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Effectiveness of reforestation & other practices in controlling soil erosion.

THE EFFECTIVENESS OF REFORESTATION AND OTHER PRACTICES IN CONTROLLING SOIL EROSION

by

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PURPOSE OF STUDY

The purpose of this study is to review and discuss the problems of soil erosion resulting from water action with special reference to the effectiveness of reforestation in controlling soil erosion.

INTRODUCTION

Soil erosion is a very old process and a natural condition on the earth's surface. It was not until man disturbed nature by changing the earth's floor covering that excessive soil losses began: that is, a condition was established so that soil was removed faster than it was formed. The result was that large areas of land were turned into submarginal, near sterile, badly eroded, and worthless soil.

During the past eight years much erosion-control work has been done; because the federal government made large sums of money available for this type of work, and because there was a surplus of manual labor which had to be employed. The control measures practiced were often limited to building large check dams, transplanting sod, and the planting of black locust trees. It has now been found that these measures cannot usually be justified on the basis of cost, benefits derived, or additions to the beauty of nature. It is necessary and essential to make a careful and complete study of the eroded area before any control measures are attempted.

On badly eroded areas where a forest cover will grow, reforestation offers practically the only economical means for restoring the fertility to the land and protecting the soil from further erosion. The trees will yield many indirect benefits but they will also partially pay for themselves through the production of needed wooden commodities.

WHAT IS SOIL EROSION?

Soil erosion is a natural condition on the earth's surface, and is very old. For countless ages wind, rain, running water, and other natural forces have been wearing away the earth's surface. Many great valleys have been carved and many areas of land have been reduced to level plains. This type of erosion is called natural, normal, or geological, and proceeds at rates not in excess of those of soil formation. Many areas in southwestern United States such as the Grand Canyon National Park, have been designated as national parks because they contained outstanding carvings in the earth's surface which were the result of many years of natural erosion.

The word soil erosion, as used today, refers to the losses and wastages of soil, which is the result of accelerated or man-induced erosion, brought about by the destruction of the balance between soil formation and soil removal which is obtained under natural undisturbed conditions.

Man has increased soil wastage very much by cutting away protective forest from sloping areas, loosening soil with cultivation, practicing ignorant and wasteful methods of farming, and by permitting large areas of protective covering to burn. In this way man has permitted water to ruin millions of acres in a short time. It takes nature from 300 to 1000 years to build a single inch of topsoil, but this accelerated, or man-induced erosion, can remove an inch of topsoil in from five to twenty years. It is this topsoil upon which our vegetation must be established and from which the vegetation receives most of its plant nutrients.

Soil erosion by water which results in either sheet of gully erosion cannot be exceeded in the establishment of ugliness or uselessness. As a result of this action much of the topsoil has been removed leaving sterile bare land, and in places deep cuts in the landscape.

SEVERITY OF SOIL EROSION

During the depression of 1933 a study was made of our natural resources. The soil, which produces our food, clothing, and shelter, was found to be our greatest natural resource. The potential wealth and living standard of this nation, or any nation, depends ultimately on its storage of natural resources. If through carelessness and neglect, these resources are wasted beyond a certain point, the whole structure of national achievement must be impaired.

The enormity of the annual economic loss from soil erosion is well expressed by H. H. Bennett, who writes as follows:[1]

> From soil surveys, erosion surveys, and other measurements of soil losses, it is estimated that 282 million acres of land in United States are ruined or seriously impoverished. From an additional 775 million acres erosion has stripped away varying proportions of fertile soils. . . . Available measurements indicate 3,000,000 tons of solid materials are washed out of the fields and pastures of United States annually or an annual monetary cost of at least $400,000,000 in terms of lost productivity alone. This annual $400,000,000 direct loss would within fifty years, accumulate to not less than $20,000,000,000; and since unrestrained erosion progresses at an increasing rate, the cost may extend to $30,000,000,000 or beyond . . . Aside from destruction and impoverishment of farm threaten the permanence in navigation, power, municipal water supply, and irrigation development.

[1]Bennett, H. H. Soil Conservation, First Edition, McGraw-Hill Book Company, Inc., New York, 1939, p. 56.

Soil erosion is not a process which begins and ends with the removal of soil from the surface of the earth. Some of the more important dangers and losses accompanying the removal of the soil are: soluble plant food is carried away, organic matter is removed, deep gullies are cut into fields, adjacent lands are drained, increased quantity of water reaches streams, debris carried from area are deposited elsewhere, and the loss of water to ground storage.

After making extensive studies on soil erosion and natural resources in foreign countries, W. C. Lowdermilk wrote the following:[1]

It was the destructive handword of man more than climatic changes which reduced those prosperous and rich regions to a land of poverty and decadence in northwest China . . . . No other nation in the history of the world has gone at the destructive exploitation of its natural resources with the rapidity and thoroughness that we have here in United States. Coming events cast their shadows before them. Therefore, if we as a civilization are to be saved from the fate of some of these former decadent and fallen civilizations, it is imperative that we launch a coordinated land planning program for the conservation and restoration of our forests, agricultural and range lands, and our water resources."

It is not soil erosion, in itself, but the great difference at present between the rate of soil formation and the rate of its removal that must be considered.

[1]W. C. Fowdermilk, "Civilization and Man," Journal of Forestry, Vol. 33, 1935, p. 554.

CAUSES AND TYPES OF SOIL EROSION

Water is the most important direct cause of soil erosion in United States. In this study only soil erosion resulting from water, which means the loosening and removal of soil from its previous resting place by the action of water, will be discussed.

Water which does not evaporate or penetrate into the soil forms the run-off which causes either sheet, rill, or gully erosion. Run-off is influenced by many local conditions and therefore varies from place to place in regard to the surface slope, permeability and solubility of local rocks, character and amount of vegetation, temperature and humidity of atmosphere, and the distribution and intensity of rainfall.

Run-off varies geometrically with the slope, that is, if the surface slope of the land is increased four times:[1] the speed of the water flowing is doubled; the cutting power is multiplied by four; the power to carry soil is multiplied by thirty-two; and the size of particles it can carry is multiplied by sixty-four.

On clean cultivated slopes rainfall often causes sheet

[1] O. R. Zeasman, Control of Soil Erosion, Circular 249, University of Wisconsin, Madison, Wisconsin, December, 1931.

erosion. True sheet erosion follows no definite channels, but the water may tend to concentrate its flow and small drainageways may soon develop. These drainageways are small and easily obliterated by normal cultivation. As cultivation of this type of soil continues, the top fertile soil is slowly washed away and a poor near sterile subsoil remains upon which vegetation cannot obtain a foothold and erosion therefore continues at an increased rate.

The distinction between rills and gullies is purely one of size. Rills usually form in cultivated gentle slopes and can be filled or obliterated by normal cultivation. Gullies are too large to be checked in this way and require special measures for their control. Gullies often develop from rills, ruts in old roads, depressed cattle trails or paths, drainage ditches, improperly oncstructed terrace outlets, or other lines along which running water is concentrated. Gullies start with a very small channel, but usually increase in size very rapidly until they are large enough to hide a person or even a village.

CONTROL OF SOIL EROSION

In many areas, where soil erosion is active, the topsoil has been washed away leaving raw, comparatively unproductive, unabsorptive, intractible subsoil exposed at the surface, and erosion continues. Some control measure must be put into effect as soon as possible on this type of land. The control measure used usually is the site preparation for the tree planting program which will follow.

There are three main methods of checking soil erosion:[1]

1. Make the soil hold more water.

2. Protect the soil with vegetative cover.

3. Hold or divert the run-off.

Before any control measure may be recommended, a study of the area concerned must be made in order to determine what type of erosion is active, future use of land, extent of erosion, soil type, pioneer species, indicator plants present, and to what extent are control materials and labor available in the vicinity.

True water erosion cannot be entirely prevented by

[1] P. W. Robbins, Controlling Soil Erosion, Seeding and Planting Course, School of Forestry, Michigan State College, East Lansing, Michigan, December, 1936.

man's activities but since the causes are all definite man can control soil erosion to a great extent.

The present-day concept of soil erosion control involves the integrated and systematic use of not one, but many devices, applied in accordance with the particular needs and adaptabilities of the various areas needing protection. After the erosion is temporarily or partially controlled, tree planting often offers the only feasible solution for permanent control and the restoration of the area concerned to better land use.

Change of Present Land Use.

The statement "Nature abhors a vacuum" is often true. No sooner does man's disturbing influences cease than recovery begins. Unless all fertility has been removed, bare land soon is occupied by weeds. Grasses come in next and if there is enough moisture they are followed by shrubs and trees. Cut over woodlands if not too much damaged by fire will produce a new crop of trees in a human generation. Too often attempts to protect eroded soils have been made at great expense by building large check dams, transplanting sod, and planting trees, when nature could have recovered this land in a few years merely by man changing the present usage of the area concerned.

Erosion is often active on roads, paths, or other lines along which running water may concentrate. This type of erosion can usually be checked by chaning the course of the road or area affected in such a way that it follows the contour of the land.

When sheet erosion is active on land upon which clean cultivation or intensive grazing has been practiced the preceding years; the erosion can generally be controlled by discontinuing these practices. The land should then be permitted to lie idle for a few years, thus giving nature time to produce a vegetative cover that will check erosion.

J. A. Gibbs, regional forester for the Soil Conservation Service for the Ohio Valley Region, has estimated that grazing is the cause of ninety per cent of the soil erosion in farm woodlots. He has proved by actual field experiments that by discontinuing the present grazing practices in woodlots, soil erosion could be completely checked by natural reproduction and that vegetation could be produced on the forest floor in from two to five years.

Whether natural production can be relied on for the control of run-off can largely be judged by the proximity of seed trees, character of soil, and the amount and rapidity of run-off.

Furrows.

In areas of sheet and rill erosion, contour furrows may successfully be made around the slope to hold the rainfall on the land and store it in the vast reservoir of the soil. This condition will enable nature to produce a good growth of herbaceous plants between the furrows and check erosion. After the erosion is checked, trees should be planted in the furrows. The erosion-control work should begin at the upper end of gullies, where soil washing is active. The soil loss by washing can often be stopped by diversion of the water from the head of the gully with a furrow. The steep side slopes of gullies can be plowed in so that plantings can be made in and across the gullies.

Check Dams.

Only temporary check dams should be constructed.[1] Check dams are used to collect and hold soil and moisture in the bottom of sterile gullies so that vegetation can be established. They may also be used to check temporary erosion in the gully head or in the channel of a gully until a protective cover of vegetation is produced.

It is more desirable to build several low check dams of approximately twelve inches each than one large dam of equivalent height. They should be constructed at strategic locations, and at definite intervals. Special care must always be taken to see that the center of the dam is lower than the outer edges so as to prevent washing around the dam.

The temporary check dams most commonly used in gullies

[1]Anonymous, Ten Billion Little Dams, Soil Conservation Service, U. S. Department of Agriculture, 1939, 8 pp.

are the woven wire dam, the brush dam, the loose rock dam, and the plank or slab dam. Each name indicates the principal material used in the construction. The type of dam selected for use on any particular area depends primarily on the materials available in the immediate vicinity.

The dam will slow down the flow of water, nullify its cutting power, and force it to drop its load of silt. Vegetation, with its network of clutching roots, will then take permanent control of the bottom of the gullies. After the dam has done its work and the erosion is partially controlled, trees and shrubs should be planted.

Mulching.

Mulching is highly recommended on areas affected by sheet erosion or where gully erosion is not very active.

The materials used for mulching can usually be obtained very near the eroded area. Green pine branches, grain straw, march hay, pine needles, and some grasses serve as very good mulches. The mulch should be from two to four inches thick covering the entire area affected by erosion. It must be anchored to the ground by the use of rocks or by scattering soil over it to prevent it from blowing away. After the mulch has settled down, the area may be planted.

The benefits derived from mulching are moisture conservation, prevention of soil losses, soil protection and improvement, and lower surface soil temperatures. Mulching materials are organic and in time decay and improve the site.

Transplanting Sod.

Sod is often transplanted to eroded ares where immediate control is necessary or where grass for erosion control and beauty is needed at once.

Grass is usually transplanted near buildings, on steep roadside banks, in critical sections at gully heads, and at points along the bank or bottom of a slope where protection against waterfall erosion is necessary.

Transplanting bluegrass sod is a very successful method of checking erosion. The sod can usually be obtained on the more fertile low lands near the area. This is an expensive control measure because of the large amount of manual labor necessary. Since this country had an oversupply of available manpower the past few years, this method of control has been used extensively.

Grass anchors the soil against erosion. Its decaying remains make the soil absorptive. Its roots bind the soil in place and open tiny conduits into the earth. Grass makes water run slowly and slow water does no damage. Man has not found a more immediately effective weapon against soil and WATER wastage.

Use of Brush and Branches.

Everyone knows that wherever a limb, branch, or log is lying on the ground, the grasses and other plant materials grow thicker, taller, and much more rapidly than in an open field. These obstacles collect seed, increase and retain moisture, effect temperature, and guard against washing water and grazing animals.[1]

Only coniferous branches should be used. They provide a thick body because of the needles, twigs, and large stems; and by the nature of its shape it lies close to the ground where the first run of silt covers the needles. The branch tips are laid upstream or upslope. Branches can usually be obtained by trimming nearby trees, and brush can be obtained by thinning dense brush areas.

Branches and brush should be used only in small gullies and at the heads of small drainages or abandoned roads where the run-off will not be too heavy. At the heads of incipient rills and gullies, a light layer or mat of brush will start grass in the depressions, and extending such a layer on down stream, or down the slope helps to keep the volume and force of water down to a degree where vegetation can survive and compete successfully against erosion. The brush may be placed so as to make a continuous lining, or it may be placed intermittently in alternate lengths across the eroded area.

[1]R. E. Wilson, "Use of Brush for Erosion Control," Soil Conservation, December, 1940, p. 152.

Establish Sod.

A grass sod is often desired on gentle slopes where erosion is active, but where the area must be left open for some scenic, recreational, or service purpose.

It is not possible to establish a good bluegrass sod on inferior soil, but certain grasses and legumes can be grown on it. These plants may not be the most desirable at present, but they will control erosion and build up the soil fertility until more desirable plants can follow. In general, before any seeding is attempted, it has been found advisable to apply one and one-half tons of ground limestone and 400 pounds of twenty per cent superphosphate per acre.[1] Sweet clover can then be established on this worn out soil. After a year or two of sweet clover, the soil fertility is improved enough to permit the planting of white clover, red top, and orchard grass. As these plants grow the area can gradually be brought into a good permanent bluegrass sod.

This method of control is seldom used because complete erosion control and a good sod are not immediately obtained.

Cropping Practices.

All lands suffering from soil erosion cannot be retired to forest or forage cover. Therefore certain cropping practices, which will reduce soil and water losses from

[1]K. Welton, "Saving Soil with Sod," Farmers' Bulletin No. 1836, U. S. Department of Agriculture, 1939, p. 13.

cropland and other areas lacking adequate protective cover, must be used.

Some of the more common cropping practices are crop rotations, green manure crops, winter cover crops, strip cropping, contour tillage, and terracing. The use of the above practices and measures for soil erosion control will permit the safe use of a larger percentage of farm land for crop production.

Planting Living Dams.

It has been found much more practicable and economical to establish living dams rather than to construct costly mechanical dams in controlling erosion in gullies. Some of the more common readily available material include willow, cottonwood, blackberry, and black locust. The stock can best be planted by digging a one-spade-width trench across the bottom of the gully and then placing the plants a few inches apart on both sides of the trench. They can then be covered by refilling the trench.

These living dams should be planted at varying intervals in all strategic points throughout the gully.

ESTABLISHING WOODY VEGETATION

A two-fold consideration is necessary in the selection of woody vegetation. The plants selected must serve as a cover for permanent soil-erosion control and at the same time must yield other direct or indirect benefits to the area concerned.

On practically every farm acres of idle land can be found. Land which had been cultivated or pastured but because of erosion and changing economic conditions, have been abandoned for agricultural use. This, not only, means that the money spent in paying taxes on this land is money lost, but also that these areas are a menace to other good land above and below and to the community. By controlling erosion and planting trees on these areas we can prevent further soil losses and at the same time use these areas permanently for wood production.

Before any planting is attempted the following factors which profoundly affect the growth of plants must be studied:[1]

1. Fertility and supply of plant nutrients in the soil,

2. Toxic and foreign materials present in the soil,

[1]E. Millar, Soil and Plants, Soils 201, Lecture Notes, Soils Department, Michigan State College, East Lansing, Michigan, May, 1936.

3. pH of the soil.
4. Temperature,
5. Air supply,
6. General slope and contour of the surface,
7. Condition of drainage,
8. Occurrence of gravels, nodules, or hardpan,
9. Condition of tilth, soil type and depth of soil, and
10. The average annual rainfall and how it is distributed during the year.

The use of hardwood cuttings is sometimes practiced. There are many shrubs and a few trees such as willow, and cottonwood which can be more quickly and conveniently produced from cuttings than from seed. Cuttings should never be made from twigs that are over two years old. They should be selected in such a way that each has at least two buds. The upper end of the cutting should be cut just above a well developed bud and the lower end just below a bud.

While cuttings may be successfully cut and planted at the same time, it is considered better practice to collect cuttings during the fall of the year after the leaves have fallen and store them in moist sand pits for the winter.

The most common use of cuttings in erosion control is in planting stream banks and gully bottoms. The usual practice is to force a hole in the ground with a tool slightly larger than the cutting. The cutting is then inserted in the hole in an erect position so that there is a bud both above and below the ground. The soil is then firmed around it. They are usually spaced from two to four feet apart.

Tree seeding on eroded areas may be practiced, but it has been found that rodents, adverse weather conditions, and competition with the surrounding vegetation usually result in a very high mortality among the trees. Therefore, seedling and transplant stock is advocated for planting eroded areas; that is, stock from one to five years of age and from six to twenty-four inches tall.

The planting stock may be obtained by collecting native wild stock, by purchasing nursery or wild stock, and by growing the stock in home nurseries. If the erosion plantings are conducted on a large scale, the stock should always be grown in home nurseries, that is, the nursery should be located in the immediate vicinity upon which the trees are to be planted.

The following are the chief advantages of using home-grown nursery stock:[1]

1. It is available for use when desired.

2. The danger of deterioration through transport is eliminated.

3. The size and age of the stock desired can be obtained with assurance.

[1]J. W. Toumey and C. F. Korstian, Seeding and Planting in the Practice of Forestry, John Wiley and Sons, Inc., New York, 1931, p. 445.

4. When grown on a large scale the cost is less.

5. There is assurance that the plants are true to name as the origin of the seed is known.

6. It is usually better adapted to the climatic and soil conditions of the planting site.

7. The introduction of harmful insects and serious fungous diseases is eliminated.

8. It can be better graded to fit the particular requirements of each planting site.

9. The conditions under which it grew are known.

Success in planting depends very largely upon the selection of planting materials from the standpoint of its vigor, growing power, and freedom from diseases and insect enemies.

Transplanting should be done after growth ceases in the autumn and before growth starts in the spring. Early spring is generally the logical time for planting.

The following are the most important rules for planting of general application which should be followed closely.

1. The collar of the tree should occupy the same position in reference to the surface that it did in its original position in the nursery.

2. The root system should be given its natural position in the soil, that is, the roots should not be crowded together, bent to one side, or planted in a single vertical plane.

3. Only good and fresh soil should be filled in around the roots, and care must be taken to avoid lumps of soil and air pockets about the roots.

4. The stem should always be given an erect position.

5. The soil should be thoroughly firmed about the roots.

6. It is advisable to leave loose dirt, which will serve as a mulch, on the surface of the earth around the planted tree.

7. A small area directly around the planted tree, usually the diameter of the planting hole, should be below the level of the surrounding land.

Irregular spacing of trees is advocated. In this manner of spacing no attempt is made to set the trees in lines in either direction. The average distance between the plants should be decided upon and the planters should not deviate too widely from it. In general, for field planting trees are planted from five to eight feet apart and for gully control three to five feet apart is usually recommended.

Generally, in establishing woody vegetation on eroded lands, the grub hoe is used if scalping is necessary, that is, removing the present vegetative cover on an 18-inch square. In the center of this square the tree is planted. The use of the planting bar, dibble, or planting mattock, are advocated with small plants, but the hole method should always be used for the larger plant materials. It is very important that the tree roots be kept moist at all times during the planting operations.

There has been considerable work done in Region III of the Soil Conservation Service in regard to fertilization of planting stock. The majority of the work has been done in connection with black locust in areas where the nutrient content of the soil was very low. The application of about 16 grams of 2-12-6 commercial fertilizer to each tree has proved practical. On the basis of 1200 trees per acre the cost of this fertilization treatment would be about one dollar per acre. Since the labor involved in fertilizing tree plantings nearly doubles the planting cost, only those parts of the area containing comparatively sterile soil should be fertilized.

The most important things to consider in the care of tree plantations are to exclude livestock at all times and to keep fires out. In most cases experience has shown that this protection insures the forest cover for both conservation of soil and wildlife and for the production of wood products. A person can improve and maintain a good woods largely by protection and by wise use.

J. A. Gibbs[1] states that, in his observations covering a wide range of soil conditions and many plant species, the soil type and soil conditions constitute the first and most important consideration relative to a decision as to what and how to plant. Proper correlation of species and sites

[1] J. A. Gibbs, "Five Years of Tree Planting in the Ohio Valley," Soil Conservation, December, 1940, p. 146.

largely accomplishes satisfactory establishment of growth at minimum cost. When the wrong species are planted, site preparation does not stimulate growth or increase survival.

In many areas erosion has completely changed the original soil conditions. These areas are characterized by serious sheet erosion and often gullies. Under the above conditions, artificial establishment of cover becomes advisable in order to provide an effective stand for erosion control and to afford economic benefits. The chief question now is what species to plant and what site preparations are necessary.

It has been found by the Soil Conservation Service that pine is the least exacting in site requirements; that black locust gives good to excellent results on many sites; and that hardwoods fail in most cases as erosion control plantings. Table 1 shows the most common and best trees to plant for erosion control, in Region 3, which includes Michigan, in regard to their site requirements.

The problems connected with the attainment of a successful plantation are involved with a variety of factors. The primary cause in many of the difficulties is the fact that the soil fertility has been depleted to a serious extent on the majority of the planting sites. Therefore it is most important that planting plans be designed very carefully because there is often a variety of soil conditions found on a small planting area.

TABLE 1

FAVORABLE SITES FOR DIFFERENT TREE SPECIES[1]

Kind of Tree	Favorable Site
Black Locust	Calcareous, well drained and arerated soils, bare gully banks. (Never where iron or manganese are present.)
Hardwoods	On good fertile soils.
White Pine	All soils except poorest and driest; north slopes best.
Red Pine	Dry, sandy, and other poor soils, (never wet soils or in shade).
Norway Spruce	Well drained moist sites.
Jack Pine	Poor sandy plains.
Scotch Pine	Poorest, driest soils.

After making a complete analysis of the tree planting problems in Region 3, Bell makes the following statement:

> Several controllable factors contribute to the success or failure of an erosion control planting. Most important are: (1) correlation of species to soil, climate, and other components of sites; (2) determination of the practical need for and method of site preparation; (3) quality of planting stock; and (4) tree planting methods, tool, and crew organization.[2]

It is essential that careful planning precede actual field operations. The types and species of woody vegetation

[1]J. A. Gibbs, Tree Planting in the Ohio Valley, Technical Notes 1, Soil Conservation Service, Dayton, Ohio, February, 1941.

[2]G. Y. Bell, "Analysis of Tree Planting Problems in Region III," Soil Conservation, Vol. 4, p. 89, 1938.

to be planted can be decided upon only after a complete and thorough study of the area concerned has been made.

A good mixed plantation of woody vegetation, composed chiefly of trees, will produce a heavy, deep, and broad-spreading root system that will help hold soil particles together. In addition, they scatter leaves, dead twigs, and branches which make a good floor covering. This litter absorbs much rainfall and enables much of it to be stored and drained through the sponge-like cover without cutting the ground surface. Trees permit the growth of other vegetation such as weeds, grasses, shrubs, and vines. They all help make the cover more effective in holding water and relieving it gradually. Trees can be established easily and cheaply, are long lived, and reproduce themselves. By planting trees a natural wilderness is soon developed which will in turn produce wild flowers, and other vegetation which will attract birds and animals. All of this adds much to the value of the land.

In planting, a variety is essential. What one species of plant may lack, another may possess. An effort should be made to attain a well-balanced habitat, approaching as nearly as possible the "orderly confusion of nature." Also by mixing two or more species of trees, they are safer from destruction by insects and fungi; they are more similar to natural stands; and they add to the variety of material produced.

HOW FOREST INFLUENCE RUN-OFF

We all know that if the rainfall could be retained near its point of contact with the land surface, there would be no run-off, soil erosion, or floods. Foresters know this is impossible but they believe that through proper land use the severity of floods can be mitigated and much soil erosion can be prevented. It is the influence of the entire forest cover upon the run-off values which must be considered in reducing the erosion from the area concerned.

Effect of Forest Litter.

By litter is meant the layer of fallen leaves, dead branches, and other vegetative remains which are found in varying depths under the crown of trees.

The popular belief that the forest controls erosion, retards run-off, and conserves water primarily because the litter and humus absorb and hold water is not entirely true. These layers do have an important absorptive and holding capacity, although they seldom become completely saturated and it is through them that the water is immediately provided which carries subtenance to the vegetative cover. But the litter is even more important in the promotion of penetration to deeper storage.

The underground storage of water by forests is very important in regulating and equalizing stream flow. The large quantity of water carried into the earth through the forest litter may percolate for months before it emerges into the stream.

Litter and humus retard flow and hold back water for absorption, their coarseness promotes penetration, they serve as a filter which holds back most of the particles that might clog the soil pores, and their presence as a blanket keeps the underlying soil moist and absorbent.

Humus also helps to bind the soil particles and aggregates, bringing about a "crumb" or granular structure. This "crumb" structure gives the maximum room for air and water, which is vital to run-off and soil erosion.

The humus in the soil resulting from the forest litter contains a large population of soil life. These small creatures feed upon the litter and in so doing increase the soil fertility, maintain looseness in the soil, and provide many small channels through which water can pass.

Lowdermilk[1] found that a forest soil covered with a layer of humus could keep on absorbing rain at a rapid rate hour after hour, and the water kept moving steadily downward into deeper soil. On naked soils the run-off accumulates fine clay which tends to seal the surface and prevent

[1]W. C. Lowdermilk, "Influence of Forest Litter on Run-off Percolation, and Erosion," Journal of Forestry, Vol. 28, No. 4, April, 1930, p. 474.

percolation through the soil, resulting in a heavy surface run-off.

In Auten's[1] study of the forest floor covering under several hardwood forest types in the Ohio Valley, he found that the upper nine inches of forest soil was 13 percent lighter at oven dryness than equal volumes of soils from adjacent non-forested areas. This indicates more pore space in the forest soils. He also found that at one inch depth over 50 times as much water was absorbed per minute on the forest soil as compared to adjacent soils, and that at three inch depth, 14 times as much was absorbed on forest soil. It was also found that by reforestation soil porosity can be greatly increased. In a 17 year old plantation at one inch depth the average rate of absorption was 107 cc. per minute, as contrasted with only .8 cc. of absorption in the adjacent unforested area.

Interception of Precipitation.

During every shower a certain amount of the rainfall is intercepted by the crown of trees. The foliage and branches of the trees break the force of the rain so that the water reaches the soil without violence and at the same tine prolongs its duration.

The Appalachian Forest Experiment Station has made some intensive studies on the interception of precipitation by tree

[1]John T. Auten, "Porosity and Soil Absorption on Forest Soils," Jour. Agr. Res., 46, 1933, p. 997.

canopies. It found that in rains of .2 inch or more, the amount of precipitation intercepted by the tree crowns varied from 1 percent to as much as 33 percent of the total rainfall. The controlling factors were age, composition, season of year, and condition of the stand. They also found that with 25 year old pine stands from one to five percent of the total precipitation reached the ground slowly by running down the trunks of the trees.

Much of the annual snowfall also is intercepted by the crowns of trees. This has some effect in retarding the rate of run-off.

Rate of Snow Melt.

A heavy snow on the forest floor remains many days after the snow has melted on adjacent open areas.[1] The reason for this is partly the shading of the ground but chiefly because of the reduction in the wind movement in the forest. Under the canopy of a woods, the snow melt is delayed because of the lower air temperature in the forest than in the open and because of the protection in part from warm rains. The run-off is less since the soil and litter in a forest are usually free from frost when the open fields are frozen which results in percolation of water in the forest soils and run-off on the frozen open field soils.

[1]A. L. Mac Kinney, "Effects of Forest Litter on Soil Temperatures and Soil Freezing in Autumn and Winter," Ecology, July, 1929, pp. 312-21.

At the Arnot Soil Conservation Experiment Station[1] in Schuyler County, New York the ground in the forest did not freeze during the severe winter of 1935-36, but the ground in the open field froze to a depth of 12 inches and remained frozen until March 15. The result was that in the open field a run-off of 7.9 inches occurred; while on the adjacent forest soil a run-off of less than one-tenth of an inch was lost. The snow covering and litter in the forest acts as an insulator protecting the soil from pronounced temperature changes.

Evaporation and Consumption of Water.

The evaporation of rainfall from the soil is universally influenced by forest cover which not only shades the ground but also greatly reduces the wind movements. European evidence, as quoted by Zon,[2] shows wide variations, but indicates that soils in the open under average conditions will evaporate approximately 50 percent of the precipitation; and that forest soils blanketed with a leaf litter will evaporate about 8 percent, and one without leaf litter around 20 percent of the total annual precipitation will evaporate.

[1] Anonymous, Forest in Flood Control, Supplemental Report to the Committee on Flood Control, House of Representatives, Seventy-fourth Congress, H. R. 12517, 1936.

[2] Rapheal Zon, Forest and Water in the Light of Scientific Investigation, Sen. Doc. No. 269, 62d Cong. 2d sess. Reprinted 1927, p. 27.

All plants rooted in the soil withdraw water from it in order to maintain growth. This water in turn is transpired or given out into the air through the leaves. The transpiration rates for American forest may only be inferred from general knowledge. The percent of the total precipitation consumed by a forest in Germany as quoted by Zon,[1] when the total annual rainfall was 31.5 inches, was about 23 percent for hardwoods, 10 percent for pine, and 29 percent for spruce.

[1] *Ibid.*, p. 30.

CONSEQUENCES OF CHANGE IN FOREST COVER

Some of the most dramatic examples of the effectiveness of soil cover for erosion control are furnished by the consequences, or results obtained from areas where the soil cover has been suddenly removed and by the experiments government agencies are carrying on to determine the effect vegetation and trees have on run-off.

Partial Cuttings in the Valleys of Switzerland.

The influence of deforestation in increasing the run-off and erosion has been accurately observed and measured in many localities. Probably the most famous of these experiments was carried on for many years at Emmental, in Switzerland. Two valleys were measured and studied, one was completely forested and the other partially forested. It was found that the stream in the forested area carried less debris and was more uniform, and that after a heavy rainfall of brief duration the forested stream carried from one-half to one-third as much water as the partially forested stream. During the summer months the forested stream kept up a higher and more regular flow. This proved that the forest was effective in producing a more uniform stream flow and carried less debris throughout the year.

Controlled Burning in Central Oklahoma.

The effect of the forest litter upon decreasing the soil and run-off is clearly demonstrated by the results obtained by burning the litter from a forested area.

From a controlled forested area in central Oklahoma 250 gallons per acre of clear water ran off during a continuous rainy period in May, 1930[1]; but from a similar area alongside where the leaf mold had been burned over 27,600 gallons of muddy water ran off. This forest mold absorbed 17 tons of rain water for every acre and in addition caused the absorption by soil beneath of 97 tons per acre in excess of the amount absorbed where the vegetable covering had been burned. This filtering and protective effect of the litter thus resulted in the absorption of more than five times as much water as was soaked up by the litter itself.

The average annual losses from this area for a three-year period have been 0.013 tons per acre and 0.11 percent of the rainfall from the virgin area, as against 0.22 tons of soil per acre and 4.53 percent of the rainfall from the burned-over area. In other words, the unburned forested area has held back 15 times as much soil and 41 times as much water as the burned-over area.

Fire is perhaps the worst enemy to forest production, the greatest aid to forest deterioration, and the starting

[1]H. H. Bennett, "Soil Erosion Studies Show Vegetation Has Dominant Role," U. S. D. A. Yearbook, 1934, p. 323.

point for soil erosion. Fire destroys the litter, kills seeds and small trees, injures trees of all sizes, and makes the entrance for decay and insects much more desirable. Under more extreme and repeated burns total destruction of the woods and its many valuable related benefits are brought about.

Forest Fire in North Dakota.

In the fall of 1931 a number of fires burned approximately 22,000 acres near Rockford, North Dakota, in the northern portion of the Black Hills. On many slopes all of the trees, as well as the cover of grasses and weeds, were killed; duff and humus were completely burned.[1]

The effect of this destruction soon became evident. During the following year (1932) rains washed down the bare hillsides carrying quantities of rock and earth to the valleys below. Deep gullies were washed in the bottoms, and homesteads were covered with silt, rocks, and debris.

This destructive erosion was very pronounced along the road paralleling South Rapid Creek. A culvert in the road was washed out three times and the bridge which was finally installed had to be replaced. No such damage had occurred before the adjacent slopes were burned over. The stream bed was deeply gullied and large fan-shaped deposits of detritus varying from a few inches to 4 feet in depth

[1]M. W. Thompson, Erosion in the Black Hills after the Burning of the Forest Cover, U. S. Dept. of Agri. Leaflet No. 1551, 1935.

were washed onto the homestead meadowlands.

It is significant to note that no gullying, depositing of soil and rocks, or washing away of culverts, bridges, and roadbeds occurred in other comparable situations where the cover on the nearby slopes had not been destroyed or damaged by fire. The contrasting areas provide a clear demonstration of the importance of keeping watersheds green and forested in order to prevent any serious soil erosion.

Studies have shown that the average forest soil contains from 12,000 to 120,000 pounds of organic matter per acre. The average annual leaf fall ranges from 2000 to 4000 pounds per acre. It was also found that in 2000 pounds of pine needles there are approximately 20.8 pounds of nitrogen, 1.9 pounds of phosphate, and 1.4 pounds of potassium. In 2000 pounds of oak leaves there are approximately 23.5 pounds of nitrogen, 2.5 pounds of phosphate, 6.6 pounds of nitrogen, and considerable lime and traces of other essential elements.[1] In a case of complete burning some of these elements are lost making it very difficult to re-establish vegetation and active erosion begins.

Watershed Protection in North Carolina.

A study conducted jointly by the Soil Conservation Service and the North Carolina Agriculture Experiment Station,

[1]Leroy Frontz, Farm Forest Enemy, Technical Notes 7, U. S. Dept. Agr., Soil Conservation Service, Region 3, Dayton, Ohio, April, 1941.

covering 28 municipalities, representing 90 percent of the water supply reservoirs in the state, and 98 percent of those found on the Piedmont area, has determined that the cost resulting from losses of storage capacity are appreciable and that the additional cost of clarifying or desilting the water for domestic and industrial use also are significant.

It is expected when partial erosion control practices comparable to those of Greenboro, Burlington, or other soil conservation demonstration areas are adopted on the watersheds, that the average proportion of suspended matter at the intake can be decreased 25 percent.[1] This would result in an average reduction in the cost of treatment of approximately seven dollars per million gallons or an annual saving of approximately $94,500 for the Piedmont towns. In addition to this annual saving, the life of the reservoir will be extended several years.

In general the erosion on the watershed can best be controlled, by establishing and protecting a growth of timber on them.

H. H. Bennett, chief of the Soil Conservation Service said March 23, 1941 that soil erosion has cut the useful life of over twenty percent of the water-supply reservoirs of the United States to less than 50 years. Another twenty-

[1] A. M. Garin, "Soil Erosion Damages Public Water Supply," Soil Conservation, Vol. 6, No. 7, January, 1941, p. 178.

five percent will be lost in fifty to one hundred years an only fifty-four percent of our water-supply reservoirs in this country will provide sufficient storage to meet present requirements, 100 years hence. The most feasible and economical method to increase the life of our water supply reservoirs is to produce a good woody vegetation on the adjoining watersheds.

Cropping in Wisconsin.

During the summer of 1929 about forty "erosion traps" were put into operation on farms and different cropping conditions in southwestern Wisconsin.[1] The study was made particularly to bring out the part played by the forest on a well balanced farm. Table 2 shows the comparisons of average figures for run-off on different uses of the land. The forest had an average maximum run-off of 2.8 percent or approximately one-tenth of that of the cultivated fields.

[1] C. G. Bates and O. R. Zeasman, Soil Erosion--A Local and Natural Problem, Agri. Exp. Station, University of Wisconsin, Madison, Wisconsin, Research Bulletin 99, 1930, p. 71.

TABLE 2

AVERAGE MAXIMUM RUN-OFF FOR THE DIFFERENT CHARACTER OF COVER

Character of Cover	Average Maximum Run-off Percentage
Forest	2.8
Wild pastures	7.2
Cultivated hay	17.7
Small grains	25.6
Cornfields	25.7
Seeded pastures	26.7

Grazing in Woodlot in Wisconsin[1].

The results of experiments at the Upper Mississippi Erosion Station at La Crosse, Wisconsin contribute tangible evidence on the part which cleared pastures, grazed, and ungrazed woodlots play in relation to run-off and erosion on steep slopes. The three areas selected were: (1) a pasture recently cleared on timber; (2) a typical hardwood forest that is being grazed; and (3) a typical woodlot upon which no grazing is permitted.

During 1935 there occurred eight storms of rather high intensity, although the average rainfall for the year was not above the normal of 30.8 inches. That year, therefore was an especially good one to test the effectiveness of

[1]Anonymous, Influences of Vegetation and Watershed Treatments on Run-off, Silting, and Stream Flow, Misc. Pub. No. 397, Forest Service, U. S. Dept. Agr., July, 1940, p. 47.

grazing on run-off and erosion.

The results showed that the run-off during the period May to November was 3 percent for the cleared pastured, 9 percent for the grazed woodlot, and only .15 for the ungrazed timbered woodlot. The soil lost during the same period amounted to 600 pounds per acre for the cleared pasture, 1,600 for the grazed woodlot, and only 17 for the ungrazed timbered area.

It will be noted that the 17 pounds of soil lost per acre from the ungrazed woodlot and the 0.75 percent run-off are so small as to be insignificant, thereby proving again that natural managed forest stands are the best control measures for run-off and soil loss.

Logging in Colorado.

The Water Wheel Gap Experiment[1] was carried on in Colorado on two steep watersheds each of about 200 acres. The soil was extremely open and porous and was an immature development from hard reasonably fine igneous rocks. The mean slope gradient was computed to be 26 percent. The forest was chiefly douglas fir, spruce, and aspen.

After satisfactory records had been kept on each area for eight years, the one area was logged during the fall and winter of 1934. The tops and loggings with most of

[1]C. G. Bates, "The Forest Influence on Streamflow under Divergent Conditions," Journal of Forestry, Vol. 34, 1936, pp. 961-69.

the aspen was burned in long windrow piles with the long axis running up and down the slopes. Between 20 and 25 percent of the total area was left as bare strips after the burning.

From May 26 until October 30, 1935, eight rains totalling 12.33 inches fell. Two of the rains which had ten minute intensities of 2.82 and 3.36 inches per hour produced run-off on the forested area. For these eight rains the logged area had a total run-off of .39 inches or 3.1 percent of the entire rainfall and lost 603 pounds of soil per acre. The corresponding figures for the forested watershed were a run-off of .02 inches or .08 percent of the rainfall and a soil loss of 17 pounds. In this case the logged area lost 35 times as much soil per acre as the well managed natural forest.

Experimental Fires by the Soil Conservation Service.

Some of the best effects of woods fire and soil losses are shown by tests conducted over a five year period by the Soil Conservation Service at Guthrie, Oklahoma, and Tyler, Texas. At Guthrie the average annual percent of surface run-off was more than 20 times greater and the soil losses more than 11 times greater from a woods subject to annual burning as compared to the undisturbed, virgin woods. At Tyler, Texas, the water loss was approximately 5 times greater and the soil loss more than 3 to 6 times greater from the burned woods compared with the unburned.

Studies on the rate of absorption in the Ohio Valley show that the unburned forest soil absorbed water more than 5 times as rapidly as did the burned woods soil.[1]

The maximum flood water discharge in California from a recently burned area was 22 times as large as from an unburned area and the amount of soil and debris lost was 1,100 times greater, all factors being equal except for burning.

The above experiments prove conclusively that burning greatly increases run-off which results in large soil and water losses.

[1] John T. Auten, Station Note No. 16, Central States Forest Experiment Station, Nov. 20, 1934.

CONTROL OF EROSION BY REFORESTATION

The restoration of plant cover offers practically the only economical means for restoring the fertility of depleted soils on a large scale. Where a forest cover will grow it produces one of the best opportunities for the rehabilitation of depleted farm lands. Such a cover affords the best protection against erosion and further depletion of the soil; the organic matter added each year will gradually restore many of the elements which have been lost through the effects of erosion; and the land will again be valuable to the community and to the individual owner.

The climate makes restrictions on the use of forest but nearly one-half of the area of the United States did and will support forest growth. Many of the more acute erosion situations occur on land which once supported forest but was cleared by man for agriculture or other reasons. Therefore, successful reforestation is the intelligent and obvious measure to apply to control soil erosion.

The Soil Conservation Service is the leader in the war against soil erosion and the cause for much of the growing interest in conservation among the people of this country. The Soil Erosion Service was established on September 19, 1933 in the department of Interior. The chief reasons for the establishment of this agency was to aid the unemployment situation and at the same time practice conservation on the soil. On April 27, 1935 the Soil Conservation Act was passed which transferred the Soil Erosion Service to the Department of Agriculture and changed the name of the agency to the Soil Conservation Service. This Agency as it is now set up is composed of several activities which are working together for "a common, ultimate goal of better land use, conservation, and a more abundant life for the poeple of the country."[1]

During the past four years, 38 states have passed laws for the establishment of soil conservation districts. There are now 435 districts covering an area of more than 271,000,000 acres.[2] It is the farmer who must practice erosion control methods so that they can make better use of their land and continue to make a living from the soil. At present there are 1,600,000 farm families; or about one-fourth of all the farm families in the United States, living within soil conservation districts. It was the Soil Conservation demonstration program and the educational efforts which put the American people wise to the problem of erosion.

Many farmers and conservation minded people have watched the once bountiful crops grow less in quality and

[1]H. H. Bennett, Soil Conservation. New York: McGraw-Hill, 1939, p. 314.

[2]Claud R. Weekard, "A Foreward to This Issue," Soil Conservation, VI, No. 8-9 (February-March, 1941), 189.

quantity during the years until many of the tillers could no longer make a living from the worn-out land. On many of these farms sheet-erosion has taken from 50 to 75 percent of the topsoil on all crop lands and gullies are often active on part of the cultivated area. The farm in general is in bad run-down condition.

The conservation plan for a farm generally consists of mechanical erosion control measures, adjustments in major land uses and cropping systems, and changes in the livestock system.

The central idea of the Soil Conservation Service is the cooperation with nature. Of course they realize the wholesale retreat to trees would be economic and cultural suicide, but the service contends that we must go part way. This means that cultivation must be confined to level land and areas of very little active erosion. This also means that all steep and erodible lands must go under a perennial vegetative cover.

There are numerous cases in the New England region where plantations were set out some years ago and are now completely overtopped and suppressed by volunteer reproduction. Nearly every forester has made the mistake of planting too soon, of putting in trees where, as it later turned out, they were not needed. Obviously, there are many places, particularly on the lighter soils and drier sites, where planting will be the only means of reforestation.

It is therefore most important that one knows when to reforest and when natural regeneration will produce the necessary soil cover to control soil erosion.

Natural Regeneration.

Trees have the capacity to grow on worn-out farm land as has been proven by the eastern states. On large areas of land which once had been cleared and cultivated for crops, but because of the active soil erosion the crop yields became progressively lower each year until finally the farmers were forced to leave their land and move farther west to the virgin fertile soils. Today much of the eastern United States especially the New England states, which once was eroded farm land now supports a dense second growth forest cover. The old boundary lines of stone fences and the rows of cultivated fields can still be distinguished in the new forests. These trees have become established without the aid of man. At present many of the forests have a closed canopy, a good undergrowth, and a deep litter to cover the forest floor. A forest of this type offers the first line of protection against soil erosion.

In order to control soil erosion by natural reforestation, after the land has been changed from its present use such as cropping or grazing, there must be seed trees within the immediate vicinity of the area affected. Even if the seed trees are present it often takes from 5 to 15 years for the new seedlings to appear and in some areas new seedlings never become established. Therefore it is important that a careful study of the area affected be made in order to determine the possibility of obtaining natural reforestation to control the soil erosion, or if artificial reforestation with or without additional control measures can be justified to produce tree growth for the area.

Of the total area in eastern United States which has been returned to forest growth, small areas are again being farmed with special precautions to prevent soil erosion. But since the east is the manufacturing and business center of United States, and most of their local people are now receiving high wages accompanied with plenty of leisure time; these forested areas have become very important for recreational uses. Many of these natural reforested areas are producing direct benefits to the land owners through the production of fuelwood, fence-post, rail-road ties, lumber, and other wooden commodities.

This eroded land has been restored to woody vegetation through natural regeneration which has produced an effective control for soil erosion and at the same time returned this worthless land into valuable property both for the individual owner and for the community at large.

Artificial Reforestation.

In 1933 the first large-scale erosion control program was organized in United States. Each successive year thereafter has been more successful than the previous year both by an increase in the total acreage upon which work was done and in the success of the control measures applied Table 3 shows the work accomplishments of the Soil Conservation Service C. C. C. Camps during the past eight years. The C. C. C. Camps have planted more than 625,000,000 trees during this period and have carried out work on 20,000,000 acres of land in 728 localities in 42 states. Of course much more soil erosion control work has been done than Table 3 shows because many farmers and private land owners have furnished their own labor and necessary materials with the advice of the Soil Conservation technicans to check their eroding soil.

TABLE 3

SOME OF THE WORK ACCOMPLISHMENTS OF THE SOIL CONSERVATION C. C. C. CAMPS FROM BEGINNING OF OPERATION UNTIL DECEMBER, 1940[1]

Treatment of Gullies:	
Check dams, permanent and temporary, number	3,444,454
Gully banks sloped, square yards	79,734,349
Gullies seeded and sodded, square yards	369,260,642
Tree planting for gully control, square yards	351,897,116
Diversion ditches, linear feet	536,706,581
Sheet-Erosion planting, acres	537,708
Field planting of trees, acres	235,843
Roadside erosion-control demonstration, miles	686
Terracing, miles	26,648
Terrace outletting:	
Channel construction, linear feet	38,177,783
Outlet structures, number	333,204
Planting, seeding, sodding outlets, square yards	113,034,801
Impounding and large diversion dams constructed	2,074
Fences relocated to permit contour farming, rods	13,511,843
Land prepared for strip cropping, acres	187,908
Contour furrows and ridges, miles	119,497

The influence of soil type and site factors on the success of erosion control plantings was made by W. S. Legion in Region 3.[2] There were 49 Soil Conservation

[1]G. H. Gilbertson, "The C. C. C.'s Eighth Birthday," Soil Conservation Service, VI, No. 10 (April, 1941), 262.

[2]W. S. Legion, "Influence of Soil Type and Other Site Factors on the Success of Tree Plantings for Erosion Control," Journal of Forestry, XXXVIII (1940), 226. (Abstract of paper presented before a meeting of the Society of American Foresters held under the auspices of the American Association for the Advancement of Science at Columbus, Ohio, December, 1939).

Service erosion control plantings studied within the region. The majority of the plantings were five years old. The study consisted of black locust, various pines; and a variety of hardwoods, which were field plantings, gully plantings, and combinations of the two. There was a total of 25 different soil series and a wide range of erosion conditions included in the planting areas studied. The data secured is based on existing field conditions. The following Tables 4, 5, and 6 show the information obtained from this study.

TABLE 4

FACTORS DEFINITELY CONTRIBUTING TO FAILURES[1]

Soil Series	Locust							Pine						
	Soil Factors	Grazing	Inter Planting with Pine	Poor Planting Methods	Mice Damage	Drought	Other Vegetation	Soil Factors	Insects and Disease	Poor Stock	Poor Planting Time and Method	Grazing	Drought	Inter Planting with Pine
Muskingum	7				1	1		4	1			1	1	1
Wellston	1							1						
Tilsit	3							1						
Hanceville	1									1				
Belmont	1			1							1			
Meigs-Upshur		1					1		1					
Cincinnati	2					1								
Gibson	2													
Frederick	1													
Bedford	1													
Lawrence	1													
Dickson	1													
Memphis										1	1			
Grenada	2							1	1			1		1
Brandon	5													
Lex-Rust	1								1					
Atwood	2		1											
Total	31	1	1	1	1	2	1	8	4	2	2	2	1	2

[1]*Ibid.*, 1940.

TABLE 5

RESPONSE* OF BLACK LOCUST, PINE, AND HARDWOOD PLANTINGS WITH REFERENCE TO SOILS[1]

Soil Series	Number of Plantings Studied	State	Black Locust			Pine			Hard-woods		
			E	M	F	E	M	F	E	M	F
Residual Sandstone Shale and Limestone Soils:											
Muskingum	13	O.-Ind.	2	4	3	7	2	1	0	0	7
Wellston	4	Ohio	0	2	2	3	1	0	0	0	3
Tilsit	5	O.-Ind.	0	1	2	1	1	0	0	0	2
Hanceville	1	Ky.	0	1	0	0	1	0	0	0	1
Zanesville	1	Ky.	1	0	0	--	--	--	--	--	--
Maniton	1	Ky.	0	1	0	--	--	--	0	0	1
Westmoreland	4	Ohio	2	1	0	2	2	0	0	0	3
Brooke	1	Ohio	1	0	0	0	1	0	0	0	1
Belmont	1	Ohio	0	0	1	0	0	1	0	0	1
Upshur	3	Ohio	2	1	0	--	--	--	0	0	2
Meigs	5	Ohio	2	1	0	2	1	0	0	0	3
Loess and Coastal Plain Soils:											
Princeton	2	Ind.	2	0	0	1	0	0	1	0	0
Alford	1	Ind.	1	0	0	--	--	--	--	--	--
Memphis	3	Ky. Tenn.	2	1	0	0	1	0	0	0	1
Grenada	5	Ky. Tenn.	3	2	0	1	1	1	--	--	--
Brandon	5	Ky.	0	0	5	0	1	0	--	--	--
Lexington-Ruston	2	Tenn.	0	1	1	0	1	1	0	0	1
Ruston	2	Tenn.	0	1	1	1	1	0	--	--	--
Atwood	2	Tenn.	0	0	2	2	0	0	--	--	--

*E - Excellent to good; M - Medium to fair; F - Poor to failure.

[1] Ibid.

TABLE 6

RESPONSE* OF BLACK LOCUST AND PINE PLANTINGS WITH REFERENCE TO LOCATION OF SANDSTONE AND SHALE SOILS[1]

Soil Series and Tree Species	Surface Plantings		Gully Plantings															
			Sandstone Predominant								Shale Predominant							
			Ridges		Sides		Bottoms		Concretions Present		Ridges		Sides		Bottoms		Concretions Present	
	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F	S	F
Muskingum Black Locust	5	3		2		3		2		2	1	5	4	2	4	2		2
All Pines	28	5	3	3	3	3	2	3			9	1	2	4		4		
Wellston Black Locust	1	2										1		1		1		1
All Pines	10	1									3		3			3		
Tilsit Black Locust		1										3	2	1	3			
All Pines	3	1									1			1				1

*S - Satisfactory; F - Failure.

[1]*Ibid.*

The effectiveness of reforestation in controlling soil erosion is largely determined by the survival and growth of the planted stock. The preceding tables and study as summarized by Legion indicates (1) that black locust grows best on calcareous soils, soils of good drainage, aeration, and moisture holding capacity, soils free from compact impervious layers and high content of concretionary or indurated materials; (2) that pine will grow on soils more acid, droughty, and infertile than will black locust; (3) that all hardwood, excluding black locust fail in most erosion control plantings.

It must be remembered that in the past the selection of species to plant was determined to a large extent by the availability of planting stock. At the outset of erosion control plantings black locust was the species available in large quantities and was considered suitable for all planting sites. Table 7 shows the trend in the proportion of black locust, pine, and hardwoods during the past years. It shows very clearly that pine is being planted more and the locust and hardwoods are being used less. The result is that a larger percentage of the reforested areas are now effectively controlling soil erosion and yielding other direct and indirect benefits to the land owner and the community at large.

TABLE 7

PERCENTAGE OF SPECIES USED IN PLANTING PROGRAM OF REGION III[1]

Year	Percentage Planted		
	Black Locust	Pine	Hardwoods
1934-1935	83	14	3
1935-1936	79	8	13
1936-1937	60	13	27
1937-1938	42	27	31
1938-1939	35	52	13

The results of the planting program in Region III based on the survival counts are given in Table 8. The figures are of special interest and value as a partial measure of the success of erosion control plantings. There is much work being done at present to solve planting problems both by the Soil Conservation Service and the forest service experiment stations. Both agencies are keeping accurate records on planting stock, planting site, survival of material, and the effectiveness of the planting in regard to erosion control, indirect benefits, and timber production.

Previous to 1938 each camp forester in Soil Conservation

[1]J. A. Gibbs, "Five Years of Tree Planting in the Ohio Valley," Soil Conservation (December, 1940), 146.

TABLE 8

RESULTS OF THE SOIL CONSERVATION SERVICE PROGRAM OF PLANTING TREES AND SHRUBS[1]

State	Planted to Date Soil Conservation Service Records	Examined and Reported 1937	Percentage of Planted Area Examined	Satisfactory Survival		Unsatisfactory Survival		
				Acres	Average Survival Percent	Acres	Average Survival Percent	Percent of Acres Examined 7 ÷ 3
1	2	3	4	5	6	7	8	9
Indiana	7,539	2,899	38	2,221	83	678	49	23
Kentucky	7,839	3,210	41	2,204	80	1,006	58	31
Michigan	127	119	94	110	81	9	64	8
Ohio	11,819	3,587	30	2,457	84	1,130	46	31
Tennessee	3,744	797	21	768	88	29	61	4
Total or Average for all States Under Soil Conservation Service Program	217,664	109,534	50	79,083	78.4	30,451	39	28

[1]John F. Preston, "Results of the Soil Conservation Service Program of Planting Trees and Shrubs," Journal of Forestry, XXXVII (1939), 20.

Camps made his count on survival in his own wya, which usually varied from a 100 percent count of living trees to a general look at the plantation with the conclusion that it should or should not be replanted. In 1938 a uniform method of securing the basic data was employed so that results would be comparable and so that the same degree of accuracy in appraising the results would be obtained.

To date neither the Soil Conservation Service nor any other agency have made available any information concerning the effectiveness of different control measures in checking soil erosion. It is a known fact that a good soil cover of woody vegetation conserves the soil and water in the given area more than any other land usage. Therefore if we can restore our lands suffering with run-off and soil loss with a good forest growth we will have controlled soil erosion.

The following Figures 1 and 2 show the effectiveness of black locust in checking soil erosion in gullied areas.

Figure 3 shows some of the effects of good woodland improvement which results in complete erosion control and at the same time brings some monetary returns in the form of timber production to the land owner.

Figures 4 and 5 show how a good woods protects the land from run-off and soil loss.

Courtesy J. A. Gibbs, Soil
Conservation Service, Dayton, Ohio

Figure 1.--Black Locust Reclaims Gullied Area

Courtesy J. A. Gibbs, Soil
Conservation Service, Dayton, Ohio

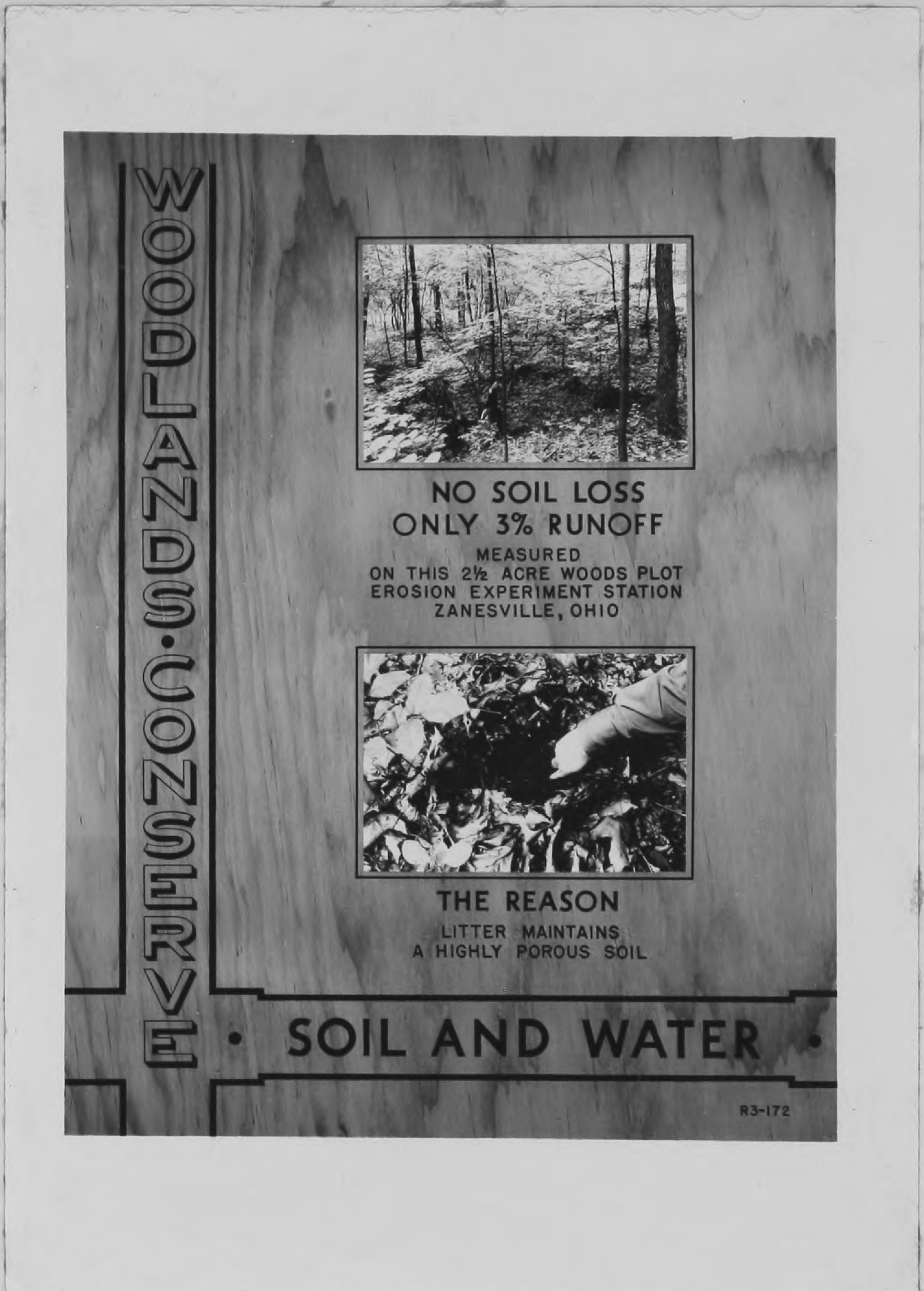
Figure 2.--Black Locust Heals Gully

Courtesy J. A. Gibbs, Soil
Conservation Service, Dayton, Ohio

Figure 3.--Wood Improvement Produces Good Vegetative Cover Which Controls Erosion

Courtesy J. A. Gibbs, Soil
Conservation Service, Dayton, Ohio

Figure 4.--Forested Soils Hold Winter Rains



Courtesy J. A. Gibbs, Soil
Conservation Service, Dayton, Ohio

Figure 5.--No Soil Loss in This Woods

At the present time most of the Soil Conservation Districts are keeping accurate records on the survival of plantings under different planting conditions and on a variety of sites. They measure the run-off and soil loss for different plantations and thereby determine the effectiveness of the planting in controlling soil erosion. The service has also started a number of research projects to measure the effects of various kinds of cover on snowfall and rainfall. Since the installations have just been made, there is no accurate information available at the present time.[1] However, according to J. A. Gibbs, regrowal forester for the Ohio Valley Region, on many areas that have been reforested there is no question about the success of planting in controlling erosion; but no measurements have been made.

[1]E. C. Sackrider, Success of Controlling Water Erosion by Reforestation, Personal Letter, October 29, 1940.

CONCLUSION

Soil erosion must be recognized as a great evil in United States. The soil which is our greatest natural resource must be maintained or improved and not be permitted through the destructive handwork of man to become near sterile, eroding, unproductive, worthless land.

The soil of United States with its great variety of uses often requires special terracing, dams, and other obstructions to control run-off, but the soil will continue to erode without the aid of vegetation. A woody vegetation of trees produces the best permanent ground cover to check soil erosion. The crowns of the trees reduce the mechanical force of the raindrops on the ground, the roots reinforce the soil, and with the forest litter, the soil organisms build up the soil fertility and keeps it absorptive all in the defense of erosion.

Wherever natural reproduction is possible, planting should ordinarily not be considered. It is most important that a careful study of the area be made before any erosion control measures are applied or any trees are planted, because soil erosion and its control constitute a complex problem, requiring for solution the coordinated efforts of specialists in many fields.

Whenever it is economically practical, trees should be the ultimate aim in the permanent control of soil erosion because they will benefit the area concerned in the following ways:

1. Make the landscape more beautiful.
2. Provide recreational opportunities, physical, mental, and spiritual.
3. Provide aesthetic features, and inspirational value.
4. Furnish a quiet, peaceful place for people to get away from everyday life.
5. Encourage game and wildlife.
6. Furnish demonstrational study areas.
7. Produce flood control.
8. Furnish employment.
9. Make increased and better balanced land utilization.
10. Produce financial returns from good forest management.
11. Moderate the extremes of climate.
12. Obtain biologic balance.
13. Add mulch and fertility.
14. Produce a better and cheaper public and municipal water supply.
15. Minimize run-off and soil loss.

Whenever reforestation is successful, that is a plantation survival of at least 80 percent and the majority of the trees have a satisfactory growth rate, the planting will be effective in controlling soil erosion.

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