A STUDY OF SOIL EROSION
CONTROL AND PREVENTION

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DEDICATION

This thesis is respectfully dedicated to Professor C. A. Allen, Civil Engineering Department, Michigan State College, in appreciation of his help and suggestions.

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PREFACE

The mission of this thesis is to collect in brief form the methods of control and prevention of soil erosion.

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INTRODUCTION

HISTORY AND ECONOMIC COSTS OF UNCONTROLLED SOIL EROSION

According to Antiochicus of Libanius, citizen of Antioch, the city of Antioch in 360 A.D. was the center of an almost Arcadia-like region. All natural resources, we are told, were poured out liberally for the benefit of Antioch. The earth, the streams, and the climate all combined to make the district fertile. The cultivated land was luxuriant with olives and yellow corn. The vineyards abounded. The heights of the mountains were covered with timber and furnished a perennial water supply. A flourishing trade was carried on in the export of agricultural produce.

But today the formerly rich highlands lie devastated and abandoned. Population has been reduced from about four hundred thousand to less than twenty-eight thousand. The mountains are denuded of forest and soil, and during the rainy reason, contribute torrential floods to rivers that no longer flow clear, and are frequently dry. While wars and earthquakes were partially responsible for the original decline of this once prosperous region, the change is fundamentally attributable to uncontrolled soil erosion caused by neglect and missuse of the land. Such destruction by man has not been limited to Antioch alone. All through northern Africa, Mongolia, and Asia Minor are found the records of once-flourishing regions whose abandonment, it is believed, was in a large measure due to the stripping of forest, over-grazing of pasture lands, or improper methods of cultivation, ending in severe erosion, desication, and desert conditions. The process has not been confined to ancient times, however, as it is going on daily in Africa, Italy, China, Puerto Rica, and many other countries.

One of the most serious conditions today exists in the United States. The United States is and has been one of the greatest despoilers of natural resources from earliest days. Fifty million acres have passed into uncultivatable condition. One hundred and twenty-five million acres still in cultivation have been largely stripped of productive topsoil, with consequent decline in productivity up to ninety per cent. One hundred million acres, if not protected, will, in the next seventy-five years, have passed into the same condition. The present area of cultivated land of about forty-five hundred million acres will have been reduced to a hundred and fifty million, if erosion is not controlled. Western grazing lands are in an equally bad condition. Many regions are headed toward desert conditions. Deposition of silt is filling reservoirs in many places, cutting down on the expected life of such projects.

The most conservative estimates of the costs of erosion amount to four hundred million dollars annually. The loss already totals ten billion dollars. The annual direct cost of four hundred million per year would amount to twenty billion dollars in fifty years, if not controlled. To this would have to be added the values of the following:

1. Great reservoirs clogged with products of erosion;
2. Abandonment of irrigated areas depending upon such projects;
3. Virtual abandonment of large agricultural areas;
4. Economic devastation of large Western areas dependent upon grazing; and
5. Transfer to relief rolls or other pursuits, of the tremendous farm population.

Fortunately, the United States government has made and is

applying a well-planned program of soil-conservation. Under this plan, erosive marginal lands are being retired from cultivation and planted to trees or pasture. Other methods being used in conserving the soil are: terracing, strip cropping, check-damming, planting of gullies, improvement of timber stands, and community fire control organizations. This work is under the direction of the Soil Conservation Service, and it is as yet confined to experimental and demonstrational watersheds. In the long run, effective control can come about only through the enlightened efforts of the farmers themselves.

All figures given were obtained from an article entitled "At Last, A Soil Erosion Program" by C. W. Collier, which appeared in the May 29, 1935 issue of the "New Republic".

CAUSES AND RESULTS OF EROSION

Soil erosion, sometimes called soil washing, is the removal of soil due to the action of surface water. It is more noticeable in the Southern states, due to the large annual rainfalls, but occurs to a somewhat lesser degree in the Northern and Central states. It has become accepted that most of the farms of the South must be protected to prevent erosion before a successful system of agriculture can be followed. Various methods of protection are being followed throughout this section. It is just becoming recognized that much of the farm land of Northern and Central states must be protected in a like manner. Although the washing in this section is of a much lesser degree, the lands carry a high evaluation, and therefore it is essential that a high degree of soil fertility be maintained at the lowest possible cost if profitable farming is to result.

There are two kinds of soil erosion--sheet washing and gullying. Sheet washing is not so noticeable as gullying, as the topsoil is removed rather uniformly from the entire area of the slopes. Gullying is due to the accumulation of run-off water in natural depressions of the soil surface. While gullying is the more dreaded of the two types of soil washing, it is in some ways not the worst. Because it is more noticeable, the need of preventative measures is apparent. While sheet washing may be present, it is not so noticeable. It is not so likely to receive the proper attention, and may go on year after year, robbing the soil.

CAUSES

Causes of erosion are various. One of the most important is the slope of the land. Soil is bound to wash when the slope is great and if

any great amount of water passes over its surface, providing nothing is done to prevent it. But lands of very little fall have also been found to wash badly when not protected.

Many slopes are too steep to cultivate successfully. It is possible to handle them so as to prevent erosion and still produce a crop, but not with profit. In such cases, it is best to sod them down for pasture use, or reforest them.

The total accumulation of rainfall per year, its distribution, together with the intensity, has a large influence on the amount of erosion. If rain comes in great quantities, over short periods of time, it is apparent that large amounts of water will run off the surface of the land, carrying with it soil, unless measures are taken to prevent such occurrence.

The type of soil has a great influence, as a heavy clay soil absorbs water slowly, while a sandy soil takes it up quickly. Soil containing much humus absorbs water more quickly than does the soil not possessing it. Open textured soils, such as sandy and fertile ones, are less likely to erode than the other types mentioned.

Methods of cultivating the soil have had a great deal to do with erosion. Shallow plowing, the running of furrows up and down the slopes, the planting of rows and cultivating them up and down the slopes are the most common mistakes. Shallow plowing means shallow seed beds, with the resultant inability to absorb much water. Plowing and cultivating up and down the slope offers small ditches for the hillside water. This water gains considerable velocity and picks up the soil, carrying it to lower levels.

The kind of vegetation on the land also effects the amount of erosion. Row crops, such as corn, cotton, and potatoes, do not offer so

much resistance as do broadcast crops, sods, or forests, while the absence of all vegetation presents the best possible conditions to encourage washing.

Gullies occur in every state, although, as was previously stated, the damage is greatest in the South. A typical case is that of an eighty-acre farm on which there were no gullies thirty-five years ago, which has been practically ruined for farming purposes due to the formation of a large gully with many branches. This gully grew to the depth of fifteen to twenty feet and ranged from thirty to sixty feet wide.

RESULTS

The greatest damage of erosion is the carrying away of soil, although there are many other bad features of gullies. They cannot be readily crossed by teams and farm implements, they grow rapidly if unchecked, and often extend throughout a farm, undermining and requiring the removal of farm buildings. They encroach upon public highways and make travel unsafe. Gullies extend across farm roads, undermining culverts and similar structures, often necessitating the building of bridges. They cause silting up of reservoirs and natural channels and of channels dredged at great expense. They carry sand-wash from hillsides, and deposit it on the rich bottomland, thus making it unproductive. Gullies make the farm unsightly in appearance, thus reducing its market value, as well as that of adjoining farms. The lives of stock that graze near the edges of undermined banks are endangered. For these reasons, gullies should not be allowed to start, or should be reclaimed if they do.

GULLIES

THEIR CAUSES AND REMEDIES

Gullies are caused by erosion due to water collecting and flowing at a velocity sufficient to move and carry away soil particles.

Stopping the gully commonly means checking it from further erosion--not filling it up. Simple methods have been found which can be applied easily on the farm to stop gullies in the Central part of the United States. The simplest way is to "heal" a gully by establishing a protective cover of trees, vines, or grasses over the surface. In healing or stopping gullies, the necessary steps are: First, to construct temporary check dams in the gully to catch up loose soil and in which to plant trees, vines, or grasses; second, to slope the banks to an angle of repose (about thirty per cent), which will also serve to put into the gully topsoil necessary for stimulating good growth; third, to plant trees, vines, or grasses selected for their ability to grow quickly and spread their roots in the soil and their tops over the soil; fourth, to protect vegetative cover from fire, live-stock, and over-cutting. In shallow, short gullies, it will often be found unnecessary to build check dams, except at or around the gully head or heads, the most critical point in an active gully.

TYPES OF EROSION

HEAD EROSION----There are several types of erosion, the first of them being head erosion. When plants and soil are unable to retain all of the rain that falls on rolling and hilly land, the surplus flows over the surface to the drainage channel at the foot of the slope in broad, thin sheets. Where depressions exist, however, the water from the surrounding

area is collected and forms a stream with power to wash away the soil. The power to erode increases as the stream increases in size and velocity, and if the depression is not protected from erosion by grass or other means, a gully will result, which is enlarged by each succeeding rain. Gullies may also be started by artificial means, such as the track of a wagon driven down a slope when the ground is soft, or by dragging a plow down a slope. Mole holes and cattle paths frequently cause the formation of gullies. One of the most common ways in which gullies are started is by the plowing or cultivating straight up and down a slope. A dead furrow extending in the direction of the slope will rapidly develop into a gully.

DITCH EROSION----Another type of erosion is ditch erosion. Where head erosion occurs on the upper part of a watershed, it makes channels for the rapid removal of excess water from the field slopes and delivers the water in large volumes to the natural drainage channels at the foot of the slopes. The capacity of these channels is overtaxed by the quick delivery of the water from all parts of the watershed, and the result is that the channels are greatly enlarged by the erosive action of the water. This enlargement continues until huge gullies are formed, often fifteen to twenty feet or more deep. The increase in size caused by ditch action is very rapid on the upper parts of the watershed where there are comparatively steep slopes. There is a general decrease downstream in ditch erosion as the fall of the channel becomes less. The fall often becomes so slight that silting instead of erosion results, particularly where the channel extends across a wide bottom and discharges into another stream.

WATERFALL EROSION----A third type of erosion is waterfall erosion. It is responsible for many of the deepest gullies or chasms, and is caused by water falling over the edge of a gully or ditch bank. The falling water

undermines the edge of the bank, which caves in, and the waterfall moves upstream. This undermining goes on rapidly if the surface soil is underlain by sand or easily eroded subsoil which is saturated with water. In this manner, gullies which often start in the banks of natural water courses have been eroded to a great depth. They extend back into the land slope and grow deeper up the slope, often attaining depths of fifty to sixty feet. As they extend backward and cross tributary water sources and natural depressions, waterfalls are in turn formed in their sides and branch gullies develop. This branching will continue until a network of gullies covers the entire watershed. Gullies formed by waterfall erosion may extend back to almost level land. Their growth is dependent upon the size of the drainage area furnishing water, and not upon the slope of the land. They sometimes grow at the rate of thirty to fifty feet in a year, depending upon the amount of rainfall, drainage area, and the character of the soil.

EROSION BY FREEZING AND THAWING----Another type of erosion common throughout the South is caused by alternate freezing and thawing followed by heavy rains. Slopes of gully banks are eroded and it does not necessarily follow water-courses. Owing to the fact that it can extend itself in all directions, this type of erosion expands over wide areas. It progresses rapidly, particularly in silted loams and clay loams.

CHECKING GULLIES

Many large gullies would never have been formed if means to check them had been taken in the beginning. Gullies from head erosion could be prevented if each square foot of the field slopes could be made to absorb all the rain that falls upon it. The water would then be slowly delivered to the main water-course below. There are several means of doing such--

increasing the humus content of the soil, deep plowing, use of cover crops, proper crop rotation, contour plowing, and tile draining. By contour plowing, is meant to plow along the contour lines and not across them.

It is not possible, of course, to make any soil absorb all the water which falls upon it during the heaviest rains. In order to prevent erosion, the excess should be taken from the field at a low velocity. This can be most effectively done by terracing the land. No matter what method is used for control and reclamation, the first thing is to check erosion at the head of the gully. Where it is possible, it is best to intercept the water before it enters the head of the gully, and divert it into a natural water-course nearby. In shallow gullies three or four feet deep at the upper end, head erosion can be quickly checked by building a low obstruction or dam at the head of the gully. Soil will be deposited between the dam and the head of the gully, the drop of the water will be reduced by the height of the dam, and erosive and undermining action of the water will be largely decreased at the head of the gully. If the gully is deep, a longer time will be required to fill it, whatever method is used, and during the time, some temporary means should be employed to stop head erosion and undermining.

One method of checking such erosion that is widely used in Iowa, consists in placing brush and straw in the head of the gully and fastening it down as shown in Figure 1. Posts should be set deep in the ground close to the bank of the gully from two to three feet apart--fence posts can be used. A layer of straw is first thoroughly packed around the posts and against the eroded

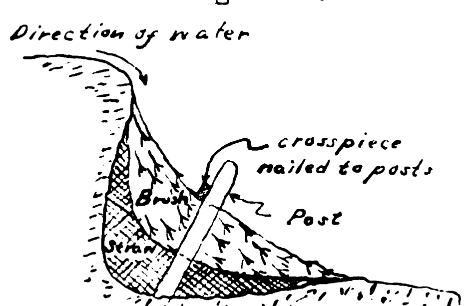

Fig. 1 · Method of checking erosion and underming of the head of a gully with brush and straw

and undermined part of the gully banks. A few branches are interwoven between the posts and laid crosswise to hold the straw in place. Brush is then packed down over the straw, the tops of the branches extending nearly to the post as shown in Figure 1. The result is a place in which water will fall without causing erosion, and stops the progress of the gully by stopping undermining until the gully is filled by other methods.

Sheet metal flumes, are sometimes used at the head of a gully, to which water has been conducted by means of earth dykes to protect the gully until it can be filled by means of dams constructed below. Some sort of protection is required at the lower end of the flume to prevent washing.

NATURE'S METHOD OF CONTROLLING GULLIES is to prevent erosion on the surface by vegetational growth and to hold the soil together by the plant-root system. Dead organic matter which accumulates on the top of the soil from year to year prevents surface erosion and absorbs much of the rainfall. Nature can control gullies, but the natural process of reclaiming them after they are formed is very slow. If eroded and badly gullied land is abandoned, a volunteer growth of some sort usually springs up. The kind of growth depends upon the locality. Wild native grasses, weeds, shrubs, and trees are the most thrifty and the best for rapid and permanent control of the gullies. Pine trees spring up of their own accord in some sections, and in conjunction with the weeds and grasses, form a good natural control. Wild honeysuckle grows and spreads rapidly on poor soil and is very effective in controlling erosion, but because of its tendency to spread, other plants are sometimes preferred. Large gullies with steep caving banks are the most difficult to control by natural means. They generally continue to enlarge for many years after land has been abandoned for farming. Large trees figure prominently in

the control of such gullies. Plants which supply both nitrogen and humus to the soil are best for natural control, for they will give to the land reclaimed for farming the required elements of fertility. Sweet clover and black locust trees furnish nitrogen to the soil, and have large branching root systems which are effective in the control and reclamation of gullies. In Pendleton County, Kentucky, large eroded areas of abandoned lands have been reclaimed by the volunteer growth of sweet clover. When the sweet clover first appeared in the county, it was regarded as a weed of the worst kind because of its big root system and teeming growth. Many farmers used to devote much time to ridding their places of this plant, but they now gather the seed and sow it on their wornout gully lands, as its value has been proven by the large crops grown on the abandoned land reclaimed by the volunteer growth of sweet clover.

PLOWING-IN AND SEEDING is a simple though often rather expensive method of reclaiming gullies. It can be applied to both large and small gullies with small drainage areas and has been found to be successful in all sections of the United States. Small gullies (one to three feet deep) with no well-defined drainage area should be entirely filled. It can be first partly filled with manure, cornstalks, straw, or small brush, which should be covered with a foot or more of dirt obtained by plowing and scraping in the edges of the gully. The growth of timber, seeding of land, or keeping it in meadow or pasture will largely prevent erosion if it is not desired to cultivate the hillsides. The land should be terraced first if it is to be cultivated.

For shallow or deep gullies with gently sloping banks, the plowing is begun in the bottom or as near the bottom as possible. Dirt is thrown toward the center of the gully from both sides. Plowing is done in the same manner as in breaking land, and is continued a few furrows beyond each end of the gully. The dirt is pushed toward the center of the gully by means of an ordinary road drag or steel ditcher. If the upper part of the side slope is steep, it can be cut down and rounded off with a mattock. If sufficient dirt has not been moved into the gully after the first plowing, the plowing may be repeated until the desired amount is obtained. If the side slopes are so steep that a team cannot walk on them, a chain-hitch through a plow will permit plowing on the slope while the team is on the edge of the gully.

When plowing-in deep gullies with nearly vertical banks, the team is made to walk as close to the edge as possible, and the upper edge of the bank is plowed into the gully. The second furrow cuts the first deeper, and the third takes another slice below the second. In order that the plow may be operated down the gully while the team walks along the upper edge, a long chain is attached to the plow.

After the first line of furrows has reached as far down as a plow can be used, the procedure is repeated by again starting at the top, the object being to reduce the side slope. If the gully is not too deep, the side slopes can be so reduced in a short time that the team can walk up and down them and across the gully. The side slopes can then be reduced by means of team and scraper and part of the soil distributed over the bottom of the gully, or the same method used for gullies of gently sloping banks can be employed. The freshly plowed earth in the gully affords a good seed bed. Trees should be planted or grasses sown to hold the soil in place. A few of the grasses in use for this purpose are Bermuda grass, orchard grass, bluegrass, red top, sweet clover, and Lespedeza. Certain grasses will be found to be best suited to different localities. More rapid growth can be obtained by supplying fertilizer elements in which the soil is deficient. Fertilizer, such as manure, will

provide these for most soils. Sorghum is very effective in controlling erosion in gullies.

"On the State agricultural experiment station farm near Holly Springs, Mississippi, some very badly gullied lands were reclaimed by the plowing-in and filling method. Areas where erosion is in an advanced stage, were reclaimed on this farm. The filled-in gullies were seeded to Lespedeza or to Bermuda grass. Most of the land was then terraced to keep the water from flowing down through the gullies. In some instances, on this farm and others, dynamite was used to advantage in leveling down and filling gullies. The banks were broken down and blown into the ditch by placing ex;losives in a row of holes two to four feet from the edge of the gully, depending upon its depth, or in a row of horizontal holes in the sides and near the bottom of the gully. The first method is preferable for gullies with broad sloping banks and the second for gullies with high, steep banks."[1]

After plowing-in, further erosion is sometimes controlled by the use of tile. Large tile, the size depending upon the area drained by the gully, is laid down the middle. The water may be led into the tile from a catch basin at the upper end of the gully or by building a dam across it and extending the tile through the dam. In many localities, gullying has been effectively checked by planting trees.

Results and conclusions[2] obtained from studies made on low muck lands of the Mississippi Valley are applicable in many portions of the South where conditions are similar. Studies were made to determine the most effective type of vegetation to hold the soil, particularly on severely eroded gully areas. On such areas, most, if not all, of the

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[1]Page 9, U.S.Dept.Agr., Farmers Bulletin 1234.
[2]Farmers Bulletin 1697: 1-17, 1932.

topsoil is washed away. That remaining is not a true soil, but rather sand, gravel, and clay that will require many years of weathering to become fertile. The difficulty is that, although vegetation often becomes established naturally in smaller gullies, very few plants invade these unproductive surface materials in the larger washes. One of the best and most widely used soil-binders is black locust. (Robina, pseudoacacia L). With its wide-spreading and interlacing root system, this rapid growing and invaluable tree can halt erosion very effectively in a very few years, even in very bad washes. It also builds up soil by contributing nitrogen. Washes as deep as thirty feet and covering several acres have been reclaimed by its use in Tennessee. After ten years or so, they make very good fence posts. If the posts are not desired, a furrow is plowed between the rows and the trees cut back so as to cause the roots to sprout and form dense thickets, which is still more effective in controlling erosion.

This method can be used with slight modification with other desirable species of trees. In early fall, the edges of the gully banks should be plowed-in. At the same time, brush dams or barriers should be built about twelve to twenty-four inches high, and near enough together so that the outwash held by any one dam will extend up the gully to the base of the dam immediately above. Dams are constructed of bushes, and limbs of small trees, laid compactly across the gully bottom, and weighted down with logs, stones, or other heavy material. The ends of such brush barriers should extend well into the gully banks to prevent side cutting. The upper sides should be thatched with straw, corn stover, pine tops, or similar material that will filter out and hold the soil, but the dams should not be made watertight, since the purpose is to hold soil, and not water.

By March or April, the dams will have caught a great deal of loose material carried off by the winter rains. Much of the topsoil will also have been deposited over the less productive soils of the gully sides. In these deposits, one year old black locust seedlings can be planted. Nursery stock eighteen inches high is best. Larger seedlings will survive no better and will be harder to plant. The amount required is about twelve hundred seedlings to the acre of land. Plant the trees six feet apart. The trees are usually planted in rows, although the regular spacing is not as vital as placing in protected spots. Young trees should be protected from grazing and fire for several years. They should also be pruned during the second summer in order to increase growth and improve form. The stand so established will often produce one thousand or more posts an acre within ten to twenty years, the posts having a market value of twenty to twenty-five cents each. Since the total expense of growing one thousand black locust posts, including planting costs and investment in land and taxes at six per cent compound interest, need not exceed fifty dollars,[3] profits may be made from gullies reclaimed in this manner. A heavy sod of bluegrass and other palatable pasture grasses are used with the locust. Another tree species used is short leaf pine (Pinus echinata Mill.). Although it does not grow as fast or have as wide-spread a root system, it grows better on pure sand. The manner in which short leaf pine seedlings come in on the rapidly eroding surfaces of the larger wahses and clinging to the unstable soils indicates that this species will find wide use in erosion control.

When planted in a large wash, it may be planted in pure sands or the more sandy exposures or in alternate rows with black locust on

[3]Farmers Bulletin 1697: 1-17, 1932.

loams and clays. Care must be taken in planting of the pines, as they will die very quickly if their roots are exposed for more than a few seconds to the open air.

Loblolly pine can be used in some places, such as the silt uplands lying south of the central Mississippi, although it is not so good for use in deep gullies. Cottonwoods and willows serve in several ways to check the growth of gullies when rain is plentiful. Closely spaced rows of cottonwood cuttings planted in gullies at right angles to the flow will often catch a surprising amount of soil. Ordinary brush dams can be effectively anchored down by pegging the brush with cottonwood and willow green limbs. As these develop, roots of the brush will be more securely anchored. The sprouts that develop will be able to withstand considerable bearing by outwash and will tend to increase the effective height of the dam. The size of the cutting will usually be from ten to twelve inches long and three-fourths of an inch in diameter. Cuttings are made in the fall and stored until spring, by burying below the frost line in sand or similar soil. Good tree-planting practice is to plant pines in dryest regions, black locust over main portion of gully, and willows in the wet and silting bottoms. In stronger soils, the pines are not so essential, while in the poorest soils, they and red cedar should be given greater preference.

Restoration of forests is probably the final means of reclaiming most of the areas destroyed by gullying.

Our lumber supply is fast becoming exhausted, with the resultant increase in prices. A progressive farmer will for that reason use a portion of his farm for a wood lot. The hilliest part of the farm can be used for this purpose. No definite rules can be given to cover the greatest slope of land which may be profitably cultivated, but

Olsen[1] recommends that all land with a slope of twelve feet or more in one hundred feet be used for pasture or wood lot purposes, while Ramser[2] advocates the same use for impervious soils possessing a slope of fifteen feet in one hundred feet, and for all other types with a slope of as much as twenty feet in one hundred feet.

Kudzu is often used in this type of work, and has been found to be very successful. The vines cling closely to the ground when there are no trees or brush present, and grow twenty to twenty-five feet in a season. Besides enriching the soil, it provides large quantities of forage which cattle like particularly well. In some cases, Kudzu has completely stopped the growth of gullies. Gullies often fill in when this vine is used. One gully in which it was used filled in ten feet. The vines catch the outwash and become covered, new sprouts catch more soil, and so on until the banks of the gully become stable. Kudzu produces very few seeds and must be grown from plants. It spreads widely from planting. The roots should be set out in March and placed about eight feet apart, requiring about seven hundred to the acre. Japanese honeysuckle can also be used for erosion control. Honeysuckle likes the society of black locust and is often used with it, but Kudzu cannot be used where there are trees, as it will climb over them and kill them.

SOIL SAVING DAMS

A common method of controlling or filling and reclaiming gullies consists of building soil saving dams across them. Temporary dams are built of earth, masonry, or concrete. The cost is often very small if materials found on the farm may be used.

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[1] A.M. Coll. of Texas Ext. Ser. Bull. B-51.
[2] U.S.D.A. Bull. 512

Most temporary dams are porous; that is, when first built, they permit the water and part of the silt to pass through them. They gradually build up as material is brought down by the water, but they are never required to withstand the pressure exerted on a watertight dam where the water is emponded above.

Most permanent dams are watertight and in order to pass from the upper to the lower side of the dam, the water must either flow over it or be diverted around it, or carried through it by conduit. If water is to flow over the dam, a spillway of non-erosiable material is provided. This spillway is generally located at the middle of the dam and should be wide enough and deep enough to remove the greatest flow of water expected. If water is carried around the ends of the dam, it is generally made to flow over firm, sodded ground. Sometimes a shallow channel is provided to carry the water around the end of the dam and back into the gully some distance down. If the water is to pass through the dam, it is carried in a pipe.

A verticle pipe connected to a horizontal line of pipe extending through the dam along the bottom of the gully provides the inlet. The top of the inlet is lower than the top of the dam so that the water above the dam does not flow out until it reaches the top of the inlet pipe. In such cases, the dam practically forms a sedimentaion basin, as the silt in the water settles to the bottom, and in time fills the gully to the top of the inlet pipe. This type of dam is often called drop-inlet soil-saving dam. It is known throughout the State of Missouri as the Adams soil-saving dam and is said to have been originated by J. A. Adams, a pioneer farmer of Johnson County, Missouri. Mr. Adams has five of these dams on his farm. All of them have successfully filled and reclaimed gullies.

STRAW DAMS----In some localities, stacks of straw are frequently used to form dams across deep, wide gullies. Where threshing is done near a large gully, it can be placed directly from the machine. Large gullies with very small drainage areas and little fall have been very successfully reclaimed by this method. Straw dams are likely to be washed out, or a channel washed around the end where there is a large quantity of water flowing through the gully. If the dam is made high at the sides and low in the middle, it will reduce the chance of failure, as the water will flow over the top of the dam at the middle. The first dam should be built near the mouth of the gully in order that all the soil being carried away by the water can be caught and held. When as much soil as can be held by the sod seeded there when the straw rots out, another straw dam should be built a short distance further up the gully, and then another until the gully is filled in. This method is simple and easy with certain types of gullies, if a large quantity of straw is available.

Further washing of small gullies can sometimes be prevented by spreading loose straw over the surface during the fall and winter. The water will trickle through and the silt will be deposited. In the spring, the ground can be plowed and the partly rotted straw turned under, adding to the fertility and increasing the humus content of the soil and thus increasing its absorbitive powers. This method is not successful on steep slopes, as the straw will be washed to the bottom by the water.

SOD DAMS can often be successfully employed in small gullies draining areas of a quarter acre or less on moderate slopes. It is necessary to place the sod above a small dam of brush or rock or other small material in order to get it well started. The best way is to place the sod in loosely woven grain sacks, tie these up, and build them into small dams in the gully. The sacks are usually placed end to end across the gully. The dam should be low enough in the center so that the water will not wash out the ends. Soil should be placed around the bags, particularly on the upper face, to prevent water from seeping through the dam. Native grasses which are heartiest in the locality can be used for this purpose.

WOODEN STAKE DAM----A cheap method of constructing a dam is the wooden stake dam. The stakes should be from three to seven feet long with a diameter of from two to four inches at the upper end. The rows should be six inches to two feet apart, and the stakes the same distance apart in the rows. The stakes should be driven into the ground until the top extends eight to twenty inches above the surface. The larger and longer the stakes, the greater the intervals. The stakes should extend across the gully and up the side as far as the water ever reaches, and at least one foot higher on the sides than in the middle. The stakes can be made of any available hardwood. If stones are available, they can be placed in the intervals between the stakes, in order to increase ability to hold the silt. Straw between the stakes will also servo for the same purpose. Series of dams should be built along the entire length of the gully. As soon as the filling in above the first series of dams is completed, other dams should be built between the first ones and the filling in process continued by additional dams until the gully is filled.

BRUSH DAMS----Very good results have been obtained by the use of brush dams, in localities where timber and brush are plentiful. In hillside gullies where the velocity of the water is small, dams are built of loose brush and weighted down with rocks or logs. Where the velocity is higher, it can be held down by cross pieces of wire and stakes. Sometimes the brush is woven between stakes across the gully. At times, the brush can be simply dumped into the gully. A good method to use in building brush dams is to place several layers of branches with tops pointing downstream as a foundation, and placing other brush crosswise of the gully with an occasional layer of branches placed with tops pointing upstream and extending beyond the face. After the dam is three feet high, logs are laid across the brush lengthwise of the dam to hold it down. Brush dams should be built lower in the middle, as in other types. Where the velocity of the water makes it necessary to provide a more secure anchorage, the bottom and sides of the gully for a distance of four to ten feet are covered with a layer of straw that will be from four to six inches deep after being pressed down by the weight of the dam. The brush is laid with the butts pointing upstream, placed closely together and thoroughly tramped down, fine brush being placed at the bottom and coarser at the top. The packed brush is held in place by crosspieces nailed to fence posts set in line in the line of the dam across the gully as shown in Figure 2. The fence posts should never be placed less than four feet deep.

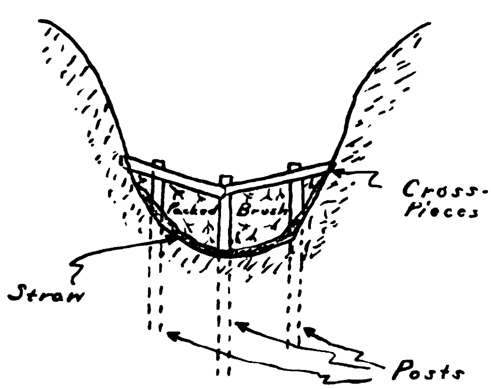

Fig. 2 - Straw and brush dam held in place by crosspieces and posts

Another method of anchoring such a brush dam is to drive rows of stakes across the gully two feet apart with the stakes one foot apart in a row. The gully is partly filled with brush before the stakes are set, and lightly driven in. When sufficient brush is placed to complete the dam, heavy wire is stretched and fastened to the stakes. The stakes are then driven in until the wire holds the brush firmly in place.

The posts from which the brush was trimmed can be used in anchoring a brush dam, especially where rock is encountered in the bottom of the gully and stakes cannot be driven. Poles are set diagonally into the lower part of the bank on both sides of the gully about three or four feet apart and bent over to the top of the opposite bank. The larger ends are set into the ground at such an angle that the poles in the opposite sides cross two or three feet above the bottom of the gully. The brush is laid between the lower parts of the poles and under the upper part so that it will be held compactly when the poles are pulled down, as in Figure 3. This type of dam usually extends ten or fifteen feet along the gully.

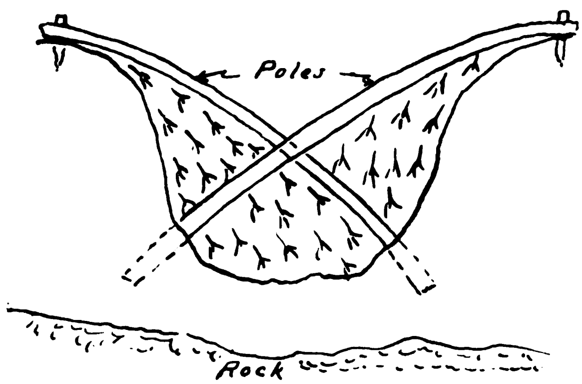

Fig. 3 Method of building a brush dam when the presence of rock prevents the use of posts

"The average cost of building brush dams ten to fifteen feet long, two feet high, and four to six feet wide, on a soil-erosion experiment farm near Guthrie, Oklahoma, was about one dollar for loose-brush dams, and four dollars for brush dams anchored with poles about ten feet long, one foot high, and four feet wide, cost about one dollar and fifty cents each, and several averaging twenty-three feet long, three feet high, and eight feet wide, cost about twelve dollars each. These costs are based on the actual labor and material required to build the dams, and do not include the cost of cutting and hauling the brush to the site of the dam, this cost having been charged to the clearing of the land."[4]

Woven willow dams have been used very satisfactorily in Europe. Live willow stakes about three or four inches in diameter and from three

[4] Farmers Bulletin 1234: page 9.

to five feet long, are driven in a row across the gully about six inches apart with tops extending one and one-half feet above the ground. The rows of stakes should extend as far up the sides of the gully as the highest water and held together by weaving willow branches between them from top to bottom.

A brush apron is made below the dam to prevent underwashing. It is built of branches six to eight feet long, laid lengthwise in a trench about six inches deep along the gully. The butts of the branches are laid upstream and partially buried in the bottom of the gully, and the downstream ends are held down by a pole laid across them and spiked to a second row of stakes about three feet from the first row. This type of dam is sometimes used in this country. Pine branches are often used in place of willows.

Another type of dam common to Europe is made with bundles of brush eight inches to two feet in diameter and from seven to fourteen feet long. The bundles are tied together in several places with wire. They are laid with their length across the gully against a row of posts set about three feet apart. Bundles are held in place by driving stakes through the center about one to two feet apart. To prevent washing around the ends, trenches are dug into the sides of the gully and the ends of the bundles extended into them, and a brush apron is provided to prevent undermining. The middle of the dam is one and one-half to two and one-half feet high.

When a farmer has a large quantity of brush to dispose of, a very common practice is to fill in the whole length of large, deep gullies with brush, which is tramped down and sometimes weighted with heavy materials. Sometimes sections from twenty-five to fifty feet in length are filled solid with brush at intervals along the gully. Another practice is to shingle the botto of the gully with brush much the same as the roof of a house is shingled, commencing at its lower end and laying the brush with the tops pointed upstream. If the velocity of the water is high, the brush can be held in place by crosspieces fastened to stakes at intervals along the gully, or it can be weighted down with rocks. Leaves scattered over the brush assist in catching the silt. When one layer of brush has been covered, other layers can be placed on top until the gully is filled. This practice works very well in filling the lower end of a gully where the fall is not great.

WOVEN WIRE DAMS----Like the brush dam, woven wire dam is found in every section of the United States. It consists mainly of a low fence across the gully. Posts must be set closely together, and anchored upstream if the force of the water is great. Common methods of building the dam is to place the fence posts across the gully about four feet apart. The end posts should be set in a trench dug into the side of the gully. The best results are obtained when a trench is dug along the upper side of the posts so that the wire may be fastened six inches or one foot below the surface. The wire should be wide enough so that about two feet extends above the surface of the ground. Wire is fastened to the upper sides of the posts and the trench in the sides and across the gully is filled up and carefully tamped. When there is not enough trash in the water to close large meshes in the wire, a little straw, leaves, or fine brush can be placed against the upper side of the wire to get a fill started.

POLE DAMS----Poles from which brush has been trimmed for brush dams can be used in the construction of pole dams. Poles are laid across the gully in layers, the bottom layer being from two to four feet wide, and the top layer one pole wide. The lower poles are laid in a trench one pole deep, and extended to the sides of the gully about two feet.

Posts should be fastened together with spikes and wire to prevent the overflowing of water from eroding the bottom of the gully and undermining the dam, an apron of poles is placed at a distance of three or four feet below the dam. A notch two to four feet wide and one to two feet deep, depending upon the size of the gully, should be left in the center of the dam to permit the water to pass over without eroding the sides. Poles should be laid and grass or straw and earth should be placed and tamped on the upper side of the dam to prevent a flow through or around the ends. Records show that an average pole dam can be built for about ten dollars.

LOG DAMS----Much the same type of dam can be made by using logs. Logs can be held against the posts by piling dirt against them, by driving small stakes on the upper side at the ends of the logs, or by spiking them to the posts. Where rock is plentiful, loose rock is placed below the dam to prevent erosion.

Where it is difficult to drive or set posts in a gully, logs may be held in place by other logs laid obliquely across them with the ends notched to fit in the corresponding notches of the logs in the dam. The free ends of the oblique logs are covered with dirt, and their hold becomes stronger as the fill above the dam grows deeper.

Where both timber and stone are plentiful, crib dams are sometimes built. The crib dam consists of a framework or box of logs across the gully filled with rock fragments or stone. The ends extend into the sides of the gully and the dam is built in a trench dug across the bottom. Undermining is prevented by a pavement of stone below the dam.

WILLOW POST DAMS----Posts cut from green willow trees are used very effectively to fill gullies. They are set two or three feet apart in rows across the gully, sometimes several rows of them close together.

Where there is plenty of water, the willow posts take root and grow, forming a hedge which catches the silt. Willow dams are usually built at the lower ends of gullies near main water courses or where the soil is naturally moist throughout the year.

LOOSE ROCK DAMS----Rock is a very good material for building low soil saving dams. Loose rock dams should not be more than two or three feet high, and should be built only in gullies of moderate slope and small drainage areas. Dams should be four or five feet wide at the base and about two feet wide at the top. Large pieces should be so arranged that the small pieces fit in almongst them. Only large stones should be used on top of the dam, as the current would carry away the small ones. The dam should be built well into the banks of the gully, and a trench about sixinches deep should be dug across the gully into which the foundation of the dam, made up of the largest rocks, should be laid. A loose rock apron should be provided.

MASONRY DAMS----Masonry dams, instead of loose rock dams, are usually built where greater height than three feet is desired, and where the fall in the gully is large, or where it is not economical to use rock. Construction is similar to that of a masonry wall, and the sides should have a batter of one and five or one and ten. The thickness at the bottom should be about one-half the height and the base should be one to two feet below the bottom of the gully for dams three to six feet high. Dams of this kind higher than six feet are not recommended, unless an excellent foundation is obtainable, and special precautions taken against undermining. The services of an engineer would be required to build a high masonry dam. A dam higher than four feet should have a notch spillway in the middle to confine the overflow water to the middle portion of the dam, which should be provided with an apron to prevent undermining.

Masonry dams more than three or four feet high are not much used, due to their high cost and difficulty in making secure.

CONCRETE DAMS----Failures of concrete dams are usually the result of poor design or falty construction. Lack of knowledge or the desire to keep costs low are responsible for many failures. A spillway must be provided, usually in the middle. Concrete dams are built of either plain or reinforced concrete--those under three or four feet in height are usually built of plain concrete and higher ones of reinforced concrete. A competent engineer should be engaged to design and construct a reinforced concrete dam.

EARTH DAMS----Two types of earth dams are used. In one type, the surplus water is carried around or over the dam by spillways, and in the other, it is carried through the dam by a pipe. In many cases, both methods are used. Earth dams are generally employed to fill very large gullies, while they are rapidly gaining favor for use in small ones. If a spillway is used, provision must be made for a capacity above the dam large enough to hold the greatest runoff in the area. In the other type of earth dam, vitrified sewer pipe, corrugated metal pipe, or a rectangular box built of concrete or creosoted lumber is generally used to carry the water through the dam. This conduit is connected to a vertical inlet pipe. Detailed plans for these types of dams can be found in the United States Department of Agriculture, Farmers Bulletin No.1234.

RECLAIMING A GULLY WITH SOIL SAVING DAMS[5]

Before work is begun, the plan should be decided on for the reclamation of the entire gully. Work should begin at the upper end where head erosion is going on. This should be stopped by building an

[5]U.S.D.A. Bulletin 1234.

over-fall of brush and straw by constructing a flume to conduct the water into the gully without erosion or by the diversion of water from the head of the gully. Next, plans should be made for filling the gully. If it decreases gradually in depth towards the lower end, and ends in a wide, shallow depression, a number of low temporary dams can be used. If the gully terminates in the side of a deep drainage channel, the lower end cannot be filled by a low dam. A high one must be built where the gully enters the channel. Unless conditions necessitate use of high dams, low ones should be built even though more of them are required, since the cost is less and they are less liable to failure. Often, the erosion of soil from the watershed is slight, and a number of years are required to fill the gully. In some cases, a series of dams should be built above each one so that some silt will be caught by each one, or a dam may first be built at the lower end of the gully and other dams built later in succession above, after the gully is partly filled in. The side slopes of the gully should be plowed in, so that farming operations can be conducted in and across the gully.

Some gullies occur in the natural channels of fields and have large drainage areas, while others occur on the slope of a hillside with very small drainage areas, which are not well defined. Gullies of the latter type may be entirely filled and then prevented from washing out by proper cultural methods or by terracing. Gullies with large well-defined drainage areas cannot be entirely filled, since it is necessary to have a waterway large enough to carry off the water. A very common mistake is so to reduce the size of the waterway by filling in the gully that the drainage water overflows its banks; this often proves disastrous to reclamation works.

In reclaiming the whole length of a gully, a series of dams is built, the distance between the dams depending upon their height and the slope of the gully. The less the slope of the gully or the greater the height of the dam, the greater may be the distance between the dams. Usually, the dams should be so spaced that the fill that accumulates to the top of one extends to the foot of the next above. A dam will cause a fill that is higher at some distance above than at its foot. The fall of the surface of the fill in the gully will not much exceed six inches in one hundred feet, and in computing the distance between dams so that the fill will extend from the top of one dam to the foot of the next, this rate of fall has been assumed and values for Table 1 were computed accordingly. The table gives the distances between dams ranging from two to ten feet in height in gullies with falls ranging from two to twenty feet in one hundred feet where vegetation greater than six inches per one hundred feet and in some instances for a thick growth of vegotation, may be as much as two feet per one hundred feet.

Table 1.
Distances between dams in gullies for dams of various heights and gullies of various bottom slopes.

Height of dam	Bottom slope of gully: 2' in 100'	5' in 100'	10' in 100'	15' in 100'	20' in 100'
	Distances between dams				
Feet	Feet	Feet	Feet	Feet	Feet
2	133	44	21	14	10
3	200	67	32	21	15
4	267	89	42	28	20
5	333	111	53	34	26
6	400	133	63	41	31
7	467	156	74	48	36
8	533	178	84	55	41
9	600	200	95	62	46
10	667	222	105	69	51

Sometimes there are contracted sections in gullies that are naturally suitable for the location of dams. Under such circumstances, it may be desirable to disregard the spacing as given in Table 1 and build the dams high enough to conform to the spacing naturally suggested. With the actual distances between the dams determined, the required heights can be taken from the table.

As a general rule, it is cheaper and more satisfactory to reclaim gullies with low rather than with high dams. A low dam costs considerably less and requires less care and attention than a high dam.

Vegetation, either volunteer or planted, should be employed wherever possible in the control of gullies. Many gullies can be controlled by means of vegetation alone if the water entering the gully can be diverted by means of terraces or a diversion ditch, and over-grazing is not permitted. In some gullies where there is difficulty in establishing a satisfactory growth of vegetation, the growth can be promoted by means of low temporary check dams built of brush or other cheap material available on the farm. Where it is necessary to maintain a gully as a permanent waterway for a large watershed, substantial dams of permanent material should be built, provided the cost is justified by the resulting benefits.[6]

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[6] Farmers Bulletin 1234: 33-34.

PREVENTION OF SOIL EROSION

Many large gullies and other erosion effects could have been prevented if steps had been taken to check them in the beginning. The use of terraces is the best and most satisfactory method of controlling soil erosion. The methods set forth below and others previously given, are used to help and may, in some instances, control the situation. But in a large number of cases where erosion is going on to any considerable degree, it is necessary to resort to the terrace in order to gain satisfactory control.

TILE DRAINAGE

Tile drainage to prevent soil washing is suitable, and will help in control with soils on moderately flat slopes where the land is fertile and well-handled. Such drainage deepens the seed bed and in this way increases the moisture-absorbing qualities of the soil. Cost of tiling often prevents its use in badly washed soils.

HILLSIDE DITCHES

Hillside ditches are in some cases necessary, but as a general rule are not to be advocated. The hillside ditch is an open ditch--i.e. excavation with two banks. The chief objections are that it offers an obstruction in the field for the use of modern machinery; its size, shape, and fall are hard to control, and therefore the erosion cannot be controlled to the best advantage. Conditions which make their use necessary are to intercept surface water from adjoining higher land and to provide an outlet for terraces.

Use of terraces is by far the most satisfactory method of control where gullying has not taken place and the land is to be cultivated.

TERRACES

TYPES----There are two principal types of terracing--the bench type and the ridge type. The bench type is a series of steps, while the ridge type is a series of ridges. Figure 4 shows the different types of each of these terraces. The bench type of terrace is of two classes--horizontal and sloping. The former has flat steps and the latter has sloping ones. There are five classes of the ridge type--the level ridge terrace in which the level refers to the fall

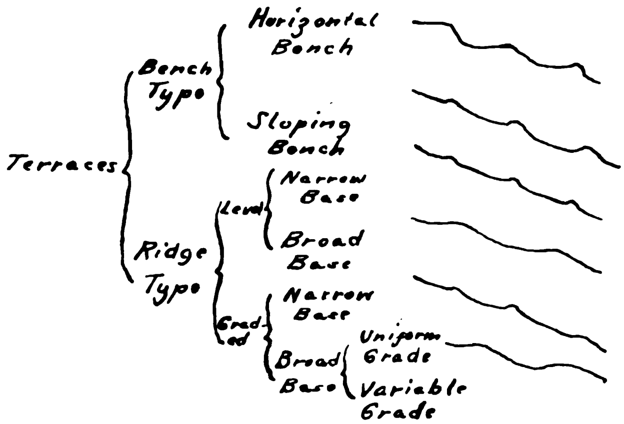


Fig. 4 - Types of Terraces
U.S.D.A. Bull. 512

along the terrace (this class is followed by both the narrow and the broad base), the graded ridge terrace which has a fall along the terrace (it also is built with a narrow and broad base), the graded broad base ridge terrace (the grade may be uniform along the terrace or it may be small at the upper end and increased as it approaches the outlet).

THE HORIZONTAL BENCH TYPE is not used to a great extent for farm purposes in this country. It is quite commonly used by landscape architects in cities and surrounding country residences, where the amount of terracing is small and expense is not so important. It is also quite common in China and Japan, where steep hillsides are cultivated and labor is cheap. The cheaper method of constructing this type is by converting a sloping terrace into a level one through the use a reversible plow with which the soil is always thrown down hill. To prevent water from flowing onto the next terrace, a small bank at the lower edge is provided when the terrace is used for farm purposes. The height of this bank varies from five to ten inches. The difference between one level of terrace to the next varies with the fall of the land, the limit being from three to twelve feet. The terrace banks should be sodded in order that they may hold their slope.

Ramser[7] gives curves in Figure 5 which show the widths of benches for different vertical spacings on lands of various slopes. These spacings are for benches which have terraced banks of a slope from one-half to one.

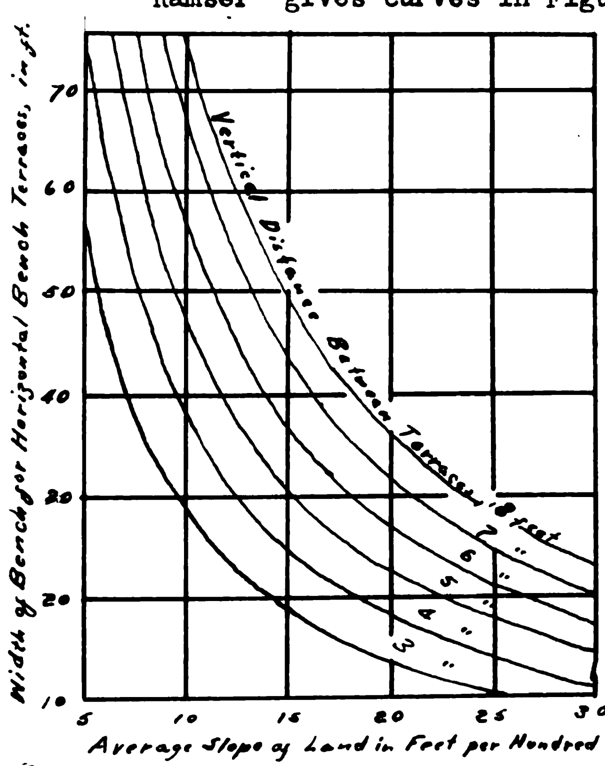
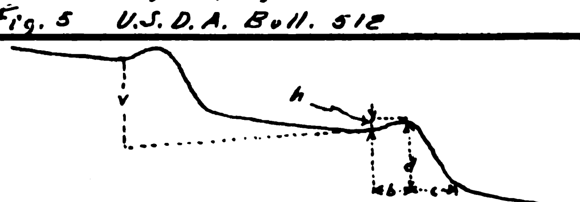


Fig. 5 U.S.D.A. Bull. 512



Crossection of two adjacent sloping bench terraces (U.S.D.A. Bull. 512)

THE SLOPING BENCH TERRACE is used somewhat in Georgia and South Carolina and occasionally in other states. Space on which a crop is planted, instead of being level, is sloping. Ramser[8] gives these rules for its design: the height of shoulder (h) should not be less than one foot on newly constructed terraces; the width (b) not less than three feet; spacing (v) depends on type of soil, slope of land, and ease of starting and maintaining sod on a steep embankment, never less

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[7 & 8] Prevention of Erosion of Farm Lands by Terracing, U.S.Dept.Agr.Bull.512.

than three feet and never more than six feet. The smaller spacings on steep slopes; the ratio of c to d should be one-half to one and the terrace should not be used on greater slopes than twenty per cent. The slope of the banks depend largely upon the type of soil. This type of terrace does not have any fall along itself, and its use is restricted to deep soils with great water absorption, and to areas of light rainfall. Its greatest drawback is the obstacle to modern machinery.

A NARROW TERRACE is a small one, three to five feet wide at the base and one to two feet high. It can be built with or without fall along the terrace. The former is called graded and the latter a level narrow terrace. It must be close together and almost always is allowed to grow up with grass or weeds. It is successful only on gentle slopes, open soils, or where the rainfall is small, as the holding capacity is small. This type of terrace is to be condemned.

THE BROAD TERRACE, or Mangum terrace, whether level or graded, is constructed in the same manner. The bottom width is from twelve to twenty-five feet, depending on the slope of the land. For the steep slopes, smaller widths are used, while for the gentler slopes, wide ones are used. This terrace is in use mostly because it can be cultivated.

There are three different methods of obstruction for obtaining the necessary fall along the terrace--level, uniform, and variable grades.

THE LEVEL BROAD TERRACE is laid off absolutely level--that is, on contour lines--and the water must back up at the upper end of the terrace in order that it run off. Long lengths of terrace must be avoided to prevent erosion. These terraces must also be placed close together and used only in localities with light rainfall. The purpose of this type is to have as large a quantity of water as possible absorbed by the soil. Their success depends on whether they are properly laid off.

All points on the terrace must be the same height--that is, the terrace must be level. Figures for the distance between the terraces may be obtained by consulting tables given in "Land Drainage and Reclamation" by Ayres and Scoates, page 280.

THE BROAD GRADED TERRACE is the most popular and gives results that rarely fail. Figures for laying out this terrace may be obtained from the same source as given above. The usual general rule for obtaining the distance between terraces is to get along with as few as possible, because they are expensive to build and maintain.

LOCATING TERRACES----The first thing to consider in the location of terraces is the surface drainage of the entire farm, and several of the adjoining farms if they effect the one to be terraced. There are several points which must be considered--how much water is to be controlled, where it is coming from, where the outlets are or how they are to be provided, the type of soil to be terraced, general condition of the eroded or eroding soils, crops to be raised on the land, and how much of the land is to be terraced immediately. The best land should be terraced first, as it will give the greatest returns for the labor expended.

LAYING OUT TERRACES----Terraces may be laid out either with a homemade level or a surveying level. Both methods will give good results, although the homemade level is less expensive but slower in its use. The method of constructing the homemade level may be found in "Land Drainage and Reclamation".

THE BUILDING OF TERRACES can be done with such machinery as is usually found on the farm--a plow and scraper. It is entirely possible to construct a terrace by use of a plow alone, although there are other machines which help greatly.

Olsen[9] gives this method for use with plow alone:

"Some of the best terraces in the state of Texas were built by using no other implement than a plow. This system simply requires re-plowing a sufficient number of times to bring the terrace to the required height and width. The double disc plow is especially fine. The size of the plow, the condition and type of the soil, the depth of plowing, the kind of plow, and the speed of the plowman determine the number of plowings necessary to put up a good terrace. The terrace line is used as a center line and the furrows are thrown toward this center line from both sides until a strip of land twenty feet wide is plowed. The center line of the terrace is again used as a beginning point, and the land is re-plowed in this manner about a half dozen times, or until a terrace of the required height and strength is built. The ground, after the second or third plowing, may be very loose and in that case, farmers sometimes wait and allow a rain to settle the terrace. This is quite risky, because a heavy rain may not only settle the terrace, but may also injure and undo some of the work, which represents a lot of hard labor."

THE COST OF TERRACING varies with the type of soil, steepness of slope, labor, and power available. It may range from one to five dollars an acre.

MAINTENANCE OF TERRACES----Terraces need maintenance and constant watching. It is desirable that the terrace be planted in some profitable crop in order that the tendency for the soil to gradually move down the hillside be held to a minimum. Those crops which develop a vigorous root system are better than those which do not. Large bodies of water should not be allowed to concentrate on terraces.

TERRACE OUTLETS----Disposing of water at the end of the

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[9] A.M.Coll.of Texas Ext.Ser.Bull. B-51

terrace offers a difficult problem. If it is not properly done, gullying will result. There are numerous methods of disposing of this water--into small ditches, open ditches, roadside ditches, sinkholes, ponds, and through tile drains. The use of hillside ditches is that used most. If it is to be constructed just for the purpose of taking care of the terrace water, it must be laid out with care and study. It must have more fall than the terrace itself, although this causes it to erode and cut a more or less deep ditch. This erosion can be controlled to some extent by giving it more width. The ditch should be as straight as possible. If there is any drop to speak of in carrying the water from the terrace into this ditch, some method must be provided to prevent the terrace from gullying.

Open ditches, creeks, branches, and small streams can often be used as outlets. The terrace must be protected from them just as in other cases.

Ditches along public highways and railroads can often be used.

In some sections of the country, there are sinkholes which will take the water and carry it away through underground channels.

Ponds, as well as gullys which are being eradicated by the natural method, offer excellent outlets for the terrace water, inasmuch as they collect water and allow the silt to settle out.

Tile drains are often successful, although this method can be used where the terrace area is small or so valuable that it makes open ditches out of the question. In this method, water is carried from the terrace down hill through tile drains and emptied into an open ditch or other outlet. Inlets to the tile should be provided and they should have a grate cover and some form of wire screen to keep debris from stopping it up.

CONCLUSION

Erosion should be controlled because it destroys the value of the land. Most farmers forget that, though the land may not be used, they must pay taxes on it. Many banks in the West will not loan money on farm lands unless a clause is inserted in their deeds of trust, which provides that measures be taken to prevent erosion of the soil.

If erosion has taken place, then the land should be reclaimed in order that it may not be totally destroyed. Reclamation will also help the unsightly appearance due particularly to gullies.

Missuse of the land caused a great deal of erosion and its resultant gullies. It is held, by many, that the stripping of the natural covering of the soil, such as grass and trees in the West, has been the cause of the too common dust storms.

Soil erosion cannot be controlled and land reclaimed by the government--it must come about through education of the farmers and resultant efforts by them.

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