
**GUIDE TO BEST SOIL AND WATER
CONSERVATION PRACTICES**



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PREFACE

Soil and water conservation is an international concern, since eroded, unproductive, poorly nourished, and improperly used land is found in many countries throughout the world. More and more people are becoming increasingly aware that their agricultural land must be kept permanently productive; and that an essential prerequisite to this is a sound practical soil and water conservation program.

Effective soil and water conservation calls for treating and using the land according to its capability and need. To do this a careful study is required so as to fit conservation techniques to the different kinds of land.

These techniques, commonly called soil conservation measures and practices, can be used singly on land with few limitations, or in varying combinations on land with more severe limitations. Also, they must be used within the farmer's economic capability and in accord with his available facilities.

All techniques which help to protect or improve the land are tools of conservation. Contours, terraces, waterways, cover crops, crop rotations, fertilizers, drainage, strip crops, and many others are counted as such tools. These will help protect or improve the land if used in the right place at the right time.

This publication presents 60 such soil and water conservation measures and practices, and briefly describes each one. It does not purport to be a detailed technical guide. It does, however, attempt to point out many of the conservation tools which can be used to control water and wind erosion, make better use of available rainfall and irrigation water, improve soil fertility, and increase crop yields.

CONSERVATION FARM PLAN

The application of an effective soil conservation program should be done in accordance with a sound, well-developed conservation farm plan. This is a plan for the treatment and use of the land, and represents a blue-print for proper farming operations over a long period of time. The purpose of the plan is to use the land according to its capabilities and to treat it according to its need for continued production.

A detailed soil survey is essential in farm planning. The survey will show the kind of soils, and may also show such factors as soil depth, natural drainage, erosion, and permeability.

Land use capability maps interpret the information contained in the soil survey maps, and should be used by the planning technicians in the development of the farm plan.

CONTOUR BANKS (Also see "Pasture Furrows")

Contour banks are similar to, but are level and larger than, pasture furrows, have a greater holding capacity, and are primarily used to promote absorption of water. As they are effective at greater distances apart than are furrows, they are more suitable for cultivated land.

CONTOUR FARMING

Contour farming is conducting farming operations on sloping cultivated land in such a way that plowing, land preparation, planting and cultivation are done on the contour. This includes following established grades of terraces, diversions, or contour strips, and farming between trees in orchards and vineyards planted on the contour.

CONTROL OF SALINITY AND ALKALI

Management practices for the control of salinity and alkali include choosing those crop varieties which will provide satisfactory yields under moderately saline conditions; the use of land preparation and tillage methods to help in the control or removal of salinity or alkali; special planting procedures to minimize salt accumulations around the seed; selecting the proper irrigation method to maintain a relatively high soil-moisture level and at the same time allow for a periodic leaching of the soil; the installation and maintenance of water conveyance and drainage systems; and conservation measures such as use of fertilizers, the addition of organic matter, and growing sod crops to improve soil structure.

The quality of water used for irrigation and the texture of the soil chiefly determine the type and extent of management practices needed.

COVER CROPS

Any crop while serving as a solid ground cover, whether or not planted specifically for that purpose, is a cover crop. Thus growing grain crops, grasses in pastures, and crops planted for turning under as green manure are cover crops. General usage, however, perhaps restricts the term more definitely to crops which are planted especially for the purpose of checking soil erosion, adding organic matter to the soil, and improving soil productivity. Cover crops, planted either in strips or in solid planting, also can effectively control soil blowing. Cover crops are most important for lands under cultivation, although the vegetative cover in any situation is valuable in soil and water conservation.

CROP RESIDUES

Many crops produce considerable plant materials (crop residues) in addition to the harvested or grazed parts. These residues may be plowed under, left on the soil surface, or partially mixed in the soil surface when preparing the seed-bed for the next crop (mulch tillage). Residues used by any of these methods will reduce runoff and erosion caused by wind and water. When plant materials are used as a mulch, they provide maximum protection to the land; when incorporated into the soil, they provide less protection.

CROP ROTATIONS

Crop rotations properly used are strong factors in reducing erosion. The crops most frequently used are a cultivated crop (row crop), a small grain, and a grass, legume, or grass/legume mixture. Grasses and mixtures of grasses are usually more effective in controlling erosion and improving soil structure than legumes alone. In general, the longer the land is in sod, the greater is the improvement in soil structure. The steeper slopes should be kept in non-cultivated crops most of the time; or erosion control measures such as strip cropping and terracing should be used to supplement the crop rotations if soil and water losses are to be kept at a minimum.

In sections where perennial grasses and legumes are not easily adaptable, a rotation of row crops, small grain, and annual legume crops can be arranged in strips. In dry farming areas the sequence of row and small grain crops, and fallow when needed, should provide for efficient use of moisture and for adequate crop residue.

DIVERSIONS

A diversion is an individually designed channel constructed across the slope to intercept surface run-off and carry it to a safe outlet. Diversions are used principally to reduce the length of slope, protect bottom land from overflow, and cut off the headwater from the top terrace when the land above cannot be terraced because of topography, land ownership, etc.

Drainage areas should be in grass, a good rotation, strip cropped, or terraced; otherwise soil deposition will fill the channel. Diversions, plus their outlets, must be designed so that the velocity of the water will not exceed that allowable for the type of vegetation present. Diversions should not be used as a permanent control on areas which can be terraced.

DRAINAGE

Drainage is an important practice in conservation farming. Excess water can be drained from the land by either open surface drainage or by internal drainage (usually tile drains).

The initial cost of surface drainage is commonly less, and can be used in certain soils of the tropics to an advantage. However, surface drains have the disadvantage of occupying land, are difficult to cross with farm machinery, and drain the surface and not the soil.

Tile drainage initially costs more, but tile drains do not waste land, are not an impediment to farm machinery, and provide a better root zone. However, they may not be effective in some soils.

In most irrigated areas drainage may be required to control the rise in the water table due to conveyance losses and over irrigation. When saline soils are reclaimed, good drainage facilities are necessary for leaching excess salts from the root zone, desalinizing the ground water, and preventing resalinization.

DUNE STABILIZATION

Drifting sand and sand dunes are much more difficult to stabilize than cultivated crops and constitute a special reclamation problem. These dune areas are usually rough and hummocky and are easiest to reclaim during periods when rainfall is most plentiful and wind velocity is at its lowest. It is best to smooth out only the crest and to work the side facing the prevailing direction of the wind first.

Where sand accumulation is shallow, use a deep furrow cultivator to bring some clods to the surface; use a lister for deeper sand accumulations. As a temporary cover, seed this stabilized land with a rapid growing grass species adapted to specific climate and soil conditions. On very deep sand accumulations use mulches of straw, hay, brush, or other vegetative matter to anchor the sand. Add the mulch on the windward side first. Plant locally adapted grasses, shrubs or trees for permanent stabilization of temporarily reclaimed areas. The final objective is the establishment of native vegetation.

In humid areas, especially on beaches, drifting sand is frequently a problem. Here stabilization measures are similar to dune control in drier areas. In some instances, log or brush barriers can be used as an initial stabilizing measure. Later, adapted species of grasses should be planted; followed by selected shrubs and trees.

Stabilized sand-dune land must be managed carefully. Cover trails and roads through loose sand with non-erodible material such as gravel or crushed rock. The grassland, scrublands and woodlands must be protected from overgrazing, fire, or excessive cutting of trees.

GRADED BANKS

Graded banks can be used on arable land where the slope is too great for broad-bench terraces. They consist of several furrows moulded to make the bank large enough to provide an effective channel above them. This collects surplus water and carries it across the slope at a gentle gradient ($\frac{1}{2}$ to $1\frac{1}{2}$ percent) to a safe outlet. Their principal functions are to promote absorption of water and to carry off surplus water slowly and safely.

GRASS CROPS

Grass crops, as defined here, are any grasses or legumes or mixture of grasses and legumes, whether seeded or growing naturally, raised mainly for seed, forage, erosion control, or soil improvement. It does not include legumes such as soybeans and groundnuts or such annual grasses as maize and sorghums grown as row crops, nor such grass crops as wheat, barley, and oats which are grown mainly for grain.

Most of the grass crops are soil builders. This is particularly true of those which are allowed to grow for several years. They protect the soil against erosion and usually improve its structure and tilth. This is in sharp contrast to the way most annual crops, especially the clean-tilled crops, affect the land.

GREEN MANURING

Green manuring is the practice of turning under plant material to improve the soil. While any dense crop will provide seasonal cover, special crops are usually grown for green manuring. Turned under, these crops may add organic matter, improve soil structure, decrease run-off and erosion, and hold nutrients which may otherwise be lost by leaching. Cover crops are frequently used to prevent soil erosion; these crops may later be turned in to act as a green manure.

Various opinions are held on the value and methods of green manuring, especially in tropical regions. Some experiments in these regions have shown that the chief benefit may come from the mineral content, not from the organic content, of the green manure crops. Others show that soil structure can be improved by the use of certain grasses, or legume/grass mixtures.

GULLY CONTROL

Gullies commonly form wherever run-off is concentrated in unprotected depression channelways.

The measures used to control or improve them depend on their size and their drainage area. Small gullies with small to medium drainage areas are those that can usually be best improved by the farmer; and one of the simplest and cheapest means of arresting their advance is to fence them and exclude livestock. Once the area is completely fenced, natural vegetation often will give adequate protection; also grass, shrubs, or trees used separately, or in combination, can be used.

Diverting run-off from the gully head is another effective gully control measure. Water may be diverted by a diversion ditch or by a series of terraces or contour furrows. The use of diversions should be limited to small drainage areas because of the difficulty in handling large volumes of water. A diversion can only be used where there is a satisfactory outlet. If the outlet is subject to erosion, the water should not be diverted. Diversions are best used in connection with small gullies in pastures where satisfactory outlets are common. Where terraces or contour furrows are used, run-off into gullies may be reduced to the extent that they will become stable through natural vegetation. Level terraces and contour furrows should be applied to the major part of the area draining into the gully. These terraces properly spaced to control erosion and conserve water should reduce run-off enough to provide control for most gullies.

Development of stockwater ponds in range sections or pastures may help to solve the gully problems. A dam built near the head of a gully can store a large part of the run-off. The storage of water behind a dam reduces run-off downstream, and the reduction in run-off may permit natural re-vegetation for a reasonable distance below the dam.

Care should be taken that the pond is properly designed, is not located on gullies which drain large areas, and is not susceptible to seepage (See Stock Ponds).

Vegetation cannot be used to stabilize all types of gullies. Determining where vegetative measures become unsatisfactory and structural measures are necessary can only be done after a careful study of individual site conditions. Structural measures consist of dams of varying designs constructed to stabilize the grade and halt further erosion. Properly installed structures will transform an unstable gully into a satisfactory waterway.

IRRIGATION METHODS

EROSION UNDER IRRIGATION

Much emphasis has been placed on reducing erosion by water on non-irrigated lands. On irrigated lands, erosion has not been considered so important, as irrigation is normally carried out in areas of flat land and of low rainfall. Yet, where sloping lands are irrigated by any method, erosion may occur as the result of moving water.

Where irrigation water is applied on level or nearly level land, or where properly managed flood irrigation of close-growing crops is practised, erosion usually is slight. Also, with properly designed sprinkler systems erosion does not occur, since the water is applied no faster than the soil will absorb it. However, when water is applied on sloping lands by the furrow method, for example, erosion is a constant threat.

BASIN IRRIGATION

Basin irrigation is done by filling a diked area of land with water to the desired depth quickly and allowing the water to enter the soil. When basins are properly graded and built to the right dimensions for the kind of soil and water supply, water can be applied efficiently. Basin irrigation is adapted to close-growing crops and rice on flat land. The method provides good control of the water applied; it is also useful for salinity control.

BROAD FURROW IRRIGATION

Broad-bottom furrows can be used on nearly level land in place of the usual V-type furrow. This method may increase the rate of water intake and eliminate compaction of the sides of the furrows by tillage equipment.

CONTOUR BORDER IRRIGATION

Contour border irrigation is applying water to a gently sloping field that has been divided into strips bounded by low earthen ridges on the contour. The ridges confine the water to each strip until the required irrigation is completed. When the desired amount has soaked into the soil, the excess is drained off and used to irrigate the next border strip below. However, for irrigating rice, the water is held on the entire field for a long period of time.

For successful contour border irrigation the soils should be medium to fine textured; and the topography smooth and reasonably uniform. Land grading may be required in some instances to remove major irregularities in the land surface.

Advantages of contour border irrigation are: an efficient and uniform distribution of irrigation water is easily obtained; maximum use can be made of rainfall; operating the system is simple and easy; and initial installation and operational costs are normally relatively low.

CONTOUR FURROW IRRIGATION

Contour furrow irrigation is applying water in furrows across rather than down sloping land. The furrows are given just enough grade for water to flow, but not enough to cause erosion. Under most conditions, row crops can be irrigated safely by the contour furrow method on gently sloping to moderately sloping land. Care must be taken in providing for drainage of excess rainfall or irrigation water.

CONTROLLED FLOODING

Controlled flooding is an irrigation method by which water is flooded downstream between closely spaced field ditches which keep the water from concentrating and causing erosion. Frequent openings in the ditches allow a uniform distribution of water over the field. Controlled floods are adaptable to close growing crops on rolling land or on pasture sod. This method provides water control and fairly uniform wetting where the land cannot be readily adapted to other methods of irrigation.

FURROW IRRIGATION

Furrow irrigation is one of the most common methods of irrigating row crops. The water is applied in the furrow between the plant rows. However, care must be taken that the furrows are not too steep, as this is one of the major causes of erosion by irrigation water. Soil conditions, crop cover, and rate of flow are also factors influencing the amount of erosion. Furrow irrigation is adapted to row crops, truck crops, orchards and vineyards on gentle slopes with all but the coarse textured soils. This method provides no conservation features unless furrows are laid on nearly level land or on the contour and water applied with care.

GRADED OR PARALLEL BORDER IRRIGATION

A graded or parallel border irrigation system consists of parallel strips of land separated by low earth ridges on a field which has been graded to a uniform slope.

A large stream of water is turned in at the head of a border strip and moves down slope as a uniform sheet guided by the ridges or borders, penetrating into the soil as it goes. As soon as the desired amount of water is applied, usually before the sheet has reached the lower end, the water is cut off. When the receding water reaches the lower end the entire strip is considered to be irrigated.

The graded border method is adapted to most soils where depth and topography permit the required land grading at a reasonable cost and without a permanent reduction in soil productivity. Slopes should not exceed 2 meters per 100 meters.

This method is fitted to a wide range of soil textures, excepting only those having extremely high or extremely low intake rates; and is well suited to the irrigation of close growing crops not damaged by temporary flooding. It is used commonly for irrigating hay crops, pasture grasses, and small grains. Orchard and vineyards are also irrigated by this method.

SPRINKLER IRRIGATION

Sprinkler irrigation, where it can be adapted and where crop returns will support the cost, provides excellent control of the water applied to the soil. Water may be applied with sprinklers at a rate that the soil will absorb it without run-off. Because the water can be so carefully controlled, sprinkler irrigation has a special use in conservation irrigation. For example, it is adapted to both level land and steep slopes; necessary erosion control measures on steep land can be used with this method of irrigation. Sprinklers, however, cannot be used universally. In hot windy climates, much water is lost through evaporation and wind drift causes uneven water application. On very heavy soils, because of low intake ability, the rate of applying water must be low; requiring closely spaced sprinklers which increase the cost of installation.

LAND GRADING

Land grading is reshaping the land surface to a planed grade. It is of most benefit to soils which are suitable for irrigation by border or furrow methods and are deep enough that needed cuts and fills can be made without permanently reducing productivity. In some instances, yields may be lowered immediately after land grading, but most soils can be restored to their original productivity by the use of fertilizers and good conservation and soil management practices. Where damage is likely to be permanent, land grading is not recommended.

Topography frequently limits the extent of land grading that is feasible. Grading is usually limited to land which can be graded economically to slopes not more than 2 meters per 100 meters. Slopes of less than 0.5 meter per 100 meters are preferable.

LAND SMOOTHING

Land smoothing, sometimes called "planing", is the removal of minor irregularities in the surface without altering the general topographic pattern. All irrigable soils can be smoothed, but the practice is useful chiefly on nearly level land or land with slight and regular slopes. Land smoothing is also the final operation in land grading. In one way or another it may be used with any type of irrigation system.

If possible, land smoothing should be done before laying out a contour border irrigation system. It straightens the contour ridges, makes farming and the operation of the system easier, and results in a more uniform application of water.

Where sprinkler irrigation is to be used on nearly level, poorly drained land, smoothing may be the most practical means of providing adequate surface drainage.

Smoothing can also be used to good advantage with sub-irrigation, as it permits the artificial watertable to be controlled at a more uniform depth below the land surface.

MULCH TILLAGE

Mulch tillage is a form of minimum tillage; that is, stirring the soil as little as possible and leaving most of the crop residue on the surface. It saves both soil and moisture. Moreover, it make use of crop residues to improve the soil structure and helps to maintain organic matter.

This method of tillage supplements terracing, strip cropping, and other well-known erosion control practices for sloping land. Since there is no plowing, there are no dead furrows to disturb row drainage; and less maintenance is required on terraced land. On gentle slopes, mulch tillage on the contour may replace terracing and strip cropping since each mulch-tilled furrow acts as a miniature terrace. Mulch tillage protects level lands from wind erosion and the impact of rain; and the furrow protects young plants from wind damage.

ORCHARDS AND VINEYARDS: CONSERVATION
AND MANAGEMENT MEASURES

Irrigation: Soil erosion is a common hazard in many orchard and vineyard areas. Selection of an irrigation system and its design must be fitted to slope and soil conditions to reduce or eliminate soil losses and to permit efficient water use. Surface irrigation is a method extensively used for orchards and vineyards; although sprinkler irrigation is sometimes used to avoid or overcome the inadequacies of surface irrigation on complex orchard sites, steeper slopes, and coarse textured soils.

With surface irrigation, the use of broad, shallow furrows directly down short, moderate slopes can adequately distribute the irrigation water over the orchard area. Connecting, cross-slope furrows between trees may be added to slow the irrigation stream for better penetration into finer textured soils. In all cases, the length of the irrigation run should be fitted to the soil and slope conditions to permit water distribution within a reasonable time over all portions of the orchard area, with a minimum of soil movement by the irrigation stream.


Permanent Cover Crops: Permanent cover crops in orchards serve a number of important objectives: erosion on steeply sloping sites is largely eliminated; irrigation water intake rate is improved on finer textured soils or compacted surface soils; organic matter may be gradually increased in the surface soil layer. Also a well-adapted and maintained permanent cover will usually suppress or prevent noxious weed development.

Mulches: Mulches are used as a soil cover for erosion control in many orchards on steeply sloping sites. They may complement the practice of weed-free, non-tillage and the use of a sprinkler irrigation system. Material used includes straw, low value hay, sawdust or wood shavings, and farm and feed lot manures. Also, the use of mulches may reduce evaporation from the surface soil and lower its radiant heat absorption and temperature.

Weed-free, non-tillage: Weed-free, non-tillage in orchards and vineyards is the practice of weed control by the use of chemical sprays. Use of this practice may result in an increased irrigation water intake rate on soils with a compacted surface layer caused by previous tillage. Harvesting, spraying, and other operations requiring equipment traffic in the orchard area are facilitated. Chemical weed control is also used to remove weed and cover crop growth from an area immediately around and under fruit trees of cover cropped orchards and in the trellised rows of vineyards.

PAIRED PLANTING

Paired planting of willow or poplar poles, or poles of other fast growing trees, spaced at three to six meters intervals at key points along the sides of incipient gullies is a cheap and effective method of controlling erosion. The roots provide an erosion resistant mattress which prevents lateral and downward erosion by water. These poles should be firmly planted two-thirds of a meter to a meter deep, and must be protected



PASTURE AND RANGELAND IMPROVEMENT

CONSERVATION GRAZING OF CATCHMENT AREAS

Gully and rill erosion on non-cultivable steep grassland can be controlled by recuperative spelling and subsequent moderate grazing of the entire catchment area affected. This has been done effectively on badly gullied steep land under both low rainfall, natural grassland conditions, and high rainfall, severely gullied conditions.

The grass cover, by promoting infiltration, improving soil structure, and offering resistance to the flow of water, slows down run-off and spreads it over a longer period; thereby reducing its erosive power.

CONTOUR FURROWS

Contour furrows are effective on ranges supporting sod-forming grasses where the slopes are gentle to moderate; and where the soil is productive enough to support the additional growth that the increased moisture encourages. Contour furrows are not satisfactory on loose soils, on rough broken lands, or on steep slopes. Nor can satisfactory response be expected on shallow, unproductive soils. Small furrows, spaced not to exceed one and a half meters apart are usually more effective than larger furrows or those more widely spaced. The small furrows regrass more rapidly, and hold the water where it is the most beneficial. Widely spaced, larger furrows regrass more slowly, if at all, and may hold more water that can be used at one point, while areas between the furrows suffer from lack of water.

PASTURE FURROWS

Well made pasture furrows have been used effectively in leading water away from wet depressions and using it to advantage in the drier parts of the slopes, as well as in preventing saturation of the slopes beneath. Their principal functions are to prevent run-off, promote absorption, and improve distribution of water on hillsides.

They are made by plowing a discontinuous furrow across the slope of the contour, or by a continuous furrows across the slope at a slight gradient.

PASTURE MANAGEMENT

Pastures are one of the most effective and economical ways of holding and enriching the soil, provided they are properly developed and managed. Two important requirements of good management are: a sufficient supply of fertilizer to make enough growth of desirable pasture plants to cover and protect the soil and to provide forage for livestock; and regulating the number and kind of livestock and periods of grazing so that the plants can maintain their growth during the grazing season.

Much of the badly eroded pasture land in countries where water erosion is a problem is the result of the soil having been washed away while the land was being cropped. When the soil became too poor to pay the cost of putting in a crop, it was abandoned; and often livestock were turned in to eat whatever would grow there. Such land, if it is to be used as pasture, should have proper development and grazing control. Otherwise, the erosion will become progressively worse.

Overgrazing is a cause of wind erosion on grazing land. Thus the importance of grazing control cannot be over emphasized. Even with controlled grazing, difficulty is often caused by animal traffic concentration around water sites at shade areas, etc. Vegetation is frequently destroyed, and these areas, although small, can initiate erosion. As they erode, surrounding vegetation is destroyed and the affected part enlarged. Control and re-stabilization of such areas must be undertaken before extensive damage is done. Supplying adequate watering sites and fencing or otherwise excluding animals from the erosive portions of the pasture can help in overcoming the problem.

PITTING

Pitting rangeland with an eccentric disk is particularly effective in improving the forage growth on short grass range. In operation, the disk scoops out shallow, discontinuous pits which will hold additional rainfall. This is a distinct advantage where the moisture from sporadic rainfall is frequently lost through run-off. Pitting is particularly adapted to ranges which, under excessive use, have reverted to a short grass cover with a high density but with low volume production of forages. The increased moisture retained in the pitted surface, the longer grazing season, and the greater supply of better forage usually combine to increase the grazing capacity.

RANGELAND GRAZING DISTRIBUTION

One of the most important features of range conservation is maintaining proper distribution of the grazing animals so that localized areas are not over-grazed while others are undegrazed.

A good distribution of stock watering places is an effective means of spreading the grazing load over all parts of the pasture.

Sufficient fences in the right places will also aid in the distribution. Fences should be so placed that animals will not have to cross deep ravines, high ridges, or other natural obstructions to travel to water and feed. Placing salt on parts of the range that might not otherwise be grazed may bring about better distribution. Rotation grazing may relieve trampling and overgrazing on many areas which are subject to concentration. Occasionally shifting the cattle by driving may be necessary if distribution is not secured otherwise.

RE-SEEDING RANGELAND

On land where the grass is not destroyed, natural processes may bring about recovery if grazing is restricted. If misuse has proceeded to the point that the grass cover is destroyed, re-seeding will be necessary. On land that has been cultivated and is being converted to grass, or on bare pastures, the first step is to stop soil blowing. On some bare land it may be necessary to plant erosion-resistant forage crops for immediate stabilization and to enable the planted grasses to become established.

Loose sandy soils are difficult to revegetate, especially if they have lost most of their plant cover and have a tendency to form dunes. Wind and moving sand on such land may kill young plants before they can form a ground cover to hold the soil in place. Revegetation by nature on loose sandy soils is usually slow. Care should be taken to stabilize them before the plantings are made.

ROTATION GRAZING

Good results may be expected from rotation grazing that allows every part of the range to grow to maturity during a cyclic period; e.g. at least once every 3 or 4 years. On many types of range more total forage will be produced under a proper system of rotational grazing than where the range is grazed continuously. It is possible in some instances to establish a satisfactory grazing rotation by simply closing the water holes on the range to be protected.

Rotation grazing is essential on severely depleted ranges or where erosion is serious. However, where the topography is such that certain areas afford protection during winter months, or if the forage produced can be utilized to advantage only during certain seasons, it may be necessary to use the same ranges more or less continuously during the same season year after year. On ranges grazed continuously during the growing season, the grazing must be light enough to permit an accumulation of reserves.

SHELTERBELTS (Windbreaks)

Shelterbelts, often called windbreaks, are barriers of trees or shrubs planted to reduce wind velocity, evaporation and wind erosion; and to protect crops, homes, farm buildings, and livestock. They are planted across and on the margins of agricultural fields or near farm buildings.

Where trees, shrubs, or hedges grow well in wind erosion areas, their use is beneficial both for wind erosion control and to protect crops from hot dry winds or from blowing sand or soil.

Shelterbelts also alter such factors of microclimate as humidity and temperature in the protected zone. Here, moisture may be conserved by reducing evaporation and transpiration. These changes in field environment usually have a favourable effect on the growth and development of the plants.

SLAB AND LOG DAMS

Slab and log dams have been used effectively to prevent scour, accumulate debris, and provide drops to lessen the erosive force of flood waters. These can be augmented by willow and poplar poles at the dam site which will root extensively and replace the structure as the log materials decay.

SOD CHUTES

A sod chute is a steep-sodded section of a watercourse constructed to conduct a flow of water for a short distance at a safe velocity. The required vegetation may be established by transplanting sod; or, if the water can be diverted around the section for sufficient time, it may be established by seeding. Sod chutes may be used at overfalls or abrupt changes in the slope of a natural waterway at the lower end of watercourses to conduct water into a natural channel, or to conduct water from a flat area next to a drainage ditch to the bottom of the ditch.

SOIL CHISELING

Chiseling is breaking or shattering parent material, a hard-pan, a plow pan layer below normal plow depth, or clay pans which impede internal soil drainage or restrict development of plant roots.

A narrow chisel-like tool is used to cut through the soil at varying depths; e.g. - one half to one meter. This operation is best done during the driest part of the season when the shattering or breaking will have the greatest effect. Fertilizer, lime and organic matter may then be placed in the channel so produced to promote deeper rooting.

SOIL CONSERVING CROPS

Soil conserving crops should be considered mainly in terms of the effect these crops have on the organic matter content of the soil.

Crops which can be grown with a minimum of tillage are, in varying degrees, soil conserving. Non-cultivated crops, such as lucerne (alfalfa), clover, selected grasses, and pasture, conserve the organic matter in the soil as well as protect against erosion. These close growing crops by restricting the erosion of the surface soil help maintain the organic matter and those mineral fertilizers, especially nitrogen, which it contains.

Cultivating the soil for small grain crops, for example, causes some loss of organic matter, and allows for more erosion than with pasture or meadows. A small grain crop may be called soil conserving only in comparison with a crop which is more soil depleting, e.g. maize or cotton. Likewise, in comparison with pasture, small grains would be soil depleting.

STOCK WATER SUPPLY

RESERVOIRS (Also see "Stock Ponds")

Reservoirs can be used to augment stock water supply. Some reservoirs are sited in natural swampy depressions in upland valley floors where the gradient is low and the width sufficient to provide inexpensive storage, as the fill required is relatively small. Alternate locations are on terraces or lower flats where water from gully or grassed waterway can be diverted along the contour to the excavated reservoir well clear of the natural gully and watercourse.

SPRING DEVELOPMENT

Both intermittent and continuously flowing springs provide a good source of water for livestock, especially in rough, broken areas adjacent to higher lands.

To develop a spring, it is necessary to clean out the opening, locate the true water-bearing outcrop, and provide a means for collecting and using the outflow. The spring must be protected from surface damage and suitable cribbing and collection facilities should be provided to keep the collecting sumps and inflow channels open.

All springs should be protected from surface run-off; and, except for the open type development, be enclosed by a substantial fence to keep out livestock. A suitable interception ditch is desirable to divert surface water around the spring. The drinking trough should be placed outside the fenced enclosure, where animals will have easy access to it from as many directions as the natural terrain will permit. Rock or gravel can be placed around the trough to prevent the formation of mud holes; and a dense vegetative cover around the spring will help reduce erosion.

STOCK PONDS

Stock ponds should be sited on safe locations, preferably on small flats and in depressions on the hills; or by constructing a dam across a watercourse or a natural basin. Their size depends on the rainfall, the number of stock to be watered, and the size of the catchment area. It is best to site them away from existing gullies which drain large areas, concentrate flow, and make provision for safe overflow difficult. Other factors to consider in selecting a suitable site are its location in respect to good grazing lands, the distance from other sources of water, and the probable cost of the dam and spillway.

Care should be taken that the catchment area is not too large, as run-off from heavy rains may overtop and destroy the dam. On the other hand, if the area is too small the pond may dry up when it is needed most.

STREAM BANK EROSION CONTROL

The purpose of stream bank erosion control is to hold in check bank cutting to protect valuable land and reduce the silt load of the stream. This control is done mainly through the use of vegetation; supplemented by whatever mechanical installations necessary to insure the satisfactory establishment of the vegetation.

Streambank work done on any segment of a stream will be affected by the condition of the stream above and below the segment being considered. Thus, it is best to protect the entire length of the stream at the same time. Frequently, it may not be possible to do this, but a plan for the entire stream should be made so that work done on any one segment will later fit into the entire project.

STRIP CROPPING METHODS

BUFFER STRIP CROPPING

In buffer strip cropping, strips of grass or a legume or a mixture of the two are laid out between strips of crops grown in regular rotations. The buffer strips may be broad or narrow and of even or variable widths. They can be placed either on the steep, badly eroded parts of a slope, or at more or less regular intervals on the entire slope. The buffer strips are used mainly to give more protection from erosion than is afforded by a solid planting of grains or intertilled crops.

CONTOUR STRIP CROPPING

In contour strip cropping, the crops are arranged in strips on the contour at right angles to the natural slope of the land. Usually the strips are cropped in a definite rotational sequence and so arranged that a strip of grass or close growing crop is alternated with a strip of clean tilled crop or fallow. This type of strip cropping is commonly used for the control of water erosion. Sometimes it is also used effectively on sloping land in areas where wind erosion may be as serious a problem as water erosion.

FIELD STRIP CROPPING

In field strip cropping, the strips are of uniform width and are placed across the general slope, but they do not necessarily curve to conform to the contour; for example, in crossing drainageway depressions. This method of strip cropping is recommended only for those areas where the topography is too irregular to make contour strip cropping practical.

WIND STRIP CROPPING

In wind strip cropping, the strips are uniform in width, usually straight, and laid out as nearly as possible at right angles to the prevailing winds. This practice is best used on level or nearly level land where erosion by water is not a serious problem.

STUBBLE MULCHING

Stubble mulching is a year around method of managing plant residues on crop land. Harvesting, seed-bed preparation, planting, and cultivating are all done so as to leave residues of the previous crop on top of the soil until the next crop is seeded. These residues - or stubble - of the last crop make a mulch. Such stubble mulch reduces the impact of the rain on the surface of the soil and slows down the flow of water down the slopes; both of which help to control water erosion. The stubble also prevents close contact between soil and wind; thus retarding wind erosion.

TYPES OF TERRACES

BENCH TERRACES

Bench terracing is one of the oldest methods of erosion control. It consists principally in transforming steep land into a series of level or nearly level strips, or steps, running across the slope. These are separated by almost vertical risers of rock or earth protected by a heavy growth of vegetation. Bench terraces retard erosion losses and make cropping operations on steep slopes possible and safe. Whenever the absence of adequate level lands, or the special adaptability of particular slopes to high income crops, necessitates the cultivation of steep land, the bench terrace will continue to be useful.

BROAD BASE TERRACES

These terraces have a wide, gently graded bank with a large capacity shallow channel above it; and are so designed that there is no hindrance to modern implements. Such a terrace thus meets the requirements of one which will break up long uniformly sloping land without physically impeding cultivation.

They reduce run-off and erosion and serve as guidelines for contour cultivation. Gradient terraces closely follow the contour of the land with just enough grade to allow for an orderly disposal of water at the outlet; yet not enough grade to cause erosion. Broad base terraces should be constructed so that crops may be grown on them as well as on the intervals between them.

BROAD CHANNEL TERRACES (Also see "Broad Base Terraces")

The broad-channel terrace is commonly used to conduct excess rainfall from the fields at non-erosive rates. Since low-velocity surface removal of excess water is required, the channel and not the ridge is important. A wide, relatively shallow channel of low gradient with gentle side slopes and ample water carrying capacity will give the most desirable results. The ridge should be considered as supplemental to the channel and should meld gradually into the surface slopes to afford a minimum of interference with tillage equipment.

RIDGE TERRACES

Erosion control by ridge terraces is done indirectly by water conservation. To increase absorption, the terrace is constructed to spread the collected run-off over as wide an area as possible. For this to be done effectively, the ridge must be high enough, and at the same time be broad enough to allow for the satisfactory operation of tillage equipment.

Ridge terraces are adapted to low rainfall areas, and to soils which will absorb the accumulated run-off fast enough to prevent damage to growing crops. However, these terraces may be used on some areas of sandy soils and gentle slopes where the rainfall is heavier, e.g. sandy coastal plains. Thorough examination of the soil absorption and rainfall rates should be made before this type of terrace is used.

USE OF FERTILIZERS

In most of the areas of the world where erosion by water is serious there tend to be soil fertility deficiencies which are major contributors to erosion conditions. Frequently, this is not well recognized, and in many countries money and effort are being spent on vegetative and engineering means for erosion control without correcting the basic soil fertility conditions.

Eroded soils, or those from which the original surface soil has been removed in levelling for irrigation or terracing, usually require heavier fertilizer applications to restore their productivity than those soils which have not been eroded. This is commonly true of nitrogen, but may not always be so for phosphorus and potassium because some soils are richer in these elements in the sub-surface layers. On such soils, when erosion has been halted and productivity has been restored, nitrogen fertilizer requirements are most likely to be influenced by the soil having been eroded. This is especially true in regions where the eroded soil is relatively high in organic matter, because the loss of organic matter in the surface soil may represent a more serious loss of nitrogen than of phosphorus or potassium.

In addition to fertilizers, the use of lime may also play an important role in the restoration of eroded soils to economic production.

VEGETATIVE WATERWAYS (Grassed waterways)

Vegetative waterways are natural or man made water courses protected against erosion by a vegetative cover; and are commonly used to carry run-off water down the slope into a drainage channel or other outlet without causing erosion. Well designed waterways also provide an outlet where excess water from terrace channels may be discharged without erosion damage to the field or outlet. The waterways must be graded accurately and made wide enough so that the water is spread evenly over a wide channel. They require a dense, vigorous growth of vegetation that will carry a flow of water without erosion; in addition, the waterways should be permanent. Some waterways can be successfully re-worked, but this may be difficult. A grass or grass mixture provides excellent cover. It should be one that can be maintained permanently or easily re-established.

WATER SPREADING

The diversion of water from natural watercourses to adjacent slopes where it can be spread over productive cropland may be profitable if suitable sites are available. This diversion not only reduces flood hazards and erosion losses, but also increases forage production on the spreading grounds. The most common type of spreader is a small dam placed in a watercourse, with gradient ditches or terraces leading the water out to gentle and uniform slopes where it is released.

Water spreading usually is not practical on loose sandy soils, on rough broken ground, or on very thin shallow soils. Water diversion structures may, however, be practical where the normal run-off from shallow land and rough broken land can be spread over adjacent valley slopes and flats with productive soil. Heavy clays may be satisfactory as spreading grounds if the water can be retained on the ground long enough to permit penetration.

WIRE NETTING AND LIVE POLE DAMS

Netting and pole dams can cope with large quantities of moving debris on gully floors. They consist of a curved row of stout poplar or willow poles (bulging downstream), placed in the wider portions of the gully, and supported by a steel cable firmly anchored in both banks. Bundles of brushwood are pegged across the gully and secured to the steel cables; these trap the silt and debris effectively. When the live poles are firmly established, wire netting is placed on their upstream side. Rubbish collects in the netting until the dam is full. When this has been done a second curving line of poles can be established, if needed.

Also, pairs of live poles can be made into an X frame; these are used to support the wire netting that collects the debris, while brushwood is used to prevent scour and undermining of the structure.

AFFORESTATION

Afforestation is a good method of conserving the soil in hilly water catchment areas as well as being an excellent tool for reclamation. By reclamation is meant the rehabilitation of land which has been eroded, gullied, buried by soil deposition from erosion, covered by spoil banks from mining operations, or degraded by bad farming practices.

The natural cover of a climax vegetation: grass: shrub, or forest, provides a good defense against most forms of accelerated erosion; and on all steep slopes and water catchments its maintenance is the best insurance against damage.

Ordinarily, however, there should be some type of land utilization, and where this includes the protective measures appropriate to the soil and climate, serious harm can be avoided.

Although rehabilitation by the protection of natural vegetation is usually best, there are occasions where tree planting is necessary.

CONTROLLED GRAZING OF FORESTED AREAS

Grazing of forested areas by domestic animals can reduce both forest production and the protection provided by forest cover. Where such grazing occurs it should be controlled by some type of fencing.

Grazing has several harmful effects. Trampling the forest floor diminishes the effectiveness of the organic cover in protecting the soil and conserving moisture. The soil of a grazed forest is more compact than that of a correspondingly ungrazed one. This lowers the infiltration rate capacity of the soil as well as reducing the beneficial effects of the forested area on the watershed area. Depletion of cover on rough, erodible land leads to serious damage from erosion by water. Also browsing and mechanical injury may eliminate the reproduction of desirable tree species.

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