to successful activities may be helpful. This

technique will not be successful in the long term without general consensus and support from residents.

Organization: Although some use control may be practiced by families, larger areas require careful community organization or organization of former users. Sometimes residents need outside support such as surveying, dermarcating land, or support for limiting use and protecting areas from proper authorities.

Combination With Other Conservation Activities

Many activities designed to restore overused land depend on properly functioning use control. There is no use planting trees if grazing animals destroy them within a few months.

Possible Production Benefits

More rational use of existing (or improved) land, natural vegetation, water or wildlife can result in increased production of food, both plant and animal, or water.

Inputs Required

Instituting land-use restrictions requires lots of explaining, convincing, "selling" on all levels: government agencies, donors, special (production) interest groups, and above all, the local population, the ultimate beneficiaries of these efforts.

Location of Previous Experience

Access and use control have been applied on numerous ranching projects, and conservation or reconstitution efforts throughout the Sahel: Chari-Baguirmi, Chad; Matameye and Toukounous, Niger; Oursi, UV; M'Biddi and Lagbar, Senegal; Nouakchott, Mauritania. Noticeable improvement occurred in many fenced compounds throughout the Sahel.

2.2 SEEDBED TREATMENT

Narrative Description

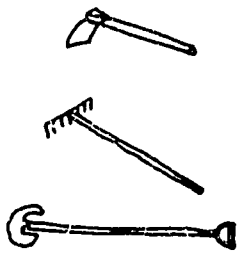
To assist natural revegetation, various forms of surface treatment improve germination conditions for grass and other seeds. Where the soil surface is scarified, freshly germinated plants can grow better than in the surrounding untreated areas; sparse rainwater infiltrates more rapidly through loose soil surface. The topsoil layer is more crumbly, better aerated - roots develop better and faster. Some of the seeds may fall into cracks between soil particles, where they are more protected from heat or drying winds.

Therefore, scraping, scratching action of any kind will often enhance the reestablishment of vegetation on large tracts of land that have been burnt, overgrazed (where compaction of soil surfaces can be a big problem), or that have been cleared for cultivation, then abandoned.

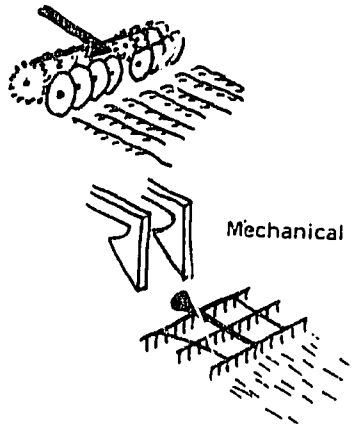
Areas of Applicability

Seedbed treatment may be used wherever reestablishment of natural vegetation is desirable. This technique enhances access and use control efforts (described in section 2.1) and gives satisfactory results, especially in the 400 to 900-mm range.

Dragging dead branches by hand, animals, vehicles, tractor, etc.



Hand tools: dabba, rake, etc.



Mechanical

Restricting Conditions

Results will be disappointing where natural seed sources are scarce or no longer present. Also, revegetation of loose sand or rock surfaces will take a long time.

Design Guidelines

The main point is to loosen and scarify the surface, providing irregularities and loose and crumbly areas. Strips (1 to 2 m wide) 5 to 10 m apart can be used to establish a pattern which may be expanded in coming years. This can be done with hand-farm tools by the local population. On a slightly larger scale, a small harrow or some other implement with teeth can be attached to a four-wheel drive vehicle (Land Rover, Unimog). Farm tractors or small bulldozers with harrows, disks or specially designed implements can be used to cover larger areas.

In Botswana, good results have been achieved by simply pulling a large bundle of dead branches or tree stumps behind Land Rovers. Treatment always must follow contour lines. Even on flat slopes all lines must be level.

Notes on Local Participation

Land: Medium-term land-use guarantees are important.

Labor: Requires additional labor, but it may be organized during slack season.

Benefits: Growth may be seen during first growing cycle, but limiting access or other protection will be needed for extended periods of time to realize long-term soil improvement benefits.

Extension: This technique may be a new idea requiring demonstration. It does not require outside equipment, although available vehicles may be useful.

Organization: May be organized by a family or community group on either voluntary or locally paid basis.

Combination With Other Conservation Activities

Seedbed treatment (in strips) combined with (direct) seeding has given excellent results, as seen with *Acacia senegal* in Senegal and Chad. Seedbed treatment is ideally suited as supplemental activity in watershed management and conservation work. This activity can easily be combined with construction of small dirt or rock berms on contours.

Possible Production Benefits

This treatment will yield additional forage, as well as firewood, gum, etc.

Inputs Required

Much can be accomplished by hand with nothing more than sticks or traditional tools. More elaborate efforts, better suited to cover larger areas, require animal-drawn equipment, trucks, tractors or heavy equipment.

Location of Previous Experience

Seedbed treatment has been successful near Massakory (Chad) in connection with gum tree seeding, and in Upper Volta (Yatenga, Kaya).

Literature Reference

Reforestation in Arid Lands (Peace Corps/VITA).

Delwaulle, J-C. (1978). Plantations Forestières en Afrique Tropicale Sèche. CTFT, Nogent-s-Marne, France. 177 p.

Ministère de la Coopération. (1975). Manuel sur les Pâturages tropicaux et les Cultures Fourragères. G. Boudet, IEMVT. Paris. 254 p.

2.3 FIRE MANAGEMENT

Narrative Description

Different components are involved. Fire prevention/education, early detection, suppression, containment (control), prescribed or controlled burning, all are important fire management tools.

Fires have an important effect on natural vegetation of an area. While the majority of uncontrolled fires have definite adverse effects on the ecologic balance of an area, some may be beneficial. Early detection and local cooperation and preparedness are very important for fire control.

Areas of Applicability

Fire management may be applied wherever dry grass, shrub or tree cover is dense enough to provide a continuous supply of inflammable material. The greatest damage from uncontrolled fires occurs when annual precipitation is between 650 mm and 1500 mm.

Design Guidelines

The more fuel and the drier and hotter the fire, the more biomass will/can be destroyed. The basics of fire suppression include: fuel and oxygen elimination and fuel temperature reduction. The basic fire control techniques are: direct - extinguish flames; indirect - use firebreaks or back-burning, either as preventive or emergency operations.

Since most fires are accidentally or deliberately set by people, prevention, suppression, control or management of fire depends entirely on awareness, education, and cooperation of the local population. No amount of equipment and organization can replace human participation and prevention. Since many fires are started for specific and often valid reasons, proper fire management as a production and conservation

tool is a complex mixture of balancing funds, personnel, equipment and technology with the existing social and cultural dynamics involved.

Notes on Local Participation

Land: Land over which fire control is to be exercised must be considered by residents to be of value, and the control must be seen to increase its value. If residents receive no valued use rights, they cannot be expected to actively volunteer to control brushfires.

Labor: Fire fighting requires labor input under difficult conditions and frequently during the dry season when men may be absent due to off-farm employment. Building firebreaks, etc., require major labor inputs and ongoing or frequent maintenance.

Benefits: Fires may be started by residents for pest or weed control, for clearing away dead growth, or for forcing young shoots of grass for animal fodder when other fodder is in short supply. Fire favors development of certain plants such as thatch grasses. Controlling fires for long-term grass, shrub, or tree production in relation to revegetation may not be of evident value to residents who have used fire for generations. Alternatives may be needed for benefits lost as a result of changing former practices dealing with fire.

Extension: Residents may need to see results of trial plots or have products with economic value added to areas which they are being asked to protect. They may need access to communications, transportation, and small fire-fighting equipment. Residents' use of (and reasons for using) fire should be considered before the program is defined.

Organization: Fires can be easily contained at their source and require increasing effort to suppress as they spread. Fire management requires support of residents throughout the area. Where fires are a problem, most farmers have traditional practices to protect their fields and homes. If the land to be protected provides no benefits to residents or if benefits fall to outsiders, payment of fire fighters will probably be required.

Combination with Other Conservation Activities

Fire greatly affects the ecologic balance of any vegetal cover. Especially during the first few years, strict fire control is required in connection with any revegetation activity (2.1-2.5).

Possible Production Benefits

Some grasses resprout after their tops have burnt. The gain, however, is temporary. Seasonal fires affect composition and density of naturally occurring vegetation. Elimination of fires will bring about gradual changes which may affect local resources negatively (a drop in honey production has been reported in one case). Biomass (total vegetative production) will increase; however, more grass, more leaves and stems and, eventually, more wood. Seedlings of many valuable tree species (indigenous as well as exotics) can not survive "hot" fires during their first few years.

Inputs Required

Fire control and fire management require basic knowledge of techniques: fire fighting, construction and maintenance of fire lanes and firebreaks, backburning, etc. Vehicles, hand tools and communication are essential.

Location of Previous Experience

Extensive experience has been gained from controlling fires in the Sahel. Special efforts in fire detection and control have been made in Senegal. There are different firebreak schemes is most Sahelian countries. Some firebreaks are maintained by allowing farmers to plant crops. Do not maintain firebreaks by using tractor-drawn disks and harrows; this will encourage the growth of annual grasses, in themselves a fire hazard when dry. Good results were gained from public education campaigns in Gaya, Niger.

Literature References

Many general manuals, but Sahel specific information is scarce.

2.4 DIRECT SEEDING

Narrative Description

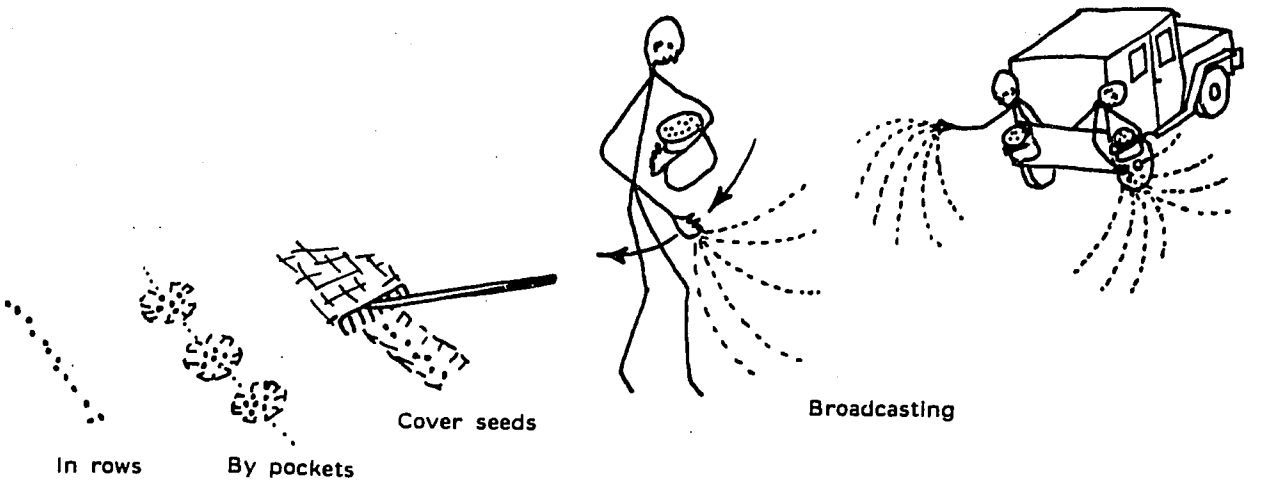
Induce plant growth by placing seeds in soil directly at final locations. Methods vary from general broadcasting only to deliberate, large scale activities of clearing surfaces, seedbed preparation, seeding and covering.

Areas of Applicability

Direct seeding of either trees or understory grasses and forbs is possible over wide areas of the Sahel either in open rangeland or in individual farm fields (for food crop trees, for example).

In addition to access control and seedbed preparation, direct seeding represents the next logical step to assist nature in accelerating on otherwise natural sequence.

Recent burns, degraded areas, newly protected surfaces are most likely sites.



Restricting Conditions

Direct seeding without seedbed preparation is likely to result in failure if soil surface conditions are unfavorable: compacted, top soil eroded, moving sand, sheet erosion.

Reseeding of large surfaces requires large quantities of seeds which may be difficult and expensive to obtain. Many tree and shrub seeds require special treatment before sowing, otherwise germination will be poor.

Design Guidelines

Do whatever increases the chance of germination and survival of sprouted seeds. Proper planting time and adequate rainfall are important.

Notes on Local Participation

Land: Generally, this activity is suggested for land which is not currently being used for crop production. It may, however, compete with land used by herders or by women collecting wild growth for fuel, food, or crafts.

Labor: Requires additional labor which may be in competition with planting season for crops.

Benefits: Secondary benefits depend entirely upon the crops or species selected for seeding and should be seriously considered. Direct benefits of erosion control may be less evident to farmers or may, in fact, benefit only those living in lower areas of the watershed.

Extension: Direct seeding requires seed, locally available tools, and local interest. It will be necessary for agents to understand what local residents want, before teh correct type of

plants can be selected. It may be necessary to demonstrate benefits to residents.

Organization: This activity can profit from a short-term group effort for planting if there is general long-term support for protection of newly planted areas. It may be an individual family effort as well.

Combination With Other Conservation Activities

Direct seeding is an excellent supplemental activity, not only in plantations, but also in connection with many construction efforts involving freshly exposed soil surfaces: embankments, cuts, ditches, berms, dams, etc.

Possible Production Benefits

This activity presents a wide range of possibilities, depending on species used. The major short-term benefit is forage production.

Inputs Required

Farm hand tools will suffice for cleaning, weeding, scarification, and seed covering, unless large areas are to be treated.

Location of Previous Experience

The treatment has been used in Niger (Tchin Tabaraden), Senegal (Ferlo), and Chad (CARE Project), etc.

Literature Reference

Reforestation in Arid Lands; otherwise scarce.

Ministère de la Coopération (1975). Manuel sur les Pâturages Tropicaux et les Cultures Fourragères. G. Boudet, IEMVT. Paris. 254 p.

2.5 PLANTING (OF SEEDLINGS)

Narrative Description

Seedlings, usually from nurseries, are transplanted at the beginning of rains. Transplanting requires adequate soil preparation, planting, arranging surface area around trees to catch a maximum amount of water, as well as weeding (to reduce root competition) and protection against animals and fires.

Area of Applicability

Applicable areas depend on the site requirements of species used. The practical lower limit without irrigation is around 300 mm. Soils must have a minimum depth to allow adequate root development. Most likely sites are degraded areas like abandoned farmland and around large watering points or where shade or farm (food) trees are desired. For production purposes, planting seedlings may be done wherever land with adequate soil is available: government reserves or communal or privately owned (farmed) areas, for instance.

Restricting Conditions

Shallow soils and eroded surfaces greatly limit survival. Planting is possible on poor sites, but special ground preparation may be necessary (terracing, mini-catchments, contour treatment, etc.).

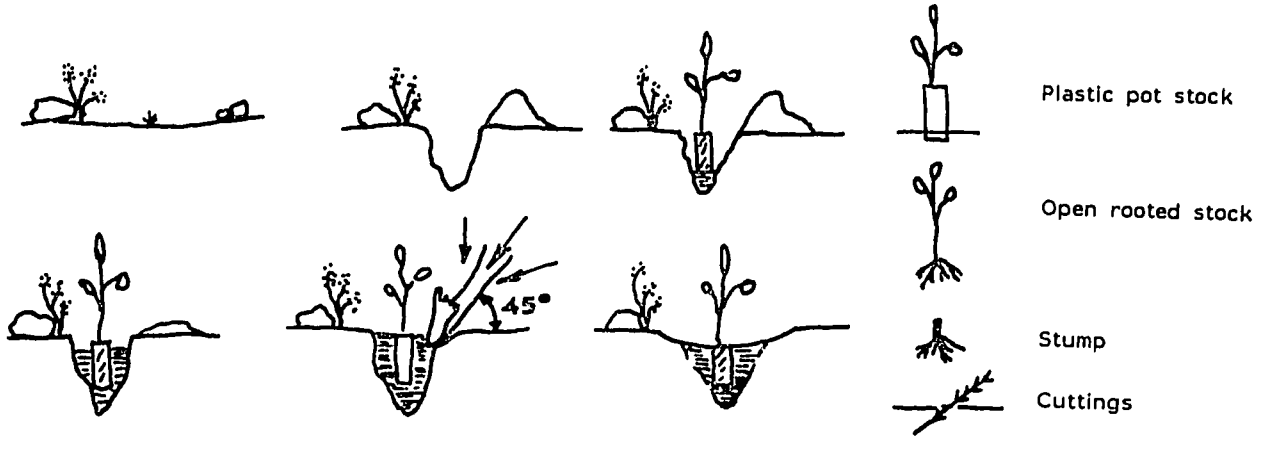
Planting trees is one thing; properly protecting them during the critical first three to six years is another. Currently, two out of three trees planted in the Sahel die or are severely stunted before they are five years old. Planting without protecting is a waste.

Design Guidelines

The most important point of seedling planting is proper timing. Ideally, planting should be done at the beginning of the rains, after soil is moist to the bottom of hole.

Proper techniques include good site preparation, proper depth of hole, correct root placement, good compaction to eliminate all air pockets, careful surface preparation, slight depression, mini-catchments, etc. These must be followed by proper protection and maintenance.

Water is always a critical factor. Survival can be greatly enhanced by shaping the ground surface in the immediate vicinity of the trees so that runoff collects at the root zone. See mini-catchments (4.1). Wherever surface runoff occurs, tree planting activities should include construction of the right kind of catch basins around each tree.



Notes on Local Participation

Land: Communal, public, or otherwise unused land where available may be used; however, long-term land-use rights, as well as distribution of any benefits from the trees, must be clear before planting is begun.

Labor: Planting activities are labor intensive and require efforts during the busy planting season.

Benefits: Because this activity requires important and competitive demands for labor and available land, species must be chosen which local residents value the products or effects. If the

benefits are not apparent to local residents, paid labor may be required for planting, but at least passive local support is crucial if the trees are to be protected or maintained.

Extension: Effective soil conservation planting activities require a number of supportive services. Not only must technical information be available to local residents, but organization of soil preparation, timely delivery of locally valued and quality planting stock, as well as long-term follow-through for maintenance must be provided.

Organization: Tree planting can be an individual family activity or communally organized depending upon availability of land and/or local traditional organizational patterns. Many group efforts of this type have failed when the community has not taken part in selecting the activity and its organization.

Combination With Other Conservation Activities

Tree planting, except for shade plantations, should be combined with as many other soil conservation efforts as possible: berms, terraces, mini-catchments, etc. Each tree should be the focal point of small catch basins to get best possible advantage of available water.

Possible Production Benefits

Possible benefits include: wood, food, forage and many other products such as fiber, tanning material, pharmaceutical products, etc.

Inputs Required

Labor, hand tools plus material and equipment for protection during first years of growth are required.

Location of Previous Experience

Widespread activities from individual shade tree efforts to large-scale reforestation perimeters have been undertaken with mixed results. Proper protection and maintenance during the first crucial years is often overlooked.

Literature Reference

Reforestation in Arid Lands (Peace Corps/VITA).

FAO (1974). Tree Planting Practices in African Savannas. FAO Forestry Development Paper No. 19, Rome. 185 p.

Delwaulle, J-C (1978). Plantations Forestiéres en Afrique Tropicale Sèche. CTFT, Nogent-s-Marne, France. 177 p.

Ministère de la Coopération (1978). Mémento du Forestier. Paris. 894 p.

3.0 EROSION CONTROL

The erosive force of wind or water can cause considerable damage to valuable farm or range land. In addition, erosion (dune formation, flooding, deposit of silt, sand, gravel) can also adversely affect roads, dwellings or other installations.

Control measures are separated according to the primary problem source: wind or water.

In the case of water damage, control activities are subdivided into sheet and channel erosion as indicated in the following pages.

3.1 WIND EROSION CONTROL

Wind erosion covers three phases: erosion, transport, and sedimentation.

Control measures for the various phases consist of:

Erosion phase:

Physical	-	barriers (i.e., palisades)
	-	chemical surface stabilization (asphalt or rubber solutions)
	-	mechanical surface stabilization (sheets, nets, coarse material)
Vegetation	-	windbreaks, hedgerows (live fencing)
	-	vegetation strips
	-	combination of windbreaks, hedgerows
Transport phase:	-	fore-dune system consisting of barriers, baffles, deflectors, windbreaks, live fencing, vegetation strips, or combinations

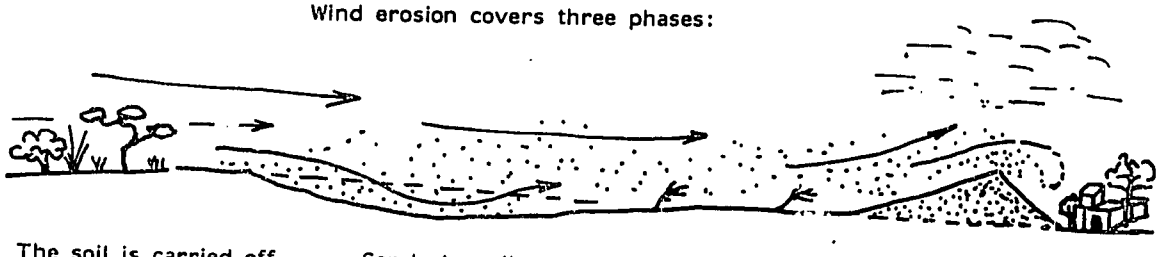
<u>Sedimentation phase</u> - dune fixation through revegetation of loose sand surfaces containing the following steps:

1. access control (2.1)
2. physical barriers (3.1.3)
3. maintenance
4. the above possibly in combination with mechanical surface stabilization

Two cases need to be distinguished:

1. Recent sand movements: In these areas recent overuse has decreased vegetation cover, and, therefore, sand is now being transported by wind. Re-stabilization is feasible through access control and revegetation.
2. Permanent sand movements: Here moving sands are a permanent, natural phenomenon. The resulting dunes have been unstable for geologically long periods of time. Dunes may threaten villages, fertile gardens, wells, roads, etc. Their fixation takes a much greater effort. Long range, systematic physical and revegetation activities are required.

Wind erosion covers three phases:



The soil is carried off | Sand, topsoil is moving | A slowly advancing dune is formed

For a good overview see UNSO/South Dakota State University (1981): Medium and long-term program for sand fixation in Mauritania.

3.1.1 Windbreaks

Narrative Description

A windbreak consists of several rows of trees or a combination of bushes and trees designed to reduce wind velocities immediately above ground surface. Windbreaks are intended to reduce wind erosion and wind damage to crops and to reduce evaporation. Properly designed and managed, windbreaks also can provide limited but important quantities of wood for fuel or construction, food or forage, and tertiary products (tannin, fiber, etc.).

Range of Applicability

Windbreaks are most effective in areas between 300 mm and 700 mm of rainfall where soils are loose and sandy. Heavily farmed areas may, in the past, have been somewhat protected by trees left in the fields. These trees may since have disappeared or been deliberately removed to provide more farmland and to allow unhindered farming.

A special need for windbreaks may exist in connection with the development of irrigation schemes.

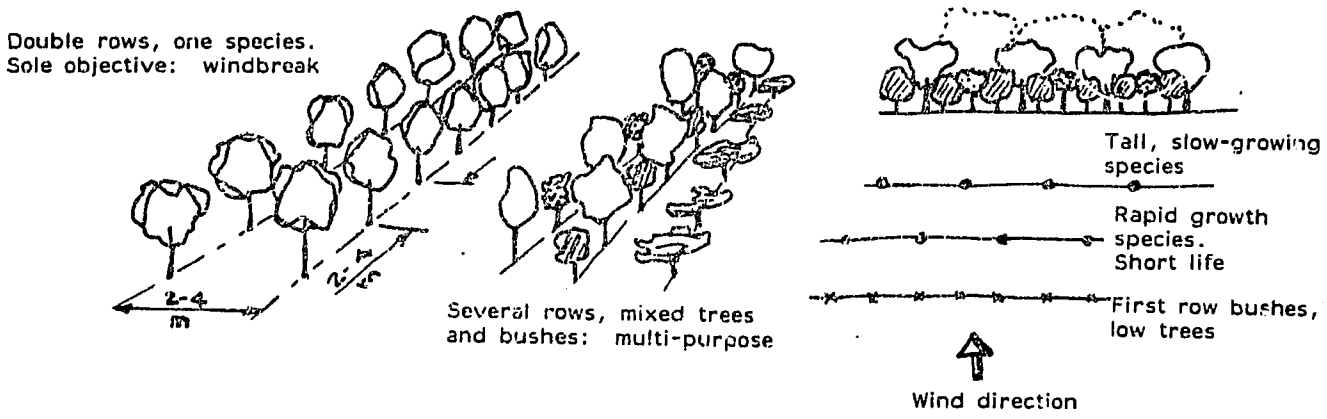
Experience has shown that the idea of windbreaks is more readily accepted by many local farmers than most other soil conservation techniques or concepts. This makes windbreaks one of the most important rural conservation tools in many areas of the Sahel.

Areas of Applicability

Flat, open terrain or ridgetops are most likely sites.

Restricting Conditions

Soils may be too shallow to support growth of trees large and tall enough to be effective. Land may be so scarce that farmers may be reluctant to accept trees in farm fields. Where shifting cultivation is necessary, windbreaks eventually may protect only abandoned land.



Design Guidelines

A semipermeable design is best. Windbreaks are placed at right angles to prevailing winds. An overall density of 60 percent is considered best. For quick results, use rapid-growth, tall species. The tallest available trees may be slow growers. These can be interplanted with short-lived, quick growing trees which can be removed when the windbreak becomes too dense. Always consider multi-purpose possibilities; a windbreak can be more than a barrier for wind.

Windbreaks generally consist of two or three rows of trees planted close enough together so that when fully grown they provide a continuous barrier against the winds.

To best perform their primary function, trees should be fast growing, relatively tall, long lived and easy to plant and to maintain. Windbreak trees should fill the entire airspace from the ground surface to their tops. No single species fulfills all these requirements. It is therefore best to use different trees at alternate spacing.

Fast growing species such as Neem or Eucalyptus are relatively short lived. They provide rapid barrier-formation, but will not last

long. Therefore, they should be accompanied by trees which also grow tall, but may develop more slowly: Acacia albida, Tamarind, Parkia, Nere, etc.

Trees mentioned so far, when fully grown, will leave an opening between the soil surface and the first branches of their crowns. This space must be filled as well; otherwise high wind velocities will occur immediately above ground.

Shrubs can provide a solution, but they should be unpalatable to animals. Euphorbia, Salvadora persica, Combretaceae or other, similar types may work well in some areas. Much depends on rainfall, soil conditions and local preference.

Carefully managed, windbreak trees can yield important forest products in addition to providing a barrier against air currents:

- Proper, intermittent coppicing or pollarding can yield wood for fuel and construction.
- Food or fodder trees can be incorporated into windbreaks, yielding pods, fruits or forage. In addition to Parkia and Nere, the following species may be of local importance:
    - Doum palm for fibre;
    - Baobab for leaves, fruit and bark;
    - Sclerocarya for fruit;
    - Ziziphus for fruit;

    and many more.
- Depending on local needs and traditions, other shrub or tree species incorporated into windbreaks might provide additional forest products. Examples are Acacia scorpioides for tannin or Acacia senegal for gum.

Notes on Local Participation

Land: Long-term land use must be guaranteed. Effective windbreaks require long strips of trees which may use up to 10% of crop space. Plots may need to be realigned, which requires extensive commitment and cooperation of neighboring land holders.

Labor: Planting must be done during intensive planting season, and the long narrow strips are difficult to protect against grazing animals.

Benefits: Farmers upon whose land the trees are planted lose valuable land. Several years are required before increases in crop production are realized. Villagers can help select species which offer desired secondary by-products, such as forage, fruit, poles, firewood, fencing materials, and edible leaves. Windbreaks may provide shady roadways.

Extension: Community-wide discussion and organization, available information, and, where possible, visits to successful sites are necessary to obtain essential local commitment. Planting stock must be available in adequate quantities and delivered in a timely fashion. Considerable follow-through is required to assure adequate management of windbreaks and to direct any harvesting activities.

Organization: This activity cannot succeed without general community-or region-wide support.

Combination With Other Conservation Activities

Combination with (1.1) *Acacia albida*, and/or live fencing (3.1.2) provides a comprehensive farm-soil conservation protection package. Windbreak effects can also be designed as part of vegetation strips.

Possible Production Benefits

Properly managed, trees and bushes used in windbreaks can provide many by-products such as forage, fruit, sticks, poles, fire-wood, fencing materials, etc. Also, a windbreak may rapidly become a travelway or road.

Inputs Required

Windbreaks require trees, planting effort, and, significantly, protection during the first three to five years. Also required are surveillance, extension efforts, public acceptance, participation, and maintenance.

Location of Previous Experience

Windbreaks have been planted in Senegal (Peanut Basin), Niger (first efforts near Maradi; excellent example of multi-purpose design at CFJA), and the Maggia Valley.

Literature Reference

Ministère de la Coopération (1978). Mémento du Forestier. Paris. 894 p.

FAO (1960) La defense des terres agricoles contre l'erosion éolienne, Cahier No. 71, Rome. 99 p.

FAO (1976). Conservation in Arid and Semi-arid Zones. FAO Conservation Guide No. 3, Rome. 125 p.

Ministère de la Coopération (1978). Plantations Forestières en Afrique Tropicale Sèche. CTFT, Nogent-s-Marne, France. 177 pp.

3.1.2 Live Fencing

Narrative Description

Live fencing consists of one or more rows of bushes or trees, trimmed to a height of 1 to 1.5 m to protect the area from free-grazing animals. The technique also reduces wind damage and provides organic material to adjacent soils.

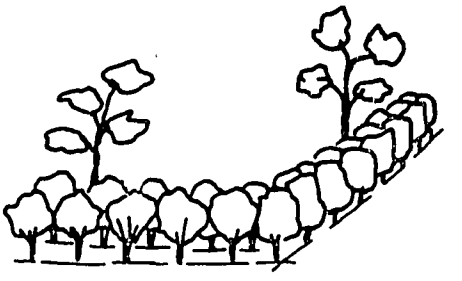
Area of Applicability

Live fencing requires soils supporting shrub growth and a minimum of 250 mm rainfall. The most likely sites are borders for vegetable gardens, manioc fields, fruit tree (mango) orchards, compounds, stock driveways, etc.

Restricting Conditions

Young plants may require watering during the first year or two. During the same time, the shrubs and trees, unless protected, may be destroyed or severely stunted by excessive grazing.

Single row,
0.50-1.00 m spacing.
Holes plugged with branches
cut from hedge



Double row with some individual
trees (fruit, shade, special products)

Design Guidelines

Young plants must be protected with "dead" fence ("zeriba") for first few years. Plant one or two rows (second row 50 cm to 1 m behind first one). Space plants 0.50 m to 1.00 m in rows. Thorny,

unpalatable shrubs give the best protection (some acacias). As an option, productive, bushy species can be interplanted (Ziziphus, Prosopis, Acacia scorpioides, etc.).

In connection with irrigated vegetable gardens, people can grow the necessary plants themselves. Direct seeding and subsequent watering has been successful. Seedlings can also be grown in plastic pots, together with a few food or fruit trees like Moringa, Papaya, etc.

Notes on Local Participation

Land: Medium to long-term use rights to land must be assured. Some crop land is lost by hedge planting.

Labor: Trees or shrubs must be planted during the busy planting season. Plants must be protected year-round for first two to three years. Hedges must be regularly trimmed and maintained, but may still provide a considerable saving of time over such traditional fences as those made yearly out of thorn branches.

Benefits: Some species suitable for live fencing also offer valued by-products after the second or third year. Protection for garden plots can be effective after two to three years. This can be an easily recognized benefit where gardeners have little access to other fencing materials. Where land pressure is great, the loss of garden space will be considered serious.

Extension: Many farmers already have traditional live fencing. In other areas live plants can be introduced inside the traditional mat or cut thorn hedges for the initial protection. Where wire fencing is introduced farmers seldom invest the time and labor to raise live fences, even if the original idea

was to use the wire temporarily and move it after the hedges were growing. Planting stock of desired species is required. Information on techniques for spacing and maintenance must be made available where needed.

Organization: Live fencing may be a family or group activity with several neighbors sharing the fence.

Combination With Other Conservation Activities

Live fencing may be combined with windbreaks, farm management, *Acacia albida*.

Possible Production Benefits

Fodder, fruit, food, thorn branches, firewood, sticks, etc., may be produced through live fencing.

Inputs Required

The technique requires planting, protection, trimming, replanting tools, etc.

Location of Previous Experience

Live fencing has been used in Niger at several locations, notably Baleyara and Telemses. People grow their own planting stock and do direct seeding.

Literature Reference

Scarce.

3.1.3 Palisades

Narrative Description

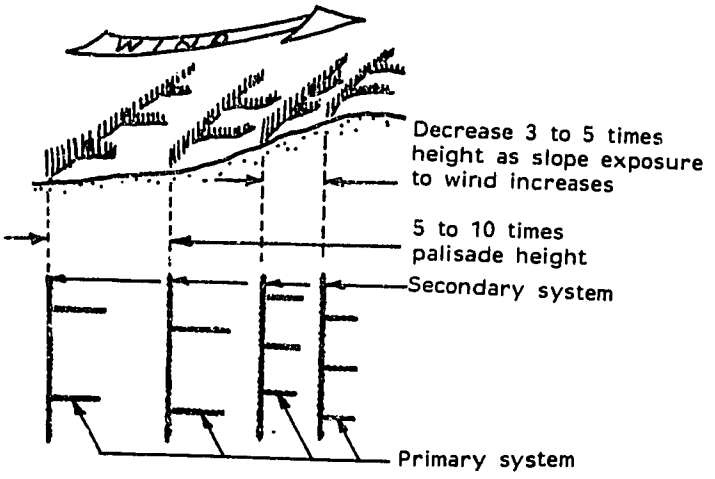
Wind velocities immediately above the ground surface are reduced by constructing barriers perpendicular to the airflow. Any material can be used to increase the resistance to wind as it strikes along the ground.

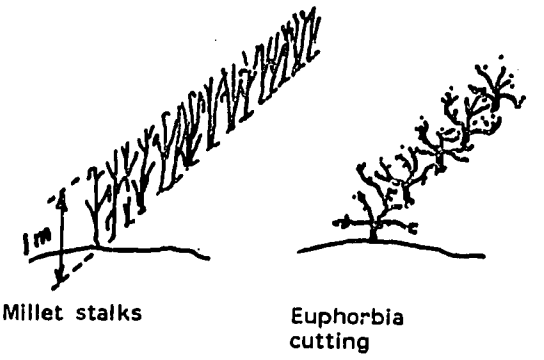
Area of Applicability

Palisades can be constructed where sand stabilization efforts are carried out. They are generally not required in areas with more than 600 mm mean annual precipitation.

Restricting Conditions

Palisades are costly to construct and to maintain, especially where sand movement is heavy.





Design Guidelines

Palisade lines must be at right angles to prevailing winds. On level ground, 10 m intervals usually suffice; their effective range is roughly ten times their height. Spacing must be reduced to 2 m on highly exposed surfaces (top of dunes, for instance). A secondary palisade system cuts down lateral sand transport (shifting winds or local turbulence). Where winds come from different directions, a checkerboard pattern of palisades is erected. Palisade walls must be semi-

pervious. Otherwise, sand will accumulate and form small dunes. In some cases, this may be desirable (especially in transport zone), but dune formation is highly undesirable where trees will be planted in the protection of palisades. Euphorbia cuttings, where available, have been used very successfully. Otherwise "dead" material will have to be used: whatever is locally available: millet stalks, palm fronds, discarded supplies, equipment, etc.

Notes on Local Participation

Land: Generally the area where palisades are established is not productive land. However, the sites residents are hoping to protect must be valuable to them, such as homes, garden sites, orchards, and over which they have long-term use rights.

Labor: This is a labor intensive activity, but most of the work can be done during the agricultural off-season. Protection and upkeep which may be needed for the palisades themselves and for the trees which may be planted in conjunction with them may require year-round labor input. When the residents are not the major beneficiaries, for example, where stabilizing a dune is to benefit those living at a distance, paid labor may be needed.

Benefits: In regions where residents have seen danger to their villages or valued productive lands from moving dunes, they have readily recognized the benefits of building palisades. Millet stalks or other products employed may represent a benefit foregone if they had other traditional uses.

Extension: Models or demonstrations can be shown to local residents who are generally aware of threatening sand move-

ments, but may not know about building palisades and their effects. Organization and technical information must be made available as well as follow through supervision. Even where paid labor is used, local understanding and support are essential to success.

Organization: Palisades are of communal interest and must have communal support. In some project areas, residents have voluntarily saved millet stalks and placed them in the designated patterns with only technical advice offered by the local agents.

Combination With Other Conservation Activities

Palisades are often a prerequisite to special seeding and planting (3.1.4) efforts. Full use control (2.1) is required, especially if millet stalks or other palatable materials are used.

Inputs Required

Palisades are labor intensive and require basic access control, gathering and transporting materials, and construction and maintenance.

Location of Previous Experience

The technique has been used in Niger (Bousa Arrondissement, Keita; Yeglalane) in medium-scale, people-oriented efforts with remarkable success; in Senegal (dune fixation research project near Lompoul); and in Nouakchott, Mauritania (utilizing live *Euphorbia* cuttings). There, dunes are now revegetated by planting *Euphorbia* cuttings over the protected area.

Literature Reference

Ministère de la Coopération (1978). *Mémento du Forestier*. Paris. 894 p.

Ministère de la Coopération (1975). *Manuel sur les pâturages tropicaux et les Cultures Fourragère*. G. Boudet, IEMVT. Paris. 254 p.

Reforestation in Arid Lands (Peace Corps/VITA).

3.1.4 Special Seeding and Planting

Narrative Description

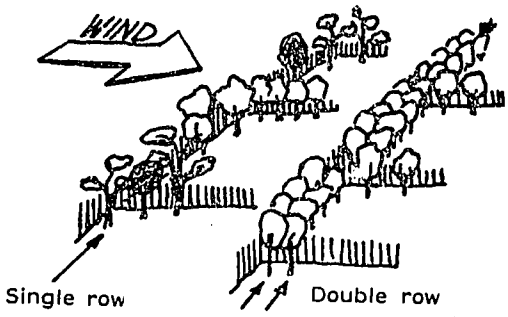
Plants adapted to dry, sandy, pioneer-type sites are introduced in areas to be protected from moving sand either by planting seedlings or direct seeding.

Area of Applicability

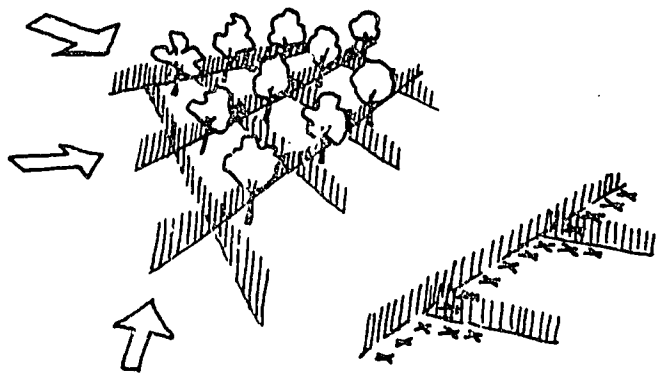
Special seeding and planting can be done where sand stabilization efforts are carried out, in areas generally receiving between 150 mm and 600 mm of precipitation annually.

Restricting Conditions

These techniques will not be successful unless animals are completely excluded, at least for the first two to five years. See Access and Use Control (2.1).



Planting behind palisades, one major wind direction



Palisade planting, wind direction changes with season

Design Guidelines

Select locally adapted species. Do not overlook propagation by cuttings (Commiphora, Euphorbia, Tamarix, etc.). Plant one or two rows behind palisades; make sure plastic pot stock is moist at time of transport. Or direct seed into shallow furrows, then cover. The first row should be planted 25 cm behind palisades. A recent experience in Mauritania (Nouakchott) is worth considering:

An area of moving sand dunes has been covered with Euphorbia cuttings spaced at 1.5 x 1.5 m and closed to all access (watchmen). Within the first two years, natural vegetation has slowly established itself inside this protected perimeter; and if present trends continue, the area will be revegetated within a few more years at relatively modest costs. Vegetation naturally occurring inside these areas include Leptadenia pyrotechnica, Acacia raddiana and Prosopis juliflora from nearby seed sources.

Notes on Local Participation

Land: Such projects are generally carried out where there is little or no existing vegetation. Current use-rights are not the major issue, but the right to use the future vegetation and to profit from the effects of planting must be clear to local populations. Where future benefit appears equitable, there will be more local support.

Labor: This activity may be carried out in conjunction with building palisades, but in itself may require labor during planting season and for access/use control for a number of years.

Benefits: Depending on species planted, participants may obtain limited fuel, fodder, gum, or other valued products within three or so years. Participants may see the value of stabilizing soil as an adequate benefit.

Extension: Residents may need to be provided seeds or seedlings and technical information, as well as help in protecting new plantings, especially in areas frequented by nonlocal herds.

Organization: These activities may use food for work or money to pay for labor inputs. However, where benefits fall directly

to local participants and where participants can afford the labor investment, the best results for continued maintenance and spread effects have come from organizing residents on a voluntary self-help basis.

Combination With Other Conservation Activities

Do not plant unless the major factor now prohibiting growth is removed. This, in most areas, means access/use control (2.1) and palisades (3.1.3).

Possible Production Benefits

These techniques may yield limited fuelwood, grazing, gum, etc.

Inputs Required

Plants, seeds, transport, labor, and surveillance are required.

Location of Previous Experience

See Palisades (3.1.3).

Literature Reference

Reforestation in Arid Lands (Peace Corps/VITA).

Ministère de la Coopération (1975). Manuel sur les Pâturages Tropicaux et les Cultures Fourragères. G. Boudet, IEMVT. Paris. 254 p.

FAO (1976). Conservation in Arid and Semi-arid Zones. FAO Conservation Guide No. 3, Rome. 125 p.

3.2 WATER EROSION CONTROL

Narrative Description

Torrential rains, especially on land not covered by vegetation, lead to surface runoff. Besides losing valuable water that under more favorable circumstances would become soil moisture, this leads to various forms of erosion:

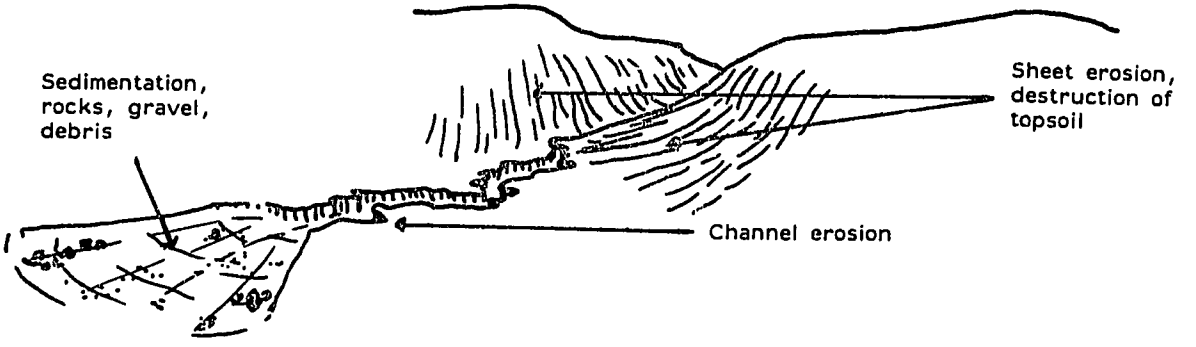
1. Surface (sheet) flow over large areas removes and washes away valuable smaller soil particles. In the process, numerous small, mini-channels (rills) are formed that soon dissect the existing topsoil layers. Much of the material is deposited downstream. This sedimentation can cause additional damage.
2. As water collects in draws and gullies, heavy runoff causes large flows of a water-mud-sand mixture that can gouge out deep and narrow channels through the area. Further downstream, where grades are flatter, much of the sand and mud are deposited, often choking the existing channel and causing widespread flooding of lowlands that may get covered with mud, gravel and rocks.

Unprotected soil surfaces become compacted under the impact of heavy rains. The finer the soil texture, the more damaging the effect. Soil compacted in this manner becomes less permeable; more surface runoff and erosion will result.

A good reference text: FAO. 1965. Soil Erosion By Water. Agric. Development Paper #7. 284 pp.

One of the restricting administrative problems in carrying out water erosion control activities is that many of the physical improvements (terraces, ditches, etc.) require rather precise levelling.

Survey equipment and trained personnel are scarce, and many project activities have had to be postponed for lack of trained personnel and expensive equipment.



Although far from ideal, a basic and practical alternative to establish elevation measurements in flat terrain (or to establish contour lines) is the "garden hose level," which can be built from locally available materials (and a 50-foot length of clear plastic hose). In a number of places in the Sahel, local people have quickly learned to use it, at least to establish contour lines accurately along slopes.

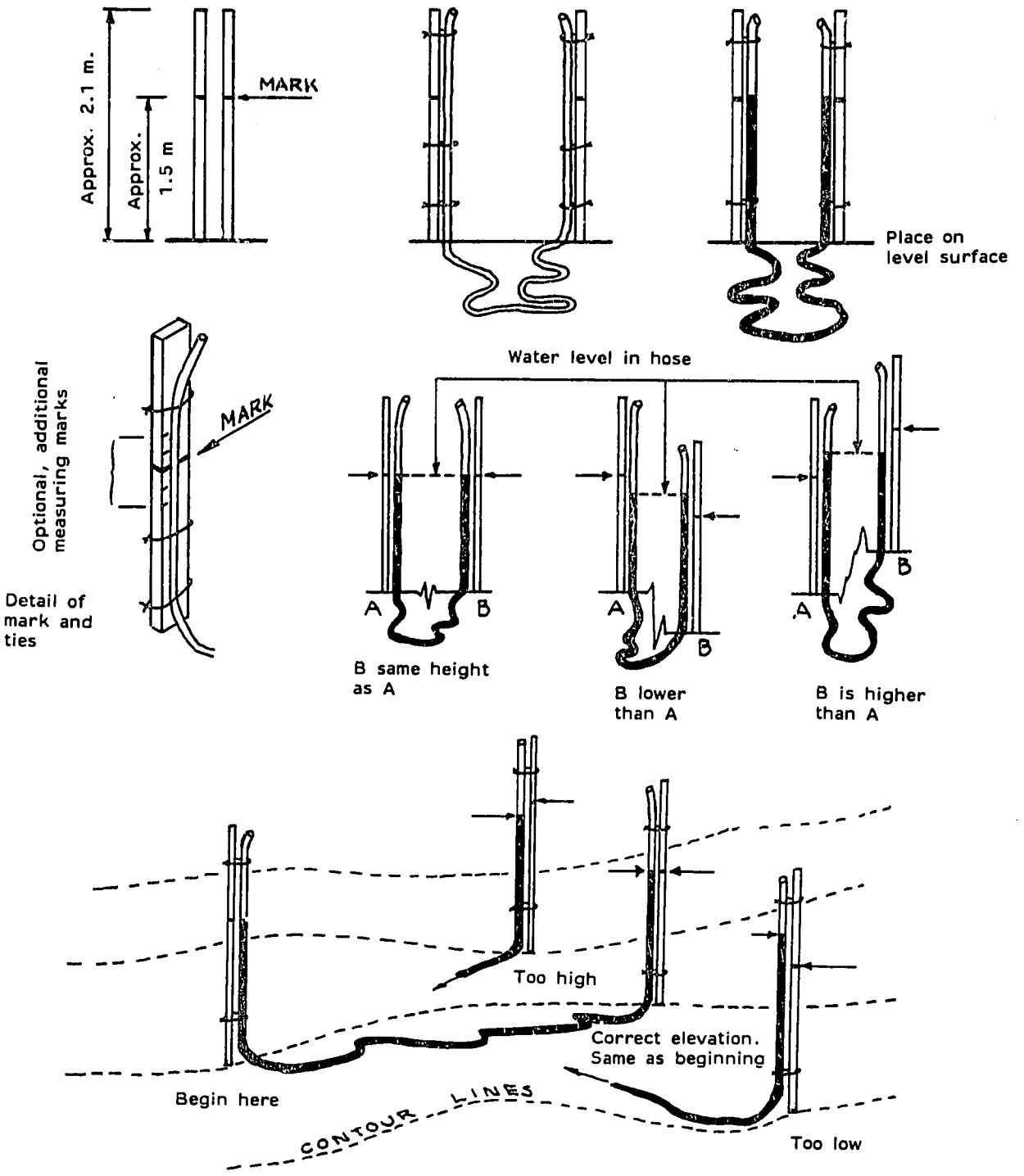
The following sketch shows the basic design of the garden hose level and how it can be used in the field.

HOSE LEVEL TO ESTABLISH CONTOUR LINES

1. Take two boards, sticks, poles. Mark as shown.

2. Tie the open ends of 20 m of transparent garden hose to each of the boards.

3. Fill hose with water until level with mark on boards.



3.2.1 Sheet Erosion

Narrative Description

Surface flow over large areas begins when more water falls than the soil can absorb. The absorption capacity of soil can be enhanced in several ways:

1. Prevent compaction of the top layers: control access/use; avoid over-grazing; do not burn plant residue.
2. Intercept water as it begins to run off: contour farming, seeding, plowing, berms or terraces; provide vegetation strips (on contours); revegetate entire surface; provide plant cover, litter, sod.
3. Increase infiltration: scarify topsoil layer with mechanical means; rake with branches, hand tools, harrow.
4. Retain water so it has time to infiltrate: construct infiltration ditches and construct berms or terraces.
5. Provide ditches and channels, so excess water is guided to the side instead of in the fall line down the slope. Runoff is directed away from the areas to be protected and the resulting flows controlled to prevent further damage.

3.2.1.1 Contour Planting/Farming

Narrative Description

Undertake all crop-raising activities and ground preparation, such as seeding and weeding on contour lines instead of across or straight up and down the slopes, especially the cultivating and weeding.

This not only reduces runoff erosion damage, but allows more water to infiltrate into the soil. Soil moisture beneficial to crop growth is thereby improved.

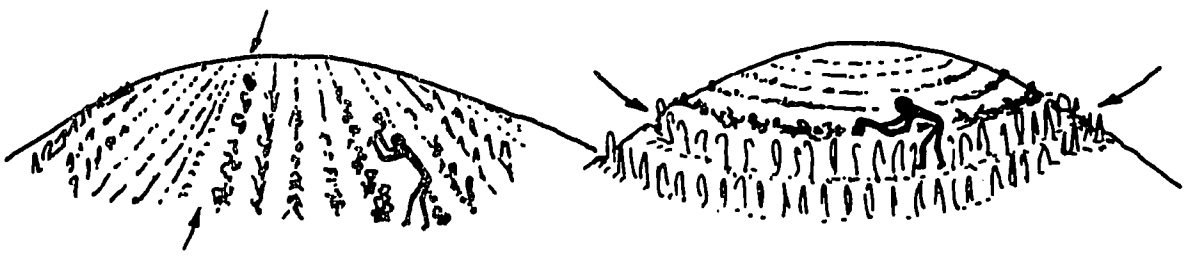
Area of Applicability

The technique can be used on any slope where surface runoff occurs. Loose, fine-grained soils are especially sensitive. The steeper the slopes, the more important that planting is done along contour lines.

Contouring is especially important where land is farmed continuously, year after year.

Restricting Conditions

It is more difficult and time consuming to farm along contour lines, especially where small farm machinery is used.



Design Guidelines

All farm work normally done in the farm fields is now done following lines of equal elevation (contours).

Notes on Local Participation

Land: Activity is carried out on farmland over which residents must have long-range use guarantees of profiting from this technique.

Labor: Requires considerable extra labor also during land preparation and planting seasons when labor may be scarce.

Benefits: Residents must be convinced of benefits and prospects of higher yields which may not be evident the first or possibly the second year.

Extension: Farmers must be persuaded that the effort is worthwhile and will help them over a period of time. Farming along contours requires much more effort. Method-result demonstrations can help show farmers the longer term advantages, but extension efforts may be needed over a number of years.

Organization: This is generally an individual or family farm activity.

Combination With Other Conservation Activities

Wherever vegetation strips (3.2.1.2), berms or terraces (3.2.1.4-3.2.1.5) are constructed, farming on contours becomes almost unavoidable. Properly located and spaced, A. albida (1.1) planting efforts can also provide the basic field layouts to induce farming along contours.

Possible Production Benefits

Greater water retention resulting from contour farming means higher yields. Contouring also keeps topsoil in place (structure, nutrients, organic matter).

Inputs Required

Contour farming requires general farm work and some surveying. See note on "garden hose" level (3.2).

Location of Previous Experience

Many agricultural research stations have pilot demonstration areas. Among the many soil conservation projects using contouring are those in Niger (Maggia) and Chad (CARE *Acacia albida* area).

Literature References

Numerous soil, farm conservation textbooks, research papers, etc.

3.2.1.2 Vegetation Strips

Narrative Description

Vegetation strips are bands of vegetation, either natural or restored, left along contour lines to stop runoff from the open slopes between. Their main function is to discourage sheet erosion; but vegetation strips can, at the same time, provide important sources of bush products, such as forage, food, wood and organic matter for adjacent fields.

Area of Applicability

Vegetation strips are used most effectively in the 300 to 700-mm annual precipitation range on slopes with highly erodible soils, especially on land under continuous cultivation.

Many cash crops require complete ground clearing and intensive weeding and cultivating (cotton, peanuts, cassava). Protection in these cases is especially important.

Restricting Conditions

Use is restricted by the shape and size of farm fields, and the layout of property boundaries. Land pressure may be so great, farmers may feel they cannot spare the necessary land. Grazing pressures may cause constant problems and damage.

Design Guidelines

Establish strips 3 to 8 m wide on contours. Strips should cover about 10% of the total area under cultivation and be as continuous as possible.

Revegetation activities (planting, seeding) can be carried out. Strips, if properly designed and reestablished, can provide valuable forage and wood supplement. Certain tree species (*Leucaena* in more humid areas) can be cropped on 2- to 4-year cycles. Stems and branches, when cut, are laid on adjacent farm soils. The leaves which will dry and fall to the ground will add organic matter to the soil. Then the wood is removed.

These strips can be rotated in time. After the trees have been cut three or four times, the stumps are left to die. The decomposing roots will add more organic matter. Other strips are then planted next to the previous ones.

Notes on Local Participation

Land: This activity will be of interest where farmers have medium to long-term land-use rights and where surplus crop land is available or fallow land can be incorporated into the system. Where field boundaries are not clearly recognized, there may be land disputes as vegetation is planted

Labor: Depending upon the types of vegetation strips used, planting labor may or may not be needed. Protection of the strips will add labor inputs for year-round surveillance.

Benefits: Primary benefits of improved crop production may be long term, but secondary products may be valued as a more immediate benefit. Herding activities in the fields may be limited, with loss of associated fertilizer and fodder benefits.

Extension: The concept must be well understood and generally accepted by the community, which may require demonstrations and technical information, as well as properly timed delivery of planting stock appropriate to local interests.

Organization: Strips of vegetation can be collectively or individually owned and managed, but protection requires community support.

Combination With Other Conservation Activities

Vegetation strips may be used in combination with infiltration ditches (3.2.1.3) immediately below each ditch. Also downslopes of berms (3.2.1.4).

Possible Production Benefits

Same as planting (2.5).

Inputs Required

Some valuable farmland has to be taken out of crop production. Animals must be controlled. Construction and installation inputs include trees, seed, protection, and maintenance.

Location of Previous Experience

Vegetation strips have been used on the Cape Verde Islands and in Kenya and Burundi (where runoff and erosion problems are severe).

Literature Reference

Scarce for the Sahel, but extensive for Europe and the U.S.

3.2.1.3 Infiltration Ditches

Narrative Description

Ditches, either level or on a slight gradient, are dug to allow surface runoff to accumulate and infiltrate through the bottom and walls, thus recharging local groundwater tables instead of causing surface erosion.

Area of Applicability

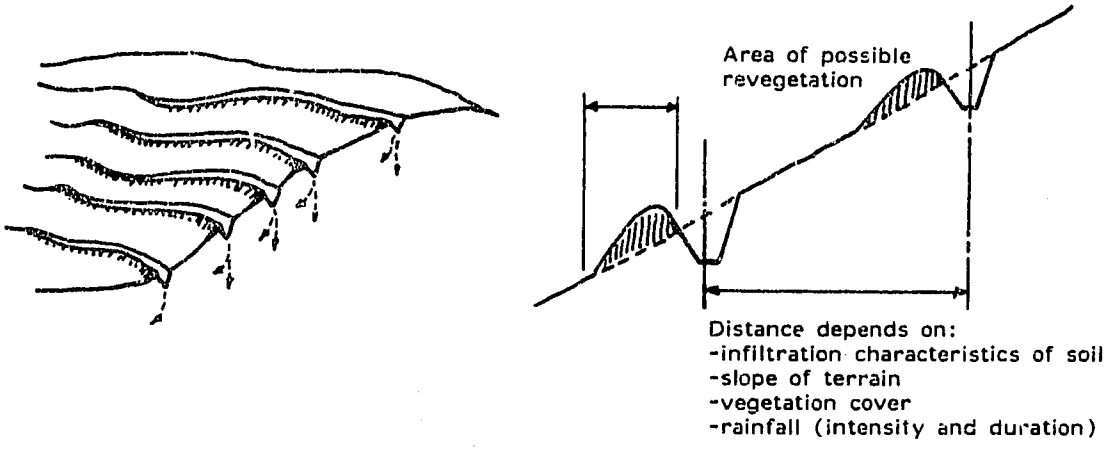
Infiltration ditches can be used in areas receiving over 400 mm of annual precipitation and on slopes over 10% with relatively impermeable soils.

The most likely sites are steep slopes with heavy, extensively farmed soils.

Use the technique only where runoff is present. This type of ditch can, indeed should be, used along the upper perimeter of cultivated slopes to prevent runoff from higher elevations from damaging farmland. In these cases, water is trapped in a collection ditch, with excess channeled to the side and discharged under controlled and protected conditions through draws or swales.

Restricting Conditions

Rock outcrops or shallow soils restrict the use of this technique.



Design Guidelines

The distance between ditches, size, grade, etc., depend primarily on soil and subsurface conditions, which can vary considerably from place to place. The runoff water is intercepted in the ditches where it will infiltrate (or in the case of gradient ditches, flow "sideways") to overflow channels. The primary parameters are rainfall (intensity), soil infiltration rates, slopes, and amount of vegetation cover.

Maintenance to keep the ditch bottoms permeable is very important. If not carried out systematically and continuously, the ditches will fill in and become impervious.

Notes on Participation

Land: Long-term land-use rights must be guaranteed to participating residents.

Labor: Requires large initial labor inputs to construct ditches, as well as annual or more frequent maintenance.

Benefits: Higher crop yields may not be visible for several years.

Extension: Specialized technical support is needed. The basic function of this method and its value must be understood and accepted by the local population.

Organization: Local participation is desirable, but unless benefits are recognized and realized directly by participants, incentives may be needed.

Combination With Other Conservation Activities

Can be integrated with tree planting (2.5), contour farming (3.2.1.1) or vegetation strips (3.2.1.2). Where gradient ditches are built, the excess runoff can be channeled into waterspreading (4.2) or reservoir (4.3) schemes.

Possible Production Benefits

None directly, but infiltration ditches may improve local groundwater regime and lead to higher crop yields.

Inputs Required

Required are surveys, local cooperation and commitment, hand tools, labor and maintenance.

Location of Previous Experience

Infiltration ditches have been used in the Cape Verde Islands and in East and North Africa.

Literature Reference

SCS Handbooks and Manuals.

Ministère de la Coopération (1979). Conservation des Sols au Sud du Sahara. CTFT, Paris. 296 p.

3.2.1.4 Berms

Narrative Description

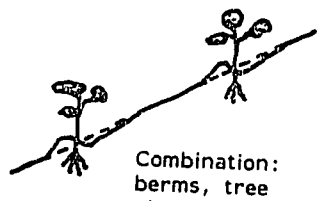
Berms are a series of ridges constructed along contour lines or on gentle gradients to intercept and temporarily store surface water that otherwise would run off the land surface, causing erosion and loss of topsoil. Contour berms (dikes) installed in local depressions to retain runoff to permit rice growing are a special adaptation of this sytem for specific sites. Generally, the entire land surface, with the exception of the berm fore-slopes is farmed.

Area of Applicability

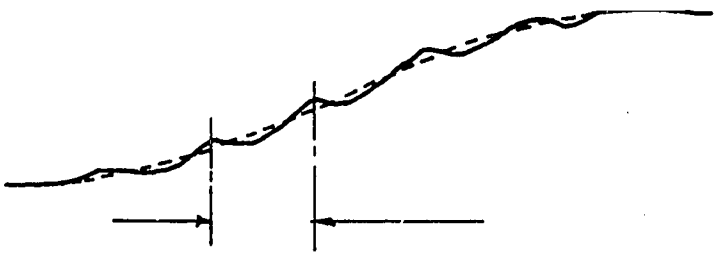
Berms can be used on slopes between 2% and 20% on soils that cause considerable runoff after heavy rains.

Restricting Conditions

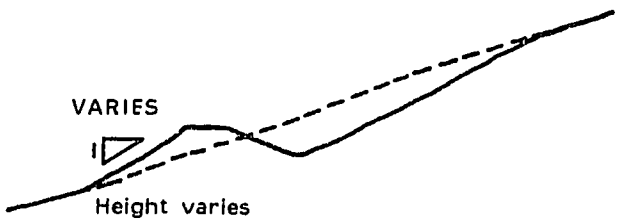
The size and shape of farm fields and the location of property lines are important considerations. Heavy remaining natural vegetation--tree trunks, stumps and roots--and rocky, shallow soils can restrict application.



Combination: berms, tree plantings



Spacing is function of rain, slope, vegetation, soils



Height varies not to exceed 4

Design Guidelines

Spacing depends on: rainfall (intensity), size of berms, vegetation cover, slope, soil (mainly "till"). Basic principle: to retain surface runoff behind each berm so that no overflowing occurs. When berms are placed on gradients, normally not over 2% lateral slope, escaping side-flow must be controlled.

Notes on Local Participation

Land: Long-term land use must be assured if participants are to be interested in this technique which uses up land surface and requires considerable investment.

Labor: Initial inputs of labor are intensive but may be made during off-season. However future planting will need to be done on the contour which requires added labor during the busy planting season. Berms must be maintained before and during the rainy season.

Benefits: Increases in crop yields above the loss experienced by the decrease in planting surface area may or may not be evident the first season depending on the rainfall and other conditions. However, the added moisture combined with increased soil stability should result in noticeably improved off-take from planted areas within several seasons.

Extension: In areas where farmers have traditionally formed steeper slopes there are often traditional uses of berms or other water/soil retentive measures. Farmers are generally aware of water run-off and soil loss. Demonstrations of simple techniques for establishing contours and availability of needed equipment may be all that is needed. However, the

building and maintaining of berms requires a commitment which may involve long term demonstrations and extension efforts especially in areas where the problem is not yet severe.

Organization: Although small berm activities can be organized on an individual farm basis in some locations, where many farms are found on steep slopes, effective programs will require an organized community effort.

Combination With Other Conservation Activities

Berms can be part of tree planting efforts on slopes. Once berms are in place, all agricultural operation must be carried out along contours. Arranged in a criss-cross pattern, gradient berms (2-6%) form mini-catchments; "diamond ditches" are one example.

Possible Production Benefits

Properly constructed and maintained, berms will not only prevent soil erosion, but also help retain rainwater that otherwise would be lost as runoff. This, in dry areas, will in turn increase crop yields. Grass and legume cover established on berm foreslopes can provide additional forage.

Inputs Required

Berms require basic survey and design. Considerable construction, such as earth moving, is involved, but can be done by hand with hand tools. Maintenance, follow-through, extension are also needed.

Location of Previous Experience

The technique has been used in Upper Volta (GERES, Yatenga, Kaya, Fada), Niger, Cape Verde, etc.

Literature Reference

French Soil Conservation Manual, or SCS Handbook (French texts through USAID).

3.2.1.5 Terraces

Narrative Description

A series of walls (rock) or steep banks (soil) is constructed to retain or establish strips of level or near-level farmland to take maximum advantage of rainfall and provide soil conditions that allow maximum, intensive cropping.

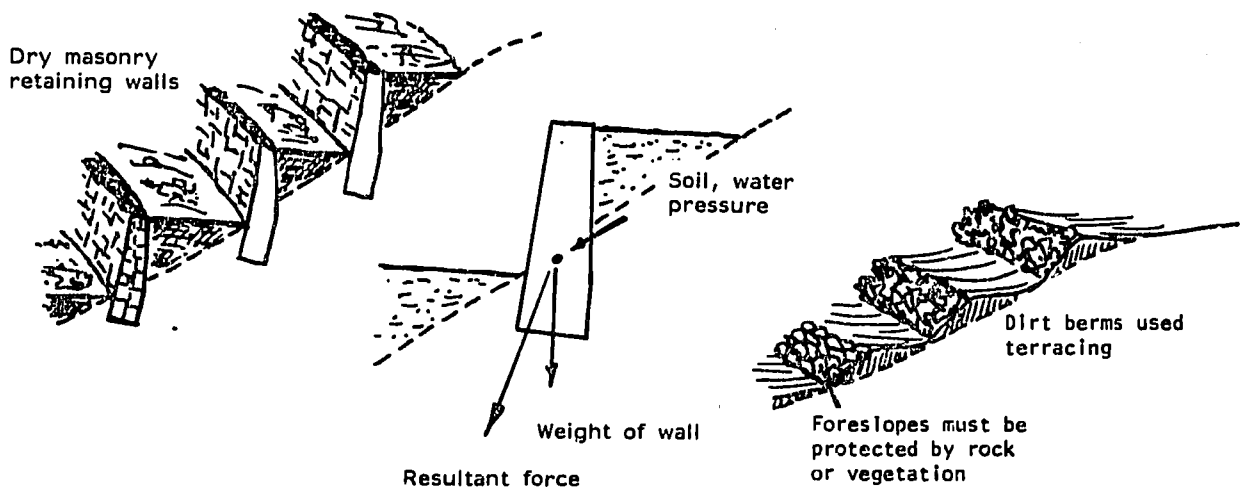
Do not underestimate the constant upkeep that a well-functioning terrace system requires.

Area of Applicability

Terracing is applicable on slopes between 10 and 60 percent, in mountainous terrain on steeper slopes, and on slopes and soils conducive to runoff after medium rains. Where flatter farmland is scarce or non-existent, terrace farming may be the only way to provide land suitable for crop grazing.

Restricting Conditions

For some of the larger terraces, foundation conditions on steep slopes may cause stability and settlement problems.



Design Guidelines

Use a 10-year rainfall for the design. The basic idea is to provide enough of a level (or near-level) surface so that all of the rainwater can be stored until it has infiltrated through the soil. Terrace spacing is dictated by:

1. The slope of the terrain. A stair-step arrangement is the ideal solution.
2. Relationships between rainfall and the ability of the soil surface to absorb all the water falling.

This depends on soils (mainly structure, "till"), slope and vegetation.

Notes on Participation

Land: Long-range land-use guarantees are required.

Labor: Terraces require a great deal of initial labor and constant upkeep.

Benefits: May be evident to residents who will be able to better use land on hillsides.

Extension: Farming tradition in many places in the Sahel includes the know-how and basic understanding of the advantages of terrace farming. Where the idea is new, its successful introduction will require considerable government inputs, patience, dialogue with local people, and extension and communication skills. It may also require heavy outside investment.

Organization: Terracing can vary among individual fields using individual inputs to elaborate systems requiring the cooperation of all farmers using a hillside.

Combination With Other Conservation Activities

A host of other activities should be incorporated: tree crops (1.2), cover crops (1.3), farm management (1.4), manure and compost (1.5), etc.

Possible Production Benefits

Terraces provide the best use of available land on steep hillsides and maximum utilization of available water. Terracing makes intensive farming possible where soil losses and erosion would otherwise cause extensive and irreversible damage.

Inputs Required

Terracing requires thorough survey and design, construction engineering and supervision, dry wall and masonry work, and extensive earth moving. Much can be done by hand, but basic construction equipment such as trucks, concrete mixers, and front-end loaders are needed. During and after construction, extensive extension education is mandatory.

Location of Previous Experience

Terracing is used on the Cape Verde Islands and is traditional in North Togo, and parts of Mali, and Niger.

Literature Reference

French Soil Conservation Manual, Memento du Forestier.

FAO documents.

3.2.2 Channel Erosion

As soon as sheet runoff concentrates in swales and gullies, water will begin to flow in channels. Small flows in the upper reaches of a watershed gradually merge into larger rivulets. After heavy rains, excessive flows occur; then the moving water gains considerable energy. This will cause massive erosion of the soils over which the flood peaks flow; gullies and ravines result. Massive amounts of soil, gravel and loose rock are removed. Further downstream, in flatter areas, much of the debris and sediment carried by the stream will be deposited over large areas, often covering and destroying valuable farmland.

Channel erosion is best controlled at the origin of the flows in the upper portion of the watershed (Revegetation, 2.0, and Sheet Erosion, 3.2.1).

Priority should be given to smaller gullies and ravines that are just beginning to form on sideslopes and in small draws. Any intervention that reduces the erosive force of water will help, such as construction of horizontal checks built from locally available material. Channel banks and slopes can be stabilized by small, temporary retention works, while vegetation is introduced that will provide a more stable cover of the exposed surfaces. Further downstream, where the forces of water are greater, more massive interventions are necessary. Here, larger check structures are necessary; often they must be constructed in series. The principle is to retain a channel grade flat enough to keep erosion at tolerable levels. The energy of water is dissipated in a sequence of falls. Normally, the best way to reduce the energy of water is to use water as a shock absorber. The method of

properly designing check dams and drop structures includes dissipating or stilling basins. These basins act as cushions for water falling into them over the weir of the dam above.

Other ways to reduce the force of water is to purposely provide irregular, rough channel bottom and banks. Where large rock is freely available, channels can be stabilized with riprap and specially designed energy dissipaters. Local materials should be used wherever possible.

To reduce erosion along channel banks, layers of large rocks, gabions or deflecting dikes can also be used. Additional bank protection can be provided by introducing vegetation, such as trees and bushes with strong root systems, along the water's edge (See next section, 3.2.2.1).

3.2.2.1 Bank and Slope Protection

Narrative Description

Introducing vegetation--grass, shrubs, or trees, depending on the forces of water--reduces scour. In swales and smaller depressions, grassed waterways can be established to prevent erosion. Along small streams and creeks, banks and slopes can be protected by establishing trees and shrubs.

Banks and slopes also can be protected against further erosion by placing rocks, boulders, gabions, etc., that break the erosive force of the flowing water. The larger the velocities, or force of the water, the more extensive the protection works have to be to hold up. Spur dikes at right or skewed angles can deflect flow away from threatened slopes.

Area of Applicability

This protection is most effective in streams and channel banks with flows less than 1 m deep, or elevated (higher) portions of larger stream or river banks.

Restricting Conditions

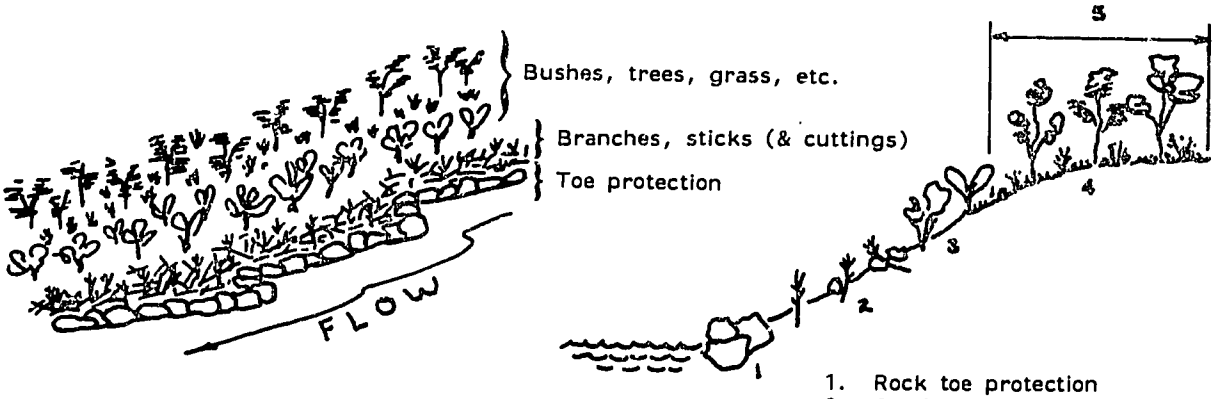
Water velocities greater than 1.5 m/sec require additional, mechanical protection (rocks, etc.). Medium to large rivers or flash flood channels fall in this category.

Design Guidelines

1. For vegetation protection:

For small depressions, establish sturdy grass or forb cover by seeding or transplanting shoots. Temporary protection by rows of branches or sticks may be feasible (watch for termites). Also, cuttings of shrubs and trees can be used to provide rows of palisades of a special kind. For larger channels, shape slopes to eliminate steep

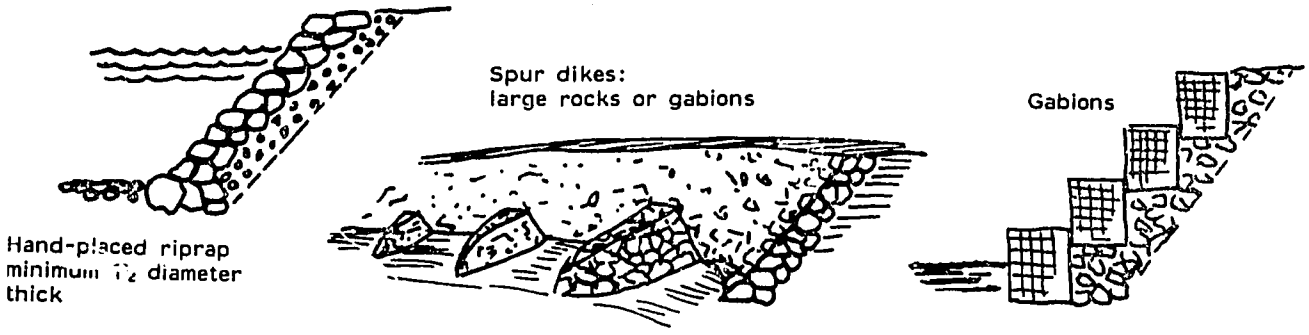
banks (1½:1 maximum). Provide temporary anchorage with sticks, branches, rockrows, etc. Behind this protection, plant sturdy, healthy trees, shrubs or cuttings of species adapted to these special conditions. Choose by observing what grows naturally along the banks. Begin first rows 1 m above high waterlines and plant downward. Along the toe of the slope, provide solid protection to prevent undercutting and erosion of the new bank; use rocks, large gravel, gabions, etc.



1. Rock toe protection
2. Cuttings, sticks, branches
3. Bushes
4. Trees
5. Seeding: grass, forbs

2. <u>For rock protection</u>:

Follow standard design procedures to determine size of rock protection needed along banks. The greater the risk, the higher the design frequency to use (normally between 10 and 50 years). Bank and slope protection measures must <u>always</u> include adequate protection against undercutting, therefore the channel <u>bottom</u> must be stabilized with riprap or low elevation check structures. Beware of choking a channel. Too great a restriction on the flow may lead to higher velocities. This might require additional protection. Proper design also must ensure that the installation will not silt up.



Notes on Local Participation

Land: Where channels threaten particularly valuable terrain (houses, gardens, fruit orchards, etc.), small-scale efforts may be carried out by local self-help.

Labor: Labor is required for all aspects of bank and slope control, and also during planting season when vegetation is planted as part of the system. Labor may vary from community effort to large-scale activities requiring a paid work force.

Benefits: Local residents can often see the importance of the activity in stopping erosion channels. Some vegetation may be selected which offers valued by-products.

Extension: Incorporating local participation requires considerable management and administrative skill. Several technical services may be involved. Even with local efforts, necessary technical and management guidance must be provided to ensure sound design and execution of work. Larger efforts may require heavy equipment, trucks, etc.

Organization: Small-scale efforts may be made by farmers on their own land, but large projects require organized community support, both from within and outside the community. When benefits are not directly felt by the residents or the effort is large, hired labor must be included.

Combination With Other Conservation Activities

Wherever gradient berms or terraces are introduced, escape channels must be provided. Banks and slopes must be adequately protected by methods described here. Small check structures (3.2.2.2) may have to be included.

Possible Production Benefits

None directly. These measures provide protection against further losses. The value of these efforts must be based on what protection can be provided.

Inputs Required

1. For vegetation protection:

The technique requires some surveying and developing the basic design. Hand work, plants, and construction materials (rock, branches, etc.) are also needed; as well as planting activities, surveillance and maintenance.

2. For rock protection:

Considerable surveying and engineering efforts are required. A large-scale mass transit capability is needed to bring materials to the scene. Labor can be used intensively for placement of rock, riprap, and gabion construction. Heavy construction equipment, trucks, bulldozers, loaders, may be necessary.

Location of Previous Experience

Bank and slope protection has been applied on Cape Verde Island and in Niger ("Kori" or "Gebi" protection near Agades and Bouza).

Literature Reference

Soil conservation and hydraulic design handbooks.

FAO (1965). Soil erosion by water. Agric. Development Paper No. 81. Rome, 284 pp.

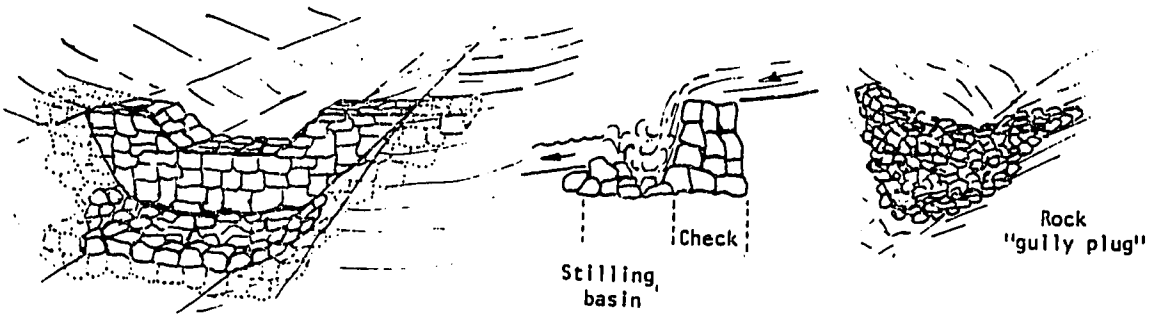
3.2.2.2 Small Check Structures

Narrative Description

The force of fast-flowing water is broken by introducing barrier-type check structures across the channel. This prevents further erosion of the channel bottom. Excessive point-erosion will occur, however, immediately downstream of such structures; channel bottom and sides will have to be adequately protected against undercutting or washouts around the structure's wings.

Areas of Applicability

Such structures can be constructed in small draws and gullies where channel erosion has begun. Note that any structure with a drop over 1.5 m must be designed according to applicable structure design analysis and rules.



Design Guidelines

Provide large enough waterway opening (notch, weir-section). Check structures are normally designed against 10- to 30-year flood frequency. Make adequate provision against washouts below as well as on the sides. A dissipation basin with proper protection of banks <u>and</u> channel bottom is an absolute must! Key sides (wings) far enough into

the sidehill to prevent water from washing around wings. Keep in mind that downstream of the structure, erosion continues (unless channel is protected). This erosion may eventually wash out the structure. Prevent this by installing series of checks downstream to flatten grades and reduce velocities.

Checks can also be built from wood; however, rot and termites will reduce the effective lifespan greatly. Under favorable circumstances, the channel may have stabilized by then, and vegetation will have become established providing additional protection.

Notes on Local Participation

Land: Local participation will depend upon residents seeing the activity as important to protect land or sites they value and over which they have long-term use rights.

Labor: The amount of labor varies from that locals may volunteer to that requiring large amounts of paid workers. Not only initial installation but maintenance will be needed.

Benefits: Benefits may be felt by area residents or by those living downstream. When benefits are not directly felt by residents, laborers will need to be paid.

Extension: Construction of small checks can be carried out by the people themselves, provided proper design and construction supervision is available on-site. Locally available but durable material can be used (rocks, gabions, metal refuse, old tires, etc.).

Organization: Individual efforts can be made on personal property for small checks, but in cases of a series of checks or larger community-wide problems, residents will need to cooperate in the support of the project.

Combination With Other Conservation Activities

Bank and slope protection (3.2.2.1) may also be required. Small checks can play a key role in watershed rehabilitation efforts where revegetation (2.0) and/or sheet erosion (3.2.1) control efforts are included.

Possible Production Benefits

Potential benefits are indirect and derive from reduced future erosion losses.

Inputs Required

Small check structures require basic survey and design, hand tools, labor; trucks for material hauling will be helpful. Occasional maintenance is required.

Location of Previous Experience

Such structures are scarce in the Sahel, but frequently used in North Africa and other arid areas.

Literature Reference

Soil conservation handbooks (U.S. and other).

3.2.2.3 Small Dams

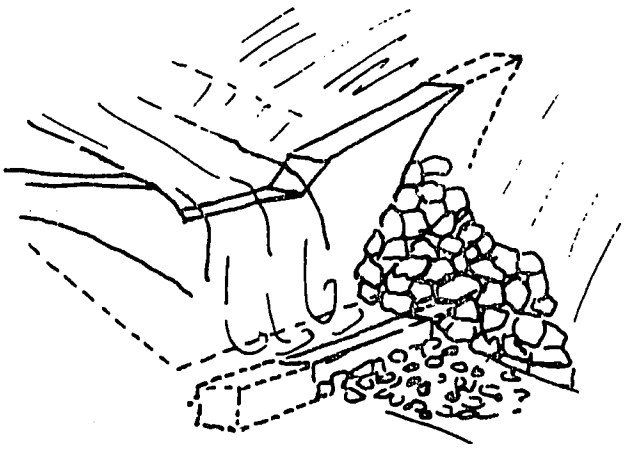
Narrative Description

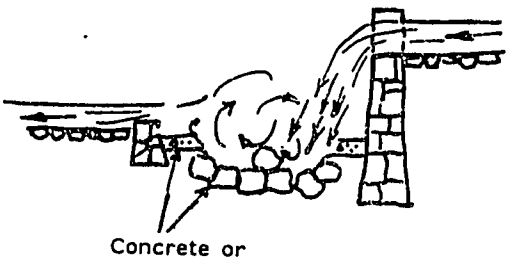
Dams to retain surface waterflows can make a great difference, not only in reducing flood (peak) flows, but also in providing a source of surface water where none existed before. In arid areas, however, success may be severely limited due to excessive flood peaks requiring extensive overflow protection provisions (spillways), problems of siltation, infiltration losses due to unfavorable subsurface conditions, and high evaporation rates.

Dams without upstream land treatment (revegetation, berms, terraces, channel control) are doomed.

Areas of Applicability

Sites must be chosen according to terrain, hydrologic considerations, and subsurface (geologic) conditions. Any dam over 1.5 m in height must be designed according to applicable engineering design criteria and include safety provisions against washouts, overflows, breaks, etc.





Design Guidelines

Dams must meet applicable safety features and be designed and constructed according to applicable rules and regulations. Site surveys, design, preparation of plans and specifications, etc., must be coordinated by technical agencies responsible for civil engineering works of this kind. The biggest problem in the past has been inadequate spillway capacities.

Notes on Local Participation

Land: Small dams change somewhat the flow of water and, therefore, the use of land. If some valued land is flooded, the owners of this land may lose. Owners of land at the edges of a new catchment may find their land producing larger harvests and, therefore, more valuable. Discussion of continued use rights of land must be conducted before land values are changed and appropriate compensation should be made to farmers who may lose land.

Labor: Although some local volunteer labor may be used, this type of project frequently requires paid labor.[1]

Benefits: Benefits may be spread through a watershed area, but those living near the dams may have advantage of access to water retained behind the dam. Where areas are newly flooded, some land may be lost to former users.

Extension and organization: Experience has shown that much of the required earth moving (excavation, placement, compac-

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[1] Properly organized and trained, most of the required labor can be furnished by local communities. A substantial number of jobs can be created, "Food for Work" models can be developed.

tion, etc.) can be done by village participation. However, the more sophisticated work (concrete forming, mixing, placing, etc.) of spillways, installation of control structures (pipes, gates, etc.) must be carried out by experienced work crews.

Combination With Other Conservation Activities

A series of small dams, properly placed and constructed in an overall watershed improvement project, can significantly improve the management of available water. Any soil conservation project planning effort should look for and identify possible locations for small dams, even if lack of funds may delay construction to some later date.

Possible Production Benefits

The major benefit is flow control. Also, retaining surface water in small dams can contribute directly to making more water available for household use, small gardens, etc. In addition, groundwater recharge in the immediate vicinity also may improve.

Inputs Required

Extensive design and construction engineering are required. Most small dams are gravity-earth or rock masonry type. Much of the construction can be done by locally available manual labor. However, building of control structures requires heavy construction skills and equipment (concrete, pipe placement, etc.).

Location of Previous Experience

Small dams have been constructed in many areas in the Sahel: Upper Volta, Niger, Senegal, Cape Verde; as well as in northern Nigeria, northern Ghana, North Africa, and the Near East. The most serious problems arise from incomplete hydrologic studies beforehand and include lack of sufficient in-flow or excess flood peaks (leading to

washouts, sedimentation and siltation). Some small dams were filled with rock, gravel and silt within a season or two!

Literature Reference

Excellent textbook on "Small Dams" by U.S. Department of Interior, Bureau of Reclamation.

Ministère de la Coopération and CTFT (1979). Conservation des sols au Sud du Sahara. 2nd edition, Paris. 296 p.

CTFT (1974). Cahiers Scientifiques No. 4. Nogent-s- Marne. 114 p.

FAO (1976). Hydrological Techniques for Upstream Conservation. FAO Conservation Guide NO. 2, Rome. 134 p.

Many other engineering design and construction texts.

4.0 SURFACE WATER CONSERVATION

One of the problems in the Sahel is that during the rainy season considerable surface water flows occur, but the water is not retained, controlled or used, and therefore lost.

The difficulty in retaining these surface flows is the excessive peaks and the large amounts of sediment they carry at flood stage.

Surface water is easiest controlled where flows are still small: at the point(s) of origin. In the upper reaches of a watershed, where sheet erosion and small channels pose the greatest danger, numerous, small activities can be undertaken that retain and divert water that otherwise would concentrate and form larger flood flows.

The conservation and protection of valuable soil is closely tied to controlling surface flow. The better erosion (water flow) is contained, the more are soils protected.

In addition to measures listed above (contour farming, tree planting, berms, revegetation, terraces, etc.), other specific activities will help conserve surface water and prevent concentration of larger flows that are more difficult to contain. Relatively little has been done in the Sahel toward those efforts. Many of the sandy soils do not lend themselves to this type of intervention. Where soils are heavier and in hilly areas with considerable rock (including laterite) outcrops, first experiences indicate that much more can be done to prevent additional erosion and--more important--conserve and better utilize the water that accumulates as a result of sporadic, but heavy rains.

Some of the methods are described on the following pages. An excellent, overall reference text is the NAS book on "More Water for Arid Lands."

4.1 Mini-Catchments

Narrative Description

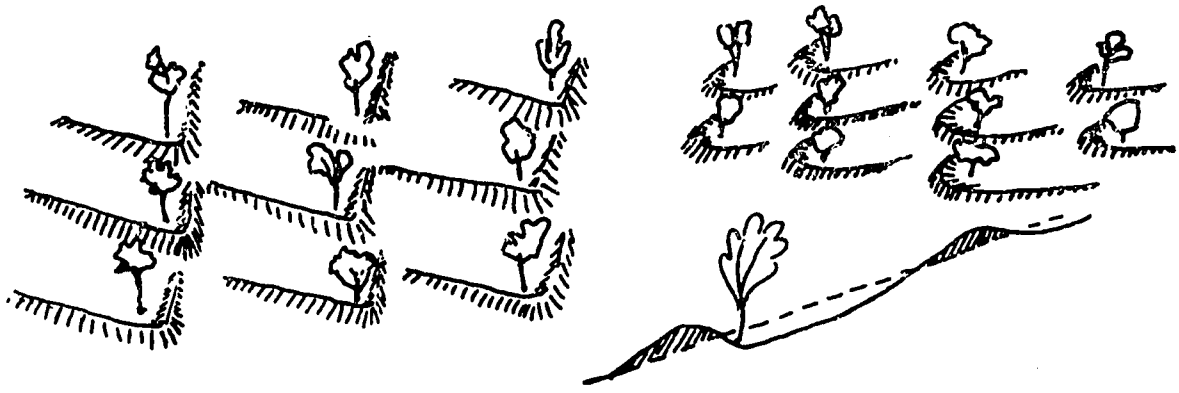
Various methods can be used to shape the ground surface and cause surface water to concentrate in one area, around the base of a newly planted tree, for instance. The principle is to construct mini-watersheds that collect sheetflow in one specific area.

Area of Applicability

Mini-catchments can be used on any slope on soils that are such that runoff occurs after rains.

Restricting Conditions

In blowing sand or loose soils, efforts soon will disappear. Maintenance is required during the first few years.



Design Guidelines

The sizes of individual "basin" are determined by the slope, the permeability of soils, intensity and duration of rains, and the storage capacity of each catchment. Different shapes are possible: half-moons, fish-bone, gradonis--all are variations of the same, basic principle. Soils, slopes, nature of rain, and ground cover are different at each site. When starting mini-catchments, one should experiment with dif-

ferent size basins, provide different amounts of storage, etc., to determine what--at a given site--works best. Beware of especially heavy, unusual rains. If too much water accumulates, the berms may wash away, one after the other, so that the entire system will have to be rebuilt. Protect against runoff from excessive rains!

Notes on Local Participation

Land: Local participation depends upon residents having assured access to land-use rights for medium to long periods.

Labor: Establishing mini-catchments requires added labor, but not necessarily during the agricultural season.

Benefits: Benefits should fall to the landholder. Because this technique is designed to accompany other activities, benefits will depend on the type of planting with which it is associated. In some cases the results may be dramatic even during the first season.

Extension: This is an ideal activity for people's participation in a self-help effort. People must be convinced of the value of the idea. Since appropriate catchments vary considerably from one piece of land to another, farmers should be encouraged to experiment with the best approaches for their own land. Demonstrations with small-scale efforts and with clay-sand models can be helpful.

Organization: Constructing mini-catchments can be either individual or group projects.

Combination With Other Activities

Any tree planting effort carried out on a slope with a possibility of surface runoff (even small and nondestructive) should be combined

with mini-catchments of some sort. This will make more water available to each tree, an important improvement enhancing the survival chances manyfold.

Possible Production Benefits

Vegetative ground cover will improve in these mini-catchments almost automatically. More forage, firewood, fruits, or other by-products will result. Grazing animals must be controlled in most locations in the Sahel.

Inputs Required

Extension and demonstration are required, as well as local manpower (labor), supervision and access control.

Location of Previous Experience

A classic mini-catchment demonstration area has been constructed in Upper Volta (Yatenga). A dramatic example can be seen in Arlit, Niger.

Literature Reference

NAS. More Water for Arid Lands.

Reforestation in Arid Lands.

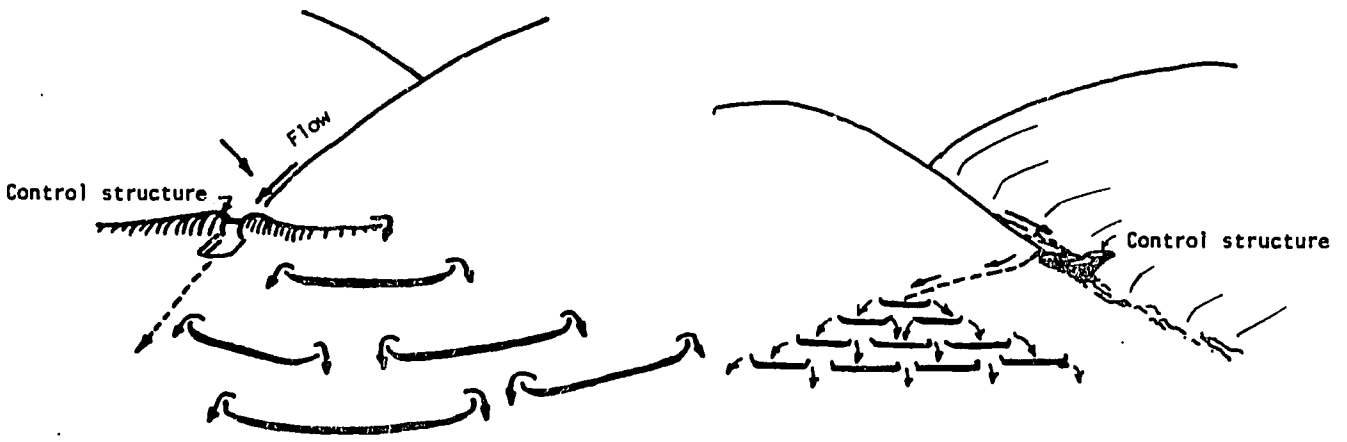
4.2 Waterspreading

Narrative Description

Water flowing in a creek bed or stream is diverted from its channel and led to nearby dry land surfaces, normally on gentle slopes. There it is diverted into different channels (like irrigation water) and permitted to flow onto dry land. The greatest problem is not to release water in flows that are too great. This would cause erosion and/or form gullies and new channels.

Area of Applicability

Waterspreading can be used on gentle slopes and on any soil that is not too sandy. Surface water flows normally are controlled through a system of channels and small dikes (or berms).



Design Guidelines

Although the principle is simple, adequate control of the flows that are released is essential. Otherwise not enough water, or too much, will be spread. The key to the system is the diversion point. Extracting a regulated flow from a creek bed or river channel (especially during flood stage) requires considerable attention, adequate structures, and constant maintenance (mainly against unwanted sedimentation).

Notes on Local Participation

Land: Only residents with long-term access to land use will be interested in this type of project; some land may be lost if new areas retain water longer and are thereby flooded.

Labor: Labor is needed not only for the construction of the system, but also for its maintenance.

Benefits: Although some small areas of land may be lost, overall benefits of more water and, therefore, increased production will be greater.

Extension: The extent and nature of the necessary construction are such that most work can be carried out by village-level efforts. Diversion and distribution facilities, however, must be carefully designed, and maintenance and proper flow control are essential, as is distribution regulation and discipline.

Organization: While this can be an individual activity, most water spreading requires not only a village level effort, but also cooperation of those along creek beds or river channels.

Combination With Other Conservation Activities

Where check structures and small dams are being constructed, waterspreading can be incorporated into general water conservation or watershed management plans. Also, in connection with berm or terrace construction (3.2.1.4, 3.2.1.5), especially of the gradient type, water-spreading systems in the lower portions of the perimeter can be added.

Possible Production Benefits

Although proper installation and maintenance of water spreading systems are relatively complex and require careful planning and skills,

the potential benefits are enormous. If water can successfully be distributed over soil surfaces that otherwise would have to rely solely on rain, production (yields) could be increased considerably. This makes waterspreading a high-risk, high-gain effort.

Inputs Required

Considerable surveying and engineering are required. Also needed are construction work, i.e., digging ditches, berms, etc. However, system construction does not require heavy equipment, except for diversion structures if flows are of considerable volume.

Location of Previous Experience

Few waterspreading systems exist in the Sahel. However, extensive successes are reported in other arid areas: Australia, the Near East, the western U.S., etc.

Literature Reference

NAS (1974). More Water for Arid Lands. 153 p.

4.3 Reservoirs

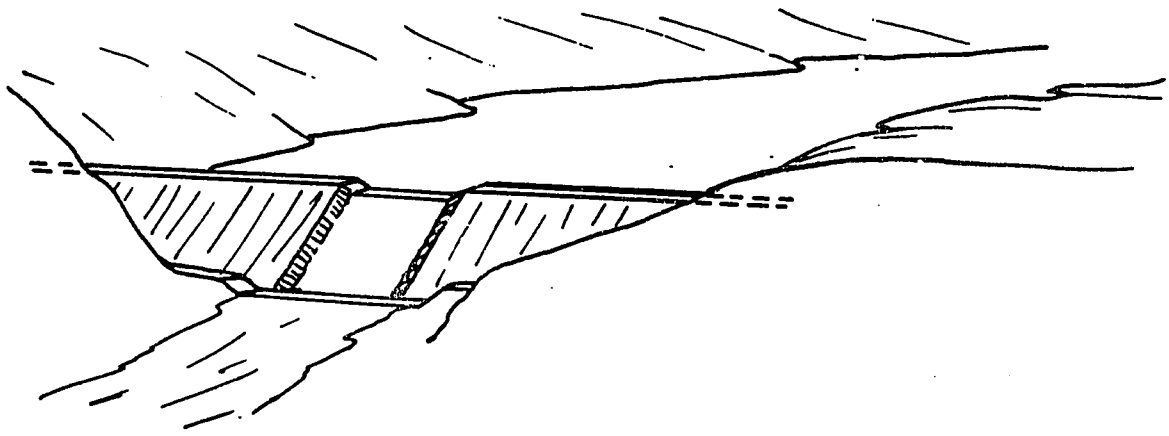
Narrative Description

Dams constructed at favorable sites may impound considerable volumes of surface flows that otherwise would be lost downstream.

A series of reservoirs may be feasible along a watercourse to retain water for use during the dry periods and for flood control; groundwater availability also may increase in the vicinity.

Area of Applicability

Reservoirs should be considered for areas where water is in short supply. This requires ideal terrain and subsurface and geologic conditions. The greatest problems are porous soils, sedimentation and high evaporation rates.



Design Guidelines

Large-scale surveys, subsoil investigations, engineering and construction are required. Reservoir construction is a job for technical agencies with considerable engineering capacity and construction supervision experience. Professional inputs from various disciplines required.

Notes on Local Participation

Land: Reservoirs benefit many landholders; however, some land is inevitably flooded. Residents living on the edges of newly available water will want their land-use rights assured.

Labor: Most reservoirs are constructed mainly by hired labor.

Benefits: Those whose land will be flooded will lose. Those whose land can benefit from being near a water source may increase their potential off-take many times through opportunities for irrigation and dry season gardening. Cattle owners may also benefit from the water source, and cattle driveways should be planned with input from farmers and herdsmen. Where a permanent source of water is to be provided negative health effects should be examined. Ideas, advice and suggestions of the local population should be included at the early stage of such a project. Provisions should be integrated into the design so that their basic needs and potential development (with accent on agriculture) should become the basic objective(s) of the effort.

Organization: Benefits and losses will affect many community residents so use plans should be considered by leaders and members of the various interest groups involved.

Combination With Other Conservation Activities

Soil and vegetation (1.0, 2.0) conservation activities can be integrated into reservoir development in many ways. An integrated approach to resource conservation and utilization will provide a well-balanced scene into which reservoir construction can be successfully blended.

Possible Production Benefits

Major benefits are possible when reservoirs are built, including more water (also for irrigation) and better use of the adjacent land. More reliable groundwater supplies are also likely.

Inputs Required

Reservoirs require major survey, design, and extensive construction efforts with heavy equipment, etc. Reservoir construction is capital intensive.

Location of Previous Experience

Several major reservoir projects have been carried out in Senegal, Niger, and Upper Volta. Some large river-basin developments also include construction of major reservoirs (e.g., OMVS, OMVG).

Literature Reference

FAO (1976). Conservation in Arid and Semi-arid Zones. FAO Conservation Guide No. 3, Rome. 125 p.

NAS (1974). More Water for Arid Lands. 153 p.

Many basic textbooks, project files of previous projects, etc.