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Senior Thesis

EROSION AND FORESTRY.

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EROSION & FORESTRY

EROSION:

The earth is not to be regarded as a finished product; on the contrary, it is subject to continual changes at present, as it has been throughout its history. Sometimes these changes are sudden, caused by a great earthquake, a volcanic eruption, or violent hurricane, but much more important are the slow, almost imperceptible changes which are brought about by the atmosphere, running water, rain, snow, and frost. These are most important because they are unceasingly active over the whole of the land.

The topography and drainage of a region go through a course of development with definite stages, which are called youth, maturity, and old age. Because of the extreme slowness of the changes and the shortness of human life, each stage may not be observed in succession, but it is possible to find each stage somewhere on the earth's surface at the present time. (25)

The term "erosion" is here used to designate the washing away of soil at a materially more rapid rate than the constructive or restorative processes allow for soil accumulation and improvement. On steep slopes, never too well clothed with vegetation, there has always been a downward movement of the soil. Under normal undisturbed conditions such as prevailed before settlement this loss on most of the land was not in excess of the additions made to the soil by the processes of weathering and of the decay of plant materials. Had this not been the case, the slopes centuries ago would have been denuded to bedrock. The normal rate of geological erosion in most places was such that the constructive processes were equal to or slightly superior to the destructive. In other words, there was a balance in soil depth and quality established, which, except for subsequent abnormal erosion, would have produced a present soil condition somewhat better than that which occurred at the time of white occupation. (10)

Why Think About Erosion?

It is estimated that not less than 126,000,000,000 pounds of plant-food material is removed from the fields and pastures of the United States every year. Most of this loss is from overgrazed pastures, and from cultivated and abandoned fields. The value of the plant-food elements (considering only phosphorus, potash, and nitrogen) in this waste, as estimated on the basis of the chemical analyses of 389 samples of surface soil, collected throughout the United States, and the recent selling prices of the cheapest forms of fertilizer materials containing these plant nutrients, exceeds $2,000,000-000 annually. Of this amount there is evidence to indicate that at least $200,000,000 can be charged up as a tangible yearly loss to the farmers of the Nation. These calculations do not take into account the losses of lime, magnesia, and sulphur. (5)

In this connection it must be remembered that rainwash removes not only the plant-food elements but also the soil itself. Certain piedmont areas whose records are known have, within a period of 30 years, lost their topsoil entirely, 10 inches or more of loam and clay loam having been washed off down to the clay subsoil; and on this clay subsoil, substituted for the departed soil, from 400 to 600 pounds of fertilizer are required to produce as much cotton per acre as formerly was grown with 200 to 250 pounds of fertilizer of no better quality. (5)

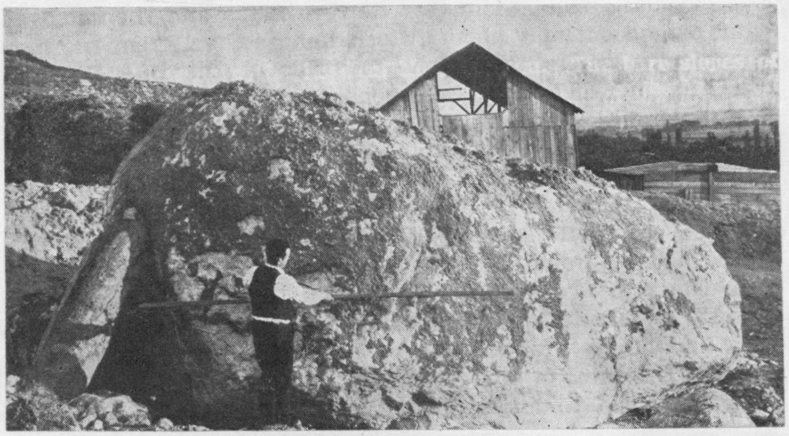
The following figures and statements are taken from Miss. Ag. Exp. Sta. Res. Bull. 63. (8)

Hitchcock stated in 1855 that the Merrimac River sends forward, annually, about 839,171 tons of sediment to its delta. The Ganges carries about 355,361,464 tons of mud each year. The Mississippi carries about 28,188,383,892 cu. ft. or one cubic mile in a little over five years. Since the whole delta contains 2720 cubic miles it would require at this rate about 14,000 years to form it.

Norton states that with an annual rainfall of about 50 inches approximately 50 per cent is discharged through rivers. He states further that the Ohio River discharges 30 per cent of the rainfall of its basin, while the Missouri carries away but 15 percent. A number of streams of the semi-arid lands of the West do not discharge more than 5 per cent of the rainfall. Desert streams may lose all of their water before they reach the sea.

Babb reports determinations made on the Potomac River which show that the average annual discharge of this stream, from a drainage area of 11,043 square miles is 20, second-feet, varying from 2,000 second-feet in time of low water, to 470,000 second-feet during the great flood of 1889. The to-

Spectacular Aspects of Erosion



Utah Ag. Ex. Sta. Cir. 92

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C. L. Forsling

tal amount of sediment transported annually averaged 353 pounds per second for a period of 6 years (1886-1891). The total loss was lowest in 1887 with 2,372,800 tons, and greatest in 1889 with 10,142,600 tons. The average daily amount varied from 1 to 21,900 pounds per second. The average amount of sediment was to the weight of water discharged as 1 to 3575. Assuming 1 cubic foot of soil to weigh 100 pounds, this average amount of sediment would cover the entire drainage area to a depth of 0.0043 inches. At this rate it would take the river 2,770 years to erode 1 foot from the drainage area.

Davis reports estimates by the Geological Survey that the amounts of sediment carried by several American rivers are as follows:

	Tons a year.
Hudson	240,000
Susqhehanna	240,000
Roanoke	3,000,000
Alabama	3,039,000
Savannah	1,000,000
Tennessee	11,000,000
Missouri	176,000,000

McHargue and Peter determined the amount of mineral matter in solution found in the drainage water of various rivers in Kentucky flowing through different geological areas. They found that the drainage from limestone areas had the most mineral matter and that from sandstone areas the least, but the potassium was higher from the sandstone areas than from limestone regions.

These authors also give results of determinations on the soluble materials found in the water of the Mississippi

River. The samples were taken at Baton Rouge, La. The parts per million as well as total tons lost per year are as follows:

Element	P.P.M. Lost in solution	Tons lost per year
P	0.07	62,188
N	9.80	630,720
K	2.09	1,626,312
Ca	28.29	22,446,379
Mg	6.62	5,179,788
S	8.52	6,732,936
Total	66.39	36,678,323

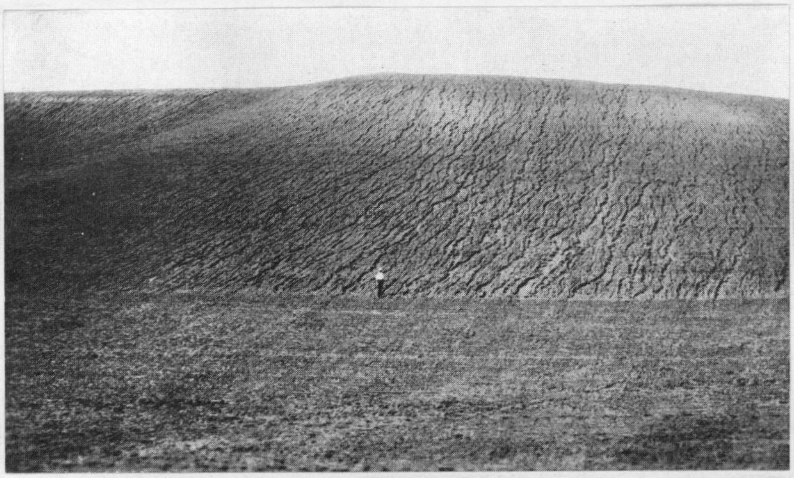
Forbes determined the silt and salt content of water from different rivers in Arizona. The increase in percentage of silt during flood time was much greater than the increase in flow of water, due to the variation in carrying power with changes in velocity. The percentage of silt varied greatly in different streams.

A summary of the silt and salts in the Salt River waters removed from Aug. 1,1899 to Aug. 4, 1900 showed that the water taken out by canals during the period was 307,399 acre feet. The total silt removed was 675,978 tons and the total salts removed was 414,716 tons. During only 7 of 42 approximate weekly periods throughout the year was the weight of silt greater than the weight of salts in solution. The total amount of sediment was sufficient to make a layer approximately 0.000603-inch deep over the entire drainage area. This would mean that the surface 7 inches would be removed in about 11,608 years.

Sheet Erosion

U.S.D.Cir. 33

Fingering



State College of Wash. Ag.Ex.Sta. Bul. 271

Gullying

U.S.D.A. Farmers Bul. 1239

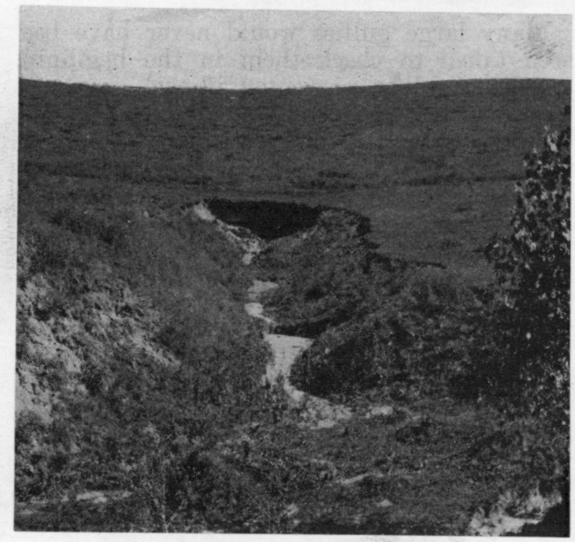
KINDS OF EROSION.

Sheet erosion is the process going on when a smooth, even surface is washed by rain. The process is best exemplified on a road surface or hard-packed smooth pasture, since the loose soil of a field seldom cuts evenly. Sheet erosion generally removes only the finest, lightest, and most valuable part of the soil, since the water is of such small volume at any point that it has little mechanical power. It usually occurs on hillsides of only moderate slope and on the more cohesive soils. The results of this type of erosion are not particularly conspicuous.

Fingering, often called "shoe-string gullying", is the process which quickly follows sheet erosion especially when the soil is loose. The term implies the formation of tiny gullies (as, for example, in each furrow of a freshly cultivated cornfield) which converge toward the lowest point of the field, and through this concentration the water acquires greater and greater cutting and carrying power.

Gullying, when fingering attains sufficient magnitude so that the channels for the water are not readily changed or obliterated, the process is called gullying. Gullying may to to any depth or extent that the conformation of the ground, the fall to a permanent channel, or the character of the substratum will permit. One type of gully has vertical, cliff-like sides which keep caving in as the water undermines them. Once started, it usually grows rapidly in length, breadth and depth with every storm, until it has developed from a mere gash into a yawning chasm. It is the most striking form of gully erosion, the most rapidly progressive in its development, and the most difficult to check. When gullies cease to extend their width or depth, and their walls in consequence recede to a slope which is more or less permanent, they are said to be "healing," a process invariably accompanied by the establishment of vegetation. A gulch is a healed gully, that is, it is a course for the drainage of a temporary waters which is fully under the control of a vegetative cover, not appreciably changing its size or shape, and, therefore, temporarily inactive so far as the erosion process is concerned. (2)

River bottom rivers erode a certain amount by means of solution and chemical decomposition upon the rocks of its bed, and, in limestones, this may be considerable, especially if the water is charged with organic acids from a swamp or a peat-bog. Very much more effective than the chemical is the mechanical erosive work, which is dependent upon the velocity of the current and varies directly as the square of that velocity. The velocity of a current is the rather complex resultant of several factors, the chief one of which is gravity; the steeper the slope of the bed, the swifter is the flow of the water, with the maximum in the vertical drop of a cataract. A second factor, important in large streams, is the volume of water; with equal slopes the velocity varies as the cube root of the volume. That is to say, that if two parallel streams flow down the same slope, one of which has eight times as much water as the other, it will flow twice as fast. This is exemplified by the bayous of any old stream, Beginning to Gully



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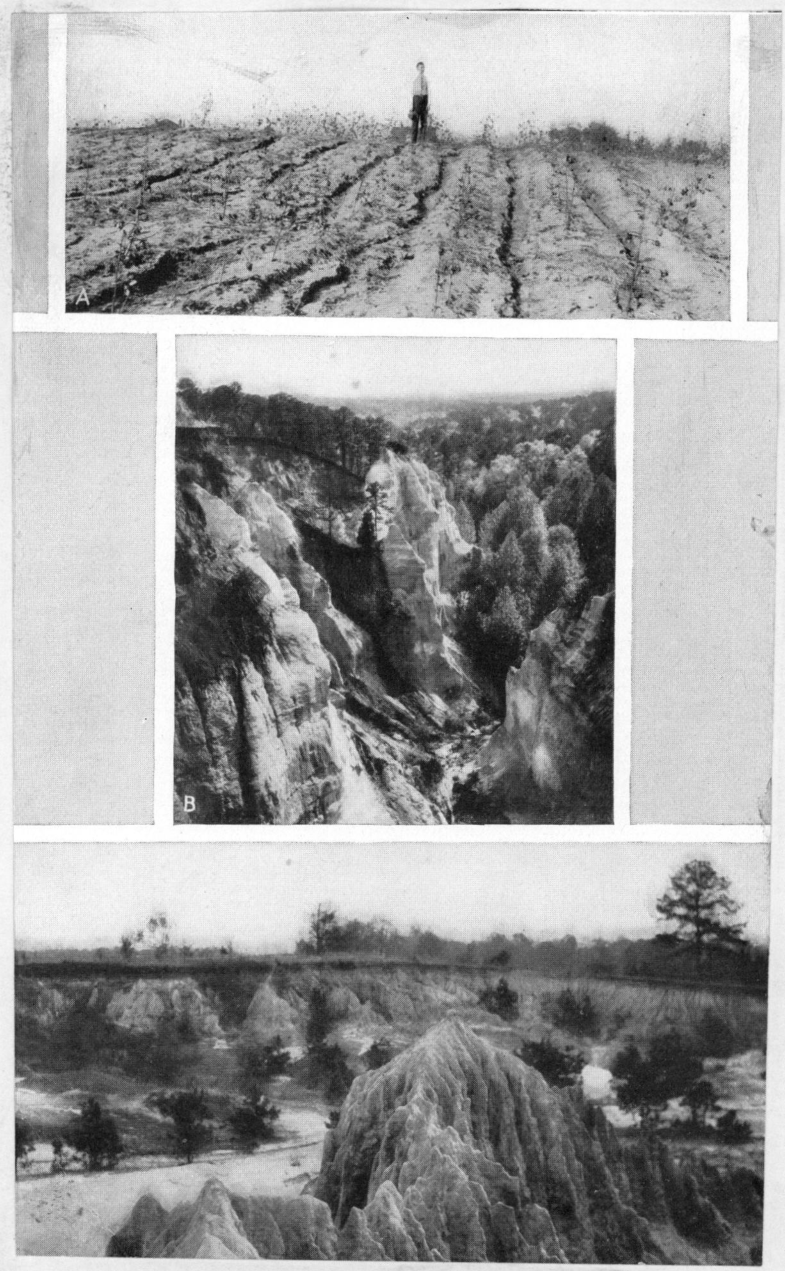
which have the same slope of bed as the river, for they leave it and return to it; yet, while the river has a swift current of five or six miles an hour, in the bayous the water seems hardly to move at all. Clear water can do little to abrade rock except in the way of solution. A stream which flows in a channel of hard rock cuts into its bed by means of the sand, gravel, and debris it sets in motion, the stream supplies the power, just as does the wind in desert erosion, but more effectively, because many rocks are somewhat softened by being wet. The cutting materials are themselves abraded and worn down by collision with one another and with the bed-rock; angular blocks are speedily worn into cobble stones and these into pebbles, the shape of which is determined by the material and the velocity of the current.

That it is difficult to determine streamflow relationships and to measure them may be illustrated by the following extract from The Transportation of Debris by Running Water by G. K. Gilbert (12): "The flow of a stream is a complex process, involving interactions which have thus far baffled mechanical analysis. Stream traction (a sweeping or dragging along of particles) is not only a function of stream flow but itself adds complications. Some realization of the complexity may be achieved by considering briefly certain of the conditions which modify the capacity of a stream to transpost debris along its bed. Width is a factor; a broad channel carries more than a narrow one. Velocity is a factor; the quantity of debris carried varies greatly for small changes in velocity along the bed. Bed velocity is affected

Gullying



U.S.D.A. Cir. 33

by slope and also by depth, increasing with each factor;and depth is affected by discharge and also by slope. If there is diversity of velocity from place to place over the bed, more debris is carried than if the average velocity everywhere prevails, and the greater the diversity the greater the carrying power of the stream. Size of transported particles is a factor, a greater weight of fine debris is carried than of coarse. The density of debris is a factor, a low specific gravity being favorable. The shapes ofparticles affect traction, but the nature of this influence is not well understood. An important factor is found in the form of channel, efficiency being affected by turns and curvature, and also by the relation of depth to width. The friction between current and banks is a factor and therefore likewise the nature of the banks. So, too, is the viscosity of the water, a property varying with temperature and also with impurities, whether dissolved or suspended.

Combination of above. One of the worst features of erosion is its tendency to progress with ever increasing rapidity. Once given a good start it will grow of itself. Where sheet erosion is taking place every bit of surface soil washed away decreases by so much the water-absorbing capacity of that which remains, and hastens its removal down to the subsoil and often to the bare rock. Where gullies have been formed the run-off is concentrated in these and frequently scours them out with almost inconceivable force. Often indeed, the undermining and caving in of the banks proceeds so rapidly during a heavy storm that it is dangerous to be too close an observer.

Moreover, the eroded material greatly increases the scouring power of the running water. The sediment of sand, gravel, and boulders, carried down in gullies and stream courses exercises a powerful influence in carving out their banks, and tearing away formations which would not be affected by water alone. This is especially true on steep slopes, since the transporting power of water varies as the sixth power of the velocity. In other words, when a current of two miles per hour can move only fragments of stone the size of a hen's egg, a torrent of twenty miles per hour can carry boulders weighing nearly one hundred tons. The tremendous scouring power which such a burden as this adds to the water and its effect in hastening the progress of erosion are obvious.

FACTORS AFFECTING EROSION.

Topography and slope of ground.

Duley and Hays (9) in their experiments upon the degree of slope on runoff and soil erosion found that the most significant thing about their results, as indicated by the table taken from their bulletin, is the very rapid rise in the rate of run-off as the slope is increased from 0 to 2 percent, followed by a more gradual rise to between 3 and 4 percent. After this there is a very much slower rise in the percent of run off. The amount of soil removed increased very slowly as the slope was increased up to 3 or 4 percent. Then with increasing slope there was a very rapid rise in the amount of soil removed. The following tables show these relationships.

Effect of slope of tankon run-off water from surface soil (rain at rate of 1" per hr.)

Slope %	Quantity of run-off Water Average	Ave. Run-off %
0	35.2	38.85
1	56.5	54.33
2	66.0	63.47
4	71.6	68.86
6	71.9	69.15
8	76.2	73.28
10	78.2	75.21
15	86.8	83.48
20	89.9	86.45

Effect of slope upon the amount of soil removed (rain at rate of 1" per hr.)

Slope	Soil Eroded	Runoff to remove 1" soil
0	117.6	651
1	581.5	211
2	392.0	367
4	616.4	253
6	1139.1	137
8	2561.3	65
10	4684.6	36
15	7821.2	24
20	12122.7	16

Conner, Dickson, and Scoates (7) found much the same thing. In general, the plats with 1, 2, and 3 percent grades lost from 5 to 6 times more water than the level plats. The 2 percent grade lost slightly more water than the 1 per cent grade, but the difference was not comparable to the difference between the runoff from the 1 percent grade and that from the level plat. The 3 percent plats in this experiment in every case lost less water than the 2 percent plats. The soil lost was twice as great from the plat with 1 percent grade as it was from the level plat, and approximately three times as great from the plat with 3 percent as from the plat with the level grade. These experiments showed an indication that the losses of soil are more directly in proportion to the steepness of the grade than are the water losses.

Character of rainfall:

Both the time of fall and the rate of fall affect the eroding capacity of the rainfall indirectly through the amount of runoff caused. A heavy rain just after a steady light rain which has soaked up the soil will have a more damaging effect than merely a continuation of the light rain. A heavy rain is liable to do damage whether following another rain or not. The rate of rainfall is the most important factor of runoff and erosion. Dulley and Miller (8) in their experiments found that in a three-day rain period in August, 2.97 inches of water fell during a total of 9 hours of actual rain. During a single hour, 2.09 inches of rain fell. As a result the erosion from a plot spaded to the depth of 8 inches during this three-day period reached 546.6 pounds. This may be compared with a rain of 2.87 inches in September which occupied a total of 16 hours, the highest hourly precipitation being but 1.14 inches. Such a distribution of the precipitation resulted in the erosion of only 110.1 pounds of soil from the spaded plot, or about one-fifth the amount mentioned above.

Rockie and McGrew (24) describe the spectacular erosion resulting from a heavy downpour as follows: "Along the foot of this slope a barbed-wire fence followed the contour line. The lowest wire of this fence averaged 8 inches above the ground before the storm; the second wire stood 18 inches above the ground and the third 27 inches. On July 30 water rushing down from the smooth slope above brought with it soil and vegetable litter, which was piled up against the lower wires, and formed a solid mat of litter and soil that reached from the ground to the wire 18 inches above the ground. The evidence showed that over the long smooth slope a blanketlike flood of rain-water had accumulated. This impinged against the fence to a depth exceeding 18 inches, and at some points was almost 27 inches deep. From one three-acre watershed of summer fallow a stream of mud about 40 feet wide laid flat, along a small stream-way draining the area, a strip of wheat that would have cut 50 bushels per acre. Numerous soil "boulders" were scattered over the alluvial plain of this streamlet to a distance of 1500 feet below the fallow ground."

Vegatative cover:

In humid regions completely clothed with vegetation, as in a dense forest, natural processes are forming soil as rapidly as it is eroded and actual net loss, if any, is imperceptible. Surface run-off is ordinarily negligible, and consequently what erosion there may be is limited to light or dissolved particles of organic matter and practically no mineral soil is removed. Where the forest and other vegetative cover is definitely scant, as under semi-arid conditions, there is still enough vegetation or debris to catch eroding soil and litter on slopes, retard run-off, and cause deposition of much of the eroded material already in motion. Even a light vegetative covering, if undisturbed, is sufficient to hold normal erosion to a negligible quantity. Vegetative cover is responsible for improvement of soil structure, protection of the surface soil from beating rains, and by intercepting runoff, reduction of the velocity and carrying power of the surface water. Lowdermild (17) points out that litter from forest cover alone will keep runoff from the surface nearly clear.

Type of soil:

Both surface erosion and deep gullying are considerable influenced by the type of soil, although a given soil type may not behave consistently under all conditions and no type of soil is entirely safe from erosion. Thus, sandy porous soils are in general least subject to gradual wearing-down by water action, since they are capable of absorbing a great amount of water in ordinary rains. On the other hand, if the rate of rainfall becomes so great they are fully saturated, or if percolation is prevented by frost, or by even thin strata of clay, the very lack of binding qualities in the sandy soils permits them to be moved at a very rapid rate. The coarseness of the material may cause it to be deposited before it has been carried any great distance.

Very heavy clay soils are more subject to gradual wearing down by water. However, in such soils the very strong cohesion between the particles offers great resistance to loosening. Given a clay soil saturated and softened by long exposure to water, as in the spring melting periods or after a long, drizzling rain, the surface layer may be expected to move off readily with surface runoff of any amount; yet it is surprising how thin a layer will be affected, since the deeper soil offers greater resistance.

It is apparent that the soils most likely to be erosed rapidly and steadily are in the intermediate class which the layman calls loams, a clayey-sand being perhaps the worst of all. These are sufficiently loose and porous to absorb and hold a large volume of water; at the same time they contain sufficient of the finer elements to make them easily plastic or semi-liquid. With support removed on one side, as in deep gullying, such soils become soggy with water and tend to slough off in great masses. This is particularly true of the loamy or clayey soils of wind-blown origin, because these soils tend, even when dry, to cleave in vertical lines rather than horizontal lines. Good loams are usually protected by a humus layer.

Disturbances of soil:

Any disturbance of the soil affects the erosion of that soil quite materially. Cultivation of soil for crops, building of road and trails, and logging all come under the head of disturbances of the soil. C. G. Bates (3) in a preliminary report upon the Wagon Wheel Gap experiment mentions the fact that although twenty percent of the area under consideration was burned over to destroy loppings and aspen, this could not be used as a cause of erosion as the burning showed no resultant increase of cutting or erosion. Had there been no road or skid trails there would have been no increased erosion, in his opinion.

Other authors consider fire as a very serious disturbing element of the soil and quite a significant factor in soil erosion, as shall be shown later in relation to litter.

FOREST COVER AND EROSION.

Forest cover in this paper will be considered as it is defined in the Copeland report of 1933. (26) It will include: (1) The trees and tall brush; (2)the herbs and shrubs growing thereunder or in openings in the forest or brush fields; (3) the litter, on the forest floor; and (4) the rich humus of partly decayed vegetable matter at the surface and in the top layer of the soil.

The effect of forest cover is not the most tangible thing in the world. Quantitatively the effect is very hard to measure, and, although it is known that forests have a favorable influence upon excess erosion, the exact figures are scarce and incomplete. The cumulative effect of the forest cover upon soil erosion can best be discussed by dividing into direct and indirect factors. The direct factors hold soil in themselves. The indirect factors influence soil erosion through the "back Door" or by influencing run-off.

The direct factors are:

1. Interception of precipitation.
2. Obstruction of surface flow by litter, roots, trunks, etc.
3. Absorption of rain and snow water by forest soil and litter.
4. Binding effect of roots upon forest soil.
5. Effect upon wind.

The indirect factors are:

1. Retardance of snow melting.
2. Effect upon stream flow.
3. Transpiration of water by the foliage.
4. Effect upon climate.

Direct Factors:

Interception of precipitation:

Precipitation intercepted by the forest is the greatest when the trees are in full leaf. A large number of experiments have been carried on in various parts of the world to determine the amount of water intercepted by the crowns of trees. The results obtained vary considerably with the character of the trees, their age, density of crown, the amount and severity of precipitation, velocity and direction of the wind, etc. Coniferous forests intercept more of the precipitation than deciduous forests as shown in table (a) from European observations. The amount intercepted is the least in a young stand and the greatest in a dense, middle-aged one. The following table (b) compiled from Swiss observations indicates the effect of the age of the stand on interception. (30)

(a) Rainfall which reached the ground in wellstocked woods, in per cent of total.

Stations	Beech woods	Spruce woods	Scotch pine woods	Larch woods
Prussian	76	78	73	
Bavarian	78	73	66	
Swiss	90	77		85

(b) Interception of Precipitation by tree crowns in beech stands of various ages.

	Age of stand			
	20 years	50 years	60 years	90 years

	Per cent	Per cent	Per cent	Per cent
Proportion which reached the ground	98	73	77	83
Proportion retained by the tree crowns	2	27	23	17

The amount of water retained by tree crowns is not much greater than that retained by a meadow of dense grass or cultivated plants at the time of their full development. Ney (30) estimates, on the basis of the average number and weight of beech leaves shed, that the aggregate foliage of a middle-aged beech forest on 1 acre would occupy 8.4 acres, and on the basis of the average yield of straw and hay, that the aggregate area occupied by the foliage of cereals would be 7.4 acres; of clover, 5.6 acres, and of meadow grass, 4.8 acres. Though cultivated plants present less surface per acre than do beech leaves, the latter offer more mechanical hindrances to the run-off of the water. It is very likely, therefore, that during the summer months cultivated field retain as much water as does a beech forest.

For the entire year, however, the tree tops intercept more water than field crops, which are present for only a few months. The foliage in deciduous forests, on the other hand, remains intact for six months, and in coniferous forests all the year around. In deciduous forests, even when the foliage is gone, the branches still prevent a portion of the precipitation from reaching the ground directly.

The interceptive influence of forests is much greater in light than in heavy rains. It is evident, therefore, that all the figures which show the interceptive affect of tree crowns have a value only for the place and time that the measurements were taken, and for this reason cannot be of general application. In regions where the precipitation is in the form of heavy or prolonged rains the ground under the forest, no matter whether the latter is deciduous or coniferous, will receive as much or nearly as much water as the bare ground, while in regions where the rains are neither heavy nor of long duration a large portion of the precipitation will remain in the crowns of the trees and not get to the soil at all.

Ney,(30, after deducting from the amount of precipitation retained by the tree crowns the amount of water which runs down the trunks and branches, computed the loss of precipitation for the whole year, through interception by the crowns, to average for beech forests, 15 per cent; for pine, 20 per cent; and for spruce, 33 1/3 per cent. Mathieu, at Nancy, on a basis of 11 years' observations, found that a forest of blue beech intercepts by its foliage and returns into the atmosphere on an average 8.48 per cent, and in winter only 5.85 per cent of the precipitation.

This effect is not entirely as effective as it sounds; That portion of the precipitation which is prevented from reaching the ground directly is not all lost to the forest. Its evaporation increases the relative humidity of the air, which, together with the lower temperature within the forest, results in the condensation, especially in a coniferous forest, of a great deal of moisture, in the form of fog, dew, and hoarfrost. Thus, though the forest, more than any other vegetable cover, intercepts atmospheric precipitation and prevents it from reaching the ground, the amount of precipitation thus lost is offset, except in dense, old stands of pure spruce, by the greater precipitation over the forest and the greater condensation of vapor within it in the form of dew, hoarfrost, etc. (30.

It is only in prolonging the time over which the precipitation reaches the ground, that the interception by tree crowns has any effect upon e rosion.

Evaporation from forest.

Evaporation from the forest soil is considerably less than that from soils in the open. It is also less from free water surface in the woods than it is from a similar surface in the open. Observations in Europe indicate that evaporation from a free water surface in the open is from $1\frac{1}{2}$ to $2\frac{1}{2}$ times as great as in the forest. (28)

The decreased evaporation from saturated soil and from free water surfaces in the forest is due to the following factors:

1. Lower wind velocity.
2. Decrease in the air and soil temperature.
3. Greater relative humidity.
4. The litter and other cover over the mineral soil.

Reduced evaporation from forest soils tends to aid erosion rather than to hinder it. It keeps the soil more nearly saturated and allows runoff to start just that much sooner.

Obstruction of surface flow:

The forest floor is penetrated by numbers of surface roots and the surface is covered by a tangle of litter, both of which offer many obstructions to the runoff and so permits the water to sink into the ground. Percolation is made still easier by the presence of deep channels in the soil, left by the decay of large roots.

The litter has more effect upon runoff than just obstructing it; that will be discussed later in the paper.

Forest litter.

In addition to the water actually absorbed by the leaf litter and so held there, there is a restraining influence which is all too often overlooked.(15) Thus while a heavy litter cover might actually absorb and so hold against capillarity an inch or more of water, the litter by means of its arrangement and its porosity holds much more water, under certain exceptional conditions probably several times as much. Hardwood leaves curl and cup, and water is so held and restrained from flowing away. The space between the bark and the wood of twigs and branches on the forest floor is often filled with water. The spaces between bundles of needles hold water for a considerable time. The litter becomes a veritable sponge and permits the soil to absorb water.

Newly fallen litter material is not as effective in restraining the flow of water over or through it as that which is partially decomposed. Hardwood leaves of many species are somewhat slick when they first drop and water does not wet them. Fresh needles are slightly resinous and water flows off as from an oiled surface. However, as decomposition takes place and water can enter the fibers, surface tension and cohesion help to hold water. In Europe, Huffel (15) found that a forest with leaf litter, after a rainfall of from 2.4 to 2.8 inches, did not give off, even on the steepest slopes, a drop of water in the form of surface run-off. He pointed out that, if water does run off from such stands it comes from the precipitation which falls on an area that is free from cover such as a road or trail.

Recent and as yet incomplete detailed investigations by the California Forest Experiment Station (18) indicate that the surface runoff from forest soils from which the litter has been removed, is from ten to thirty times greater than from soils with a complete and undisturbed mantle of forest litter. The reason for this rests with the litter. The litter prevents the beating drops of rain from so rearranging the soil particles that they clog up the pores in the soil and cement the channel openings. In other words, with a litter mulch the rain does not disturb the surface soil by its beating action, the water is kept clean at all times as the litter and raw humus strain out any pore-clogging material, and the water reaches the soil by percolation, rathan than directly, and in such a fashion that the water can be absorbed at a much greater rate than from a bare soil.

Mosier and Gustafson (21) say as follows: "The surface soil of a natural forest is usually covered with leaves and twigs, which protect it from erosion. It suffers little so long as this natural protection remains undisturbed. The raindrops do not usually strike the soil direct and thus destroy the granules, as they tend to do in cultivated fields. When this covering which nature provided is removed or destroyed erosion takes place."

The results of the California studies above referred to (18) indicate that the litter is perhaps the most important element of the forest in determining the distribution of rain into superficial runoff and into seepage. Still further do they show that the function of the forest litter to absorb water is insignificant in comparison with its function to maintain the percolation capacity of the soils. This operates to keep the water reaching the soil through seepage channels clear, even during the most intense beating storms, whereas the superficial rainoff on areas devoid of litter soon become muddy by picking up small particles in suspension, which were filtered out at the surface as the muddy water percolated into the soil.

In these experiments one set of plots was burned clean of its litter for each of three types of soil. In the experiments the superficial runoff from the burned surface was greater in every instance than from the litter covered surface. The differences in the Holland soil, a fine sandy loam were 3:1, in the Aiken, a sandy clay loam the differences were 9:1 and in the Altamont soils, a clay loam 16.5:1. Litter was more effective on the fine-textured soils than on the coars textured soils.

Contrary to expectation coarse textured Holland soil in bare conditions was not the most absorbent of rain. With this soil the average percentage of superficial runoff was 35, while on the Aiken it was 27 and on the Alamont 49. Under forest litter the absorptive capacities of the soils changed remarkably. Superficial runoff from both the Aiken and the Altamont approximated 3 per cent as against 13 per cent for the Holland --a ratio of 1 to 4. The forest litter continued to function for all durations of rain in approximately the same order.

Superficial runoff from burned surfaces was muddy while that from litter covered surfaces was clear. Difference in eroded material was far greater than in the runoff tests. The rate of erosion did not increase uniformly with the increase of total superficial runoff. The fine textured soils yielded the greatest amount of sediment.

To determine the effect of the percolation of both clear and muddy water through soil columns of otherwise uniform nature, a laboratory experiment was carried out. In this clear water was passed through four tubes of soil for 10 days to establish the relative characteristics of the material used. Thereupon muddy water was applied to two of the tubes, the water passing through the other two remaining clear. The percolation rate of the first two tubes dropped from a rate of 1,100 c.c. per hour to 500 c.c. in four hours, and then continuously in a parabolic curve to a percolation of 90 c.c. per hour. After another 10 days, muddy watter was applied to the last two tubes of soil through which the clear water had passed at a uniform rate, and the behavior of these soils was the same as that of the first two. The results were practically identical.

This experiment demonstrated the fact that muddy water percolates through sandy loam soil only at a fraction of the rate of clear water. Suspended particles are filtered out at the soil surface where they form layers of fine textured material which determines the rate of percolation capacity of the soil column. The formation of a fine textured layer at the surface of the bare soil as a result of filtering suspended particles from percolating water is, therefore concluded to be the decisive condition which increases the superficial runoff from bare areas. This fact indicates that the most important function of forest litter is to maintain the natural characteristics of a soil profile by keeping the rain water clear---a function which was for a long time overlooked, or if considered at all only with inadequate conception of its significance (18). It seems clear that with an undisturbed mantle of vegetation the percolation capacify of the soil remains at a maximum even in the extremely heavy and prolonged rains.

The superior physical condition and consequent permeability of forest soils has been demonstrated for Ohio Valley conditions by Auten (1). Samples of the upper 9 inches of soil under several oldgrowth stands in oak-hickory and other hardwood types were found to be 13 per cent lighter at oven dryness than equal volumes of soil from adjacent cultivated fields and a few pastures--indicating more pore space and better tilth. Although this difference in weight was later found to be confined to the upper 6 inches, the forest soil was still distinctly the more pervious to moisture at a depth of 8 inches. At a 3-inch depth 14 times as much water was absorbed per minute by the forest as the field soil, and at a 10-inch depth, over 50 times as much.

Auten (1) points out that the favorable affect of the forest on the soils he studied is not entirely due to the litter, but is increased by the roots, which upon their death decay and leave the soil interpenetrated with tube-like cavities; also by the activities of burrowing worms, insects, and animals, which make the soil porous. A litter cover promotes these activities. Lowdermilk reported that earthworms appeared under the litter during the second year of his comparison of runoff from bare and litter covered plots.

MacKinney (19) found that litter reduced the change from day to day in the maximum surface soil temperature 50 per cent in the autumn and 85 per cent in the spring. The minimum surface temperature and change from day to day was reduced 75 per cent in amount and in spread by litter. Litter raised the mean maximum and mean minimum surface soil temperature in the autumn and lowered it in the spring. The underground soil temperature was raised at all times by litter. Thus litter very materially delayed freezing of the soil, also kept it from freezing hard. The water from the winter rains and thaws penetrated the soil under litter, instead of running off as on the more compactly frozen bare soil. The depth of frost penetration was also diminished about forty per cent by litter cover.

Binding effect of roots.

I was unable to get any actual data which would give quantitatively the binding effect of roots upon the soil and the consequent discouraging effect upon erosion. However Forsling (10) mentioned the fact in his bulletin on the effect of herbaceous plant cover on surface runoff and soil erosion in relation to grazing, C. G. Bates and O. R. Zeasman (2) mentioned it in their bulletin "Soil Erosion--a local and national problem", E. A. Sherman (27)mentioned it in "The Protection Forests of the Mississippi River Watershed and Their Part in Flood Prevention", as well as did many others.

It is logical that a network of roots, grass, shrub,and tree would hold soil together tightly, grass is especially excellent in this matter; the roots are numerous, close to the surface and quite matted.

Effect upon wind.

Wind causes a great deal of erosion itself. Its effect is proportional to the density of vegetative cover and the looseness of the soil. Uncovered sand is a spectacular example of movement of material by wind. In places soil has been built up by the wind into deposits many feet deep- these deposits being called loess. In the forest wind erosion is practically unknown.

Indirect effects of forest upon erosion.

The retardance of snow melting:

A. J. Jaenicke and M. H. Foerster (16) studied some areas which lay within the Cocinnino National Forest on the Colorado Plateau, at the base of the San Francisco Mountains, the highest peak of which rises to an elevation of 12,794 feet above sea level. The plateau has an average elevation of from 6000 to 8000 feet above sea level, and is almost uniformly covered by Ponderosa Pine forest. The forested portion of the plateau below the Ponderosa pine type, from 6,500 to 5,000 feet is covered by 3 species of juniper, pinon pine, several species of oak and other hardwoods. On slopes above 8,500 feet the principal species are Douglas fir, white fir, corkbark fir, limber pine, bristle cone pine and Englemann spruce.

These men found no appreciable difference in the total snowfall on a forested area over a non-forested area. The slight variation in measurements was due to the difference in wind velocity and the temporary retention of snow on the tree crowns. The distribution of snow on the ground differed greatly on the forested area. The "park" snow lay in an even layer, while the forest snow was distributed in a shallow layer under the trees and in deep drifts in the openings. They found that the snow retained by the tree crowns and entirely lost by evaporation was small. During the winter the snow density in the park and forest was practically the same.

The rate of melting during the winter was greater in the forest than in the park due to higher minimum and mean temperatures, lighter disposition of snow under the tree crowns, and the radiation from trees, reproduction, rocks and logs. Because of this more rapid winter melting, the average depth of snow in the forest during winter is less than in the park. Spring thaws cause rapid melting of the park snow, while the rate of melting in the forest snow is but slightly accelerated. The park is stripped of its snow cover within a few days, which may result in flooding while heavy drifts of snow persist throughout adjacent forest areas for 2 weeks or more after the total disappearance of the park snow. On account of the very open character of the Ponderosa forest it is not nearly as efficient as a snow conserver as more dense forests with smaller openings between tree groups.

At the time of spring thaws the soil in the park was frozen to a considerable depth and was covered by an ice layer which prevented thawing. Therefore, when the park snow melted during the spring thaws, the surface run-off was excessive, and the absorption of the soil moisture by the park soil was comparatively small. In the forest the snow disappeared more gradually, the soil was almost entirely thawed out, and therefore the snow waters became seepage water instead of run-off. The forest soil, aside from absorbing more moisture, retained it better than the park soil due to the protection from evaporation by decreased wind movement, shade, and leaf litter.

W. R. Mattoon (20) found essentially the same conditions present in his study with a Ponderosa pine forest.

Dr. J. E. Church Jr. (6) did a good deal of snow work in the Sierras of California. At an eleavation of 5,500 feet he found that a reforested area thickly covered with young pines had in March of one year, 13 inches of snow, the equivalent of five inches of water. A deforested area dotted with manzanita and snow brush at the same altitude had five inches of snow, or two inches of water. A typical sage brush area of the same elevation had one and one half inches of snow or one half inch of water. The reforested area had twice as much snow and water as that that had been deforested and nine times as much as that covered by sagebrush.

An open forest of pine and cedar had in January 47 inches of snow and by the end of April had one-half inch of snow. A dense fir forest had forty inches on the earlier date and eight inches on the latter.

A. A. Griffin (14) reports the results of studies conducted in the Cascades of Oregon and Washington. There were stations established in central Oregon at Tumalo, in Southwestern Washington at Wind River, and in the Yakima area of Washington. Griffin found that one unusual factor in delaying the melting within the Douglas fir type of forest was the protection given by the irregular layer of even very slight bits of moss, twigs, bark, and other litter weathered from the trees. Fragments like those would materially hasten melting in the open by absorbing solar heat; in the forest they serve as a crude but effective insulation from the warmer air currents above the snow. In a more open forest this effect is less prominent.

The retarding effect of the forest upon snow melting is shown in the following two tables taken from the article by Griffin.

Table I. The water equivalent of mean depths of snow retained by the forested stations when the corresponding open stations became bare and for three weeks thereafter, expressed in inches and in per cent of the maximum snow cover.

Study	Maximum Water Equivalent	Weeks after open stations became bare.							
		0		1		2		3	
	Inches	In.	%	In.	%	In.	%	In.	%
Tumalo 1916	47.0	8.1	18	6.0	12	2.1	4		
Tumalo 1917	44.0	5.2	1	0.1					
Wind River 1916	25.8	13.5	52	9.5	37	8.0	31	5.3	21
Wind River 1917	7.6	3.0	40	0.6	8				
Yakima 1917	24.6	6.9	28	3.2	12	1.6	7	0.3	1
Mean	29.8	7.5	30	3.9	14	2.3	9	1.1	4

Table II. The depth of snow conserved by the stations grouped according to forest cover.

Stations	Average forest density	Snow conserved Inches	Weeks.
1,9 Open	0.00	0.00	0.6
2,3,4 Forest.	0.49	4.4	2.0
5,6,7 Forest.	0.60	21.5	3.3
1,9,10 Forest.	0.77	27.8	4.0

Transpiration of water by foliage.

A large part of the water absorbed by vegetation is taken from the soil, enters the transpiration current and is returned to the air through the leaves. The loss of moisture from the ground through transpiration is very large in well wooded regions and nothing on barren soil. Experiments have been conducted in order to get a quantitative measure of the loss for various plants and conditions, but as yet there is very little dependable information (28). Of the experiments carried on upon the amount transpired by forest trees those of Wollny, Hohnel, and Buhler are the most valuable, since they were carried on for long periods of years and with utmost care.

Zon (30) in his Bulletin lists the results of Hohnel's experiments in the following table.

Table Amount of water transpired by different forest trees per pound of dry-leaf substance.

Tree	1878 Pounds.	1879 Pounds.	1880 Pounds.
Birch	679.87	845.13	918.00
Ash	566.89	983.05	1,018.50
Hornbeam	562.51	759.01	871.70
Beech	472.46	859.50	913.80
Maple (Spitzahorn)	462.87	517.22	611.80
Maple (Bergahorn)	435.77	618.30	703.80
Elm	407.31	755.00	822.80
Oak	283.45	622.21	691.50
Oak (Zerreiche)	253.33	614.22	492.20
Spruce	58.47	206.36	140.20
Scotch pine	58.02	103.72	121.05
Fir	44.02	77.54	93.80
Austrian pine	32.07	99.92	70.05

Thus, during the vegetative period, birch and ash trees transpire for every pound of dried-out leave from 567 to 1,019 pounds of water--more than do any other forest trees; beechs and maples from 436 to 914 pounds; oaks from 253 to 692 pounds; and conifers, which transpire least, from 32 to 206 pounds. The difference in the amount of transpiration in the different years is explained by the fact that the years 1879 and 1880 had more rain and therefore more water penetrated the soil.

Hohnel (30) estimates that a fully stocked beech stand, 115 years old, consumes from 1,560 to 2,140 tons of water per acre, or 1.15 acre-feet per year. The last means that if the water were spread over an acre it would have a depth of 1.15 feet. If an acre contains 526 trees from 50 to 60 years old, the water consumption is only 1,026 tons per acre, or 0.70 acre-foot; and if it contains 1,620 trees, only 35 years old, the consumption is as low as 321.5 tons per acre or 0.23 acre-foot. Hohnel expressed the quantities of water that were transpired in 1880 in per cent of the precipitation of that year. He found that elm transpired 43½ per cent, beech 25 per cent, and birch 40 per cent of the precipitation. In 1878 and 1879 the per cent of transpiration was smaller.

Wollny (30) in observations carried on for six years, determined the amount of water transpired by different species of trees in pots, containing identical amounts and kinds of soil, by measuring the amounts of water which percolated through the pots. He found that spruce transpires, on an average, during the year 34.9 percent of the annual precipitation and birch 24.8 per cent; but that during the vegetative period the amount transpired by the two species is almost the same, spruce 33 per cent and birch 32.1 per cent.

Ney's (28) computations show that the total amount of water transpired by a fully stocked beech forest during the growing season is equivalent to 10.8 inches, spruce 3.3 inches and Scotch pine 2.9 over the entire area.

Although evaporation from the soil is much less in the forest, the loss from evaporation and transpiration combined may be and usually is much greater than from denuded areas. (28)

As may readily be realized, the demand of forests for water, as well as the amount used by them, is greater in the earlier part of the growing season than later, and the draft upon the soil water is heaviest in the early spring. Thus, even before leafing actually takes place, roots are active and much water is being taken into the tree.

Investigations in Vermont (15) show that, although there is practically no transpiration from the maple during the winter, the tree accumulates much water during the winter and early spring period. In December the water content of the trees studied was 31.5 per cent and by the middle of March 26.5 per cent based on the dry weight of the wood. In the latter part of April the maples were found to carry 47 per cent moisture. This was reduced to 26 per cent in the summer season. The average water content of sugar maple during the period when the trees are tapped was 32 per cent, while at the same time in other trees, including ash, beech, birch, butternut, elm and hornbeam, the water content was from 41 to 56 per cent.

All this was before the buds opened.

It is estimated that the forests of the Mississippi River drainage use at least 8 inches of the precipitation annually received. Since at least 25 per cent of the total water transpired by the forests is absorbed by them during the flood period, therefore they should remove at least 2 inches of water when the flood conditions are most severe and in need of aid. (15)

It should also be remembered that the conifers transpire throughout the year, rather than through the usual growing months.

Effect upon streamflow and floods.

Forests conserve snow and reduce evaporation of soil moisture and at the same time interrupt precipitation and transpire water drawn from the soil; their final effect on runoff can only be determined by the balance between these opposing influences. Whether this net effect is beneficial or harmful in any particular region is probably determined in part by the total amount of precipitation, but chiefly by the occurrence of precipitation as snow or rain, its distribution throughout the year or during only a part of it, and its arrival in light or heavy storms. American research to date, backed by a large body of observational evidence from all parts of the United States, justifies a strong belief that the forests of the country practically always benefit stream flow. (26)

Humus and litter varies in effect buth quantitatively and qualitatively, according to type, location and use. Under ordinary rainfall conditions this humus and litter is capable of absorbing and holding a considerable quantity of water for evaporation, percolation, or transpiration. The amount of moisture thus actually absorbed varies; but a quarter of an inch in depth of rainfall for each inch of depth of humus of leaf litter is known to be concervative. (15) While moisture is being absorbed by the mat of humus, the forest crown cover and forest litter also hold back or retard the run-off of water not actually absorbed.

During an extended period of rainfall the quantity of water diverted from run-off by being absorbed by the mat of humus is materially aided by the evaporation, percolation, and transpiration taking place during the same period. In addition the forest operated much like a check dam through retarding run-off by mechanical obstruction.

Forest cover breaks the force of precipitation.

Structure of forest soil has been developed through long periods of time. Root penetration, expansion and contraction with changes in temperature and moisture content, and activities of worms, insects, and animals, tend to make soil porous. The forest is a builder and a preserver of soil porosity. The penetration of roots and their eventual decay leave the soil interpenetrated with tubelike cavities. Litter keeps the percolation efficiency of forest soil effective in spite of length of rain fall. J. T. Auten (10)

Forests reduce the eroding and transporting power of water by reducing the rapidity of run-off. In addition they are a direct physical obstacle to erosion because they have large, strong, well-anchored roots which hold soil, subsoil, and rocks firmly in place. This factor of erosion is quite important in flood control work. The sediment carried by the rivers and the coarser detritus brought down by mountain streams often increase stream volume to such an extent that the height of the water is raised far beyond the point it would reach if it came free of detritus and sediment. When the channel of a stream has become filled with waste material even a slight rainfall will cause a flood, while, if the channel were deep, it would have no measurable effect upon the height of water in the stream. The filling of mountain streams with waste not only increases the frequency of floods but caused the streams to assume the character of torrents. A channel filled entirely or partially with foreign material cannot hold large quantities of water, while the denuded slopes deliver the storm water almost as fast as it falls. (30)

How great may be the volume of detritus carried by a given volume of water is shown by Demontzey (30) who computed that one mountain torrent brought down in 85,020 cubic yards of water 221,052 cubic years of detritus, or more than two and a half times its own volume.

L. C. Glenn (30) ascribes the change in regimen of many of the mountain streams in the southern Appalachian to the denudations of the steep mountain slopes and the consequent erosion. He finds conclusive evidence of increased erosion, the result of clearing on the mountain stream basins since 1885, in the character of the flood-plain deposits within recent years. When floods are small or gentle the flood-plain deposits consist of fine alluvium. When the floods are great and violent the deposits consist of coarse sand, cobbles and boulders.

Not only does the presence of sand and gravel and mud in the water increase the volume of the flood and raise its height, but in addition such abrasive material furnishes teeth to the freshet and enables it to tear up the earth, wear away embankments, and carry off accumulation of soil and other material otherwise safe from the ordinary attacks of flood waters. Erosion fattens as it feeds.

The flood problem is measured by the volume of runoff. Only a part of the total precipitation on any watershed ever appears as runoff. Necessarily, that part of precipitation which passes into the atmosphere, either by evaporation or transpiration, cannot appear in stream-flow measurements without again being deposited in some form of precipitation. On the other hand, that part which passes into the soil as percolation must eventually appear as runoff unless evaporated or taken up in plant growth. If the value of forests as stream-flow regulators and flood-preventive factors were determined by the ratio of their water-storage capacity to the total annual precipitation, such value would be relatively quite small. However, such a comparison does not give a rational basis of measurement. Floods are created only by actual run-off. Therefore the ratio of storage to run-off is a better index of flood prevention service. The importance of this item can be illustrated by the fact that of the total precipitation falling annually on the 511,636 square miles of the Missouri River watershed only 10 to 15 per cent ever reaches the Mississippi.

The other 85 or 90 per cent is transmitted to the atmosphere by transpiration or evaporation, minus such minor quantities as may possibly be retained by some chemical process or combination. (15) It is the remaining percentage which appears as runoff that contributes to the flood problem, and it is this remnant of the total for each watershed that may be in part regulated or controlled by well-managed protection forests.

The effect upon Climate. (30)

Accurate observations, continued for many years in different parts of the world, establish with certainty the following facts in regard to the influence of forests upon climate:

The forest lowers the temperature of the air inside and above it. The vertical influence of forest upon temperature extends in some cases to a height of 5,000 feet.

Forests increase both the abundance and frequency of local precipitation over the areas they occupy, the excess of precipitation, as compared with that over adjoining unforested areas, amounting in some cases to more than 25 per cent.

The influence of mountains upon precipitation is increased by the presence of forests. The influence of forests upon local precipitation is more marked in the mountains than in the plains.

Forests in broad continental valleys enrich with moisture the prevailing air currents that pass over them, and thus enable larger quantities of moisture to penetrate into the interior of the continent. The destruction of such forests, especially if followed by weak, herbaceous vegetation or complete baring of the ground, affects the climate, not necessarily of the locality where the forests are destroyed, but of the drier regions into which the air currents flow.

While the influence of mountain forest upon local precipitation is greater than that of forests in level countries, their effect upon the humidity of the region lying in the lee of them is not very great.

Forests in the above cases would tend to increase the erosion where the added moisture was not utilized in increasing the mat of vegetation on the ground, as increased runoff tends to increase the erosion.

Effect of Forest as a unit upon run-off and erosion.

In practical life and situations it is not the litter that does all the work in reducing runoff and erosion,nor it it the transpirational effect, or the retardance of snow melting; it is the forest as a unit.

Bates (3) say as a result of the Wagon Wheel Gap, experiment that the measurable detritus carried by the stream in question after the forested headwaters had been denuded increased 25% in amount. Most of this increase was secured during the flood quarter.

In another, the final report (4) he lists the effect of denudation upon run-off and erosion. In prenudation years the average annual precipitation on Watershed A (the one that was undisturbed) was 21.03 inches; the average run-off of A was 6.08 inches and that of B (the watershed that was denuded) 6.18 inches. In the post denudation period the average precipitation was 21.16 inches, and the flow of A 6.20 and B. 7.26. These figures indicate an excess flow from B of about 0.96 inches for the average of seven post dedudation years. During the prenudation period the average annual silt load of A was 691.5 pounds and that of B was 568.5 pounds. In the second period the silt load of A was 477 pounds and that of B 3,340.1 pounds. The ratio of B to A increased from 0.822 to 7.082, or about 8½ times.

Ramser (23) studied the runoff from small agricultural areas with various percentages of timber cover. He found that timber has a decided influence upon reducing the rate of runoff from a watershed, as is shown in the following table.

Effect of timber on runoff coefficients for watersheds 1 and 4 (watershed 1 with 14% timber cover and 4 with 38.9%).

Date of Rain, 1918	Ave. rate of rain fall during time of concentration		Coefficient of runoff (ration of maximum rate of runoff to average rate of rainfall		Rainfall prior to period taken as time of concentration.	
	Watershed		Watershed		Watershed	
	1	4	1	4	1	4
	In. per hour					
Feb. 19	2.4	1.89	0.40	0.22	0.39	0.37
Apr. 16	3.84	2.92	0.33	0.29	1.21	1.19
Apr. 28	4.44	3.77	0.41	0.25	0.09	0.09
May 27	3.60	3.51	0.38	0.28	0.18	0.18
May 12	1.92	1.89	0.41	0.30	0.10	0.10
May 23	3.12	2.83	0.49	0.38	0.38	0.38
June 1	3.24	3.00	0.36	0.28	0.46	0.38
June 6	2.28	2.14	0.42	0.28	0.72	0.69
July 18	4.20	3.51	0.51	0.46	0.76	0.71

Glenn (13) states that streams from forest clad slopes are only slightly discolored in flood time, and that this discoloration is due largely to macerated leaf fragments and decaying organic matter and only to a very slight extent to soil particles held in suspension.

In the United States (30) the effect of destruction of forest cover upon erosion is most impressively shown by the conditions prevailing in the Ducktown copper region, Tennessee. Smelters started about 16 years ago near Ducktown have killed, by sulphuric fumes, all vegetation in their immediate vicinity. The slopes are now bare and are being rapidly eroded. On Potato creek this eroded material is accumulating at the rate of a foot or more each year and has buried telephone poles almost to their cross arms. On Ocee River each flood deposits large quantities of sand and periodically dams the river. The country for several miles has become a barren waste.

Meginnis (22) mentions the results of studies by the Southern Forest Experiment Station of the United States Forest Service. For a flood period, Dec. 15 to Feb. 15, it was found that an average of 62% of all the rain falling on cultivated land immediately rushed off the surface, carrying with it soil totaling 34 tons an acre. An average of 54% of all the rain falling on barren, abandoned fields flowed off immediately. During many rains more than 75% and as much as 95 % of the rainfall ran off these two classes of land and contributed to the quick filling of stream channels. In contrast, an average of 98 per cent of the rain falling on scrub oak woodland was absorbed, only 2% running off. On unburned broomsedge field and virgin oak forest an average of less than one-half of one per cent of the rain flowed off the surface.

The results of the runoff studies are fully in accord with those of less formal observation of surface runoff from various land types in northern Mississippi. A single shower of even moderate intensity is usually sufficient to start a rush of soil-laden waters from every gully and cultivated field, while the most torrential rains are seldom seen to produce more than an insignificant surface flow from areas protected by a vegetative cover. The runoff from woodland ravines is usually insufficient to sweep leaf litter and other debris from the drainage lines. A high runoff ratio for the uplands of north Mississippi is indicated by the fact that many of the sand-choked streams which are characteristic of the region rise overnight following a heavy rain and then subside to a minimum flow within a few days.

Toumey (29) cites an example of experiments in the San Bernardino Mts. from which the following table was compiled.

Precipitation and run-off during December,1899.

Area of Catchment Basin.	Condition as to Cover.	Precipitation.	Runoff per sq. mi.	Runoff in percentage of precipitation.
Sq. miles		Inches	Acre-feet	Per cent
0.70	Forested	19	26	3
1.05	Forested	19	73	6
1.47	Forested	19	70	6
.53	Nonforested	13	312	40

CONCLUSION

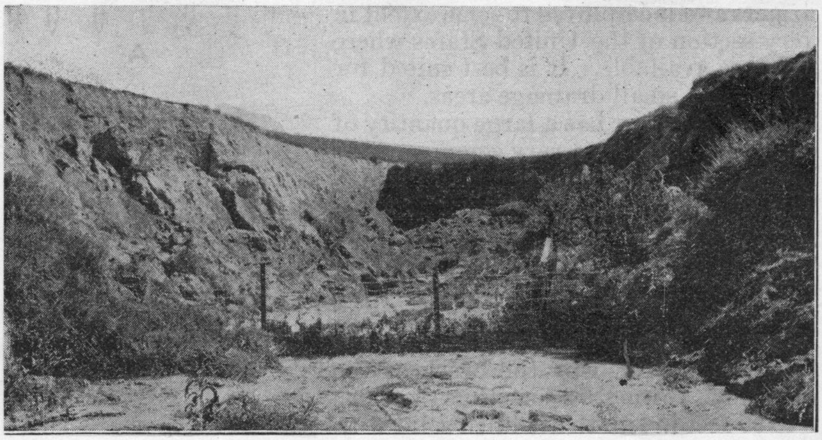
The fact that forests have a marked effect upon erosion is not to be questioned. They hold soil directly by intercepting precipitation; obstructing surface flow by means of litter, roots, trunks, etc; making litter which absorbs large amounts of water and allows forest soils to absorb water in greater quantities than do open soils; binding the soil with roots; and retarding the wind. Forests affect erosion indirectly by influencing runoff; by retarding snow melting; regulating stream flow; transpiring water through the foliage; and affecting climate.

Anything that disturbs forest cover adds to the erosion problem of that area. Fire is the most wide-spread and one of the most destructive disturbances of the forest cover. Even the lightest fire does damage. During the first few years after logging, a sloping clear cut or severely cut area will unquestionably erode somewhat. The skid trails produced by power handling of logs have been found to start erosion. Overgrazing disturbs the forest cover chiefly by consuming more of the herbage of the more palatable plants than they can withstand, and by increased trampling. Studies by the Forest Service show that there are many areas now producing not more than 20 to 30 per cent of the forage of which they once were capable, and under such conditions erosion is usually severe.

It is not claimed that forests will solve the erosion problem completely. The forest must be aided by engineering works: terracing, temporary dams at heads of gullies and also at the mouths, and permanent dams for water storage and catching silt. Using forestry and engineering with intelligence, each aiding the other the erosion problem can be greatly alleviated.

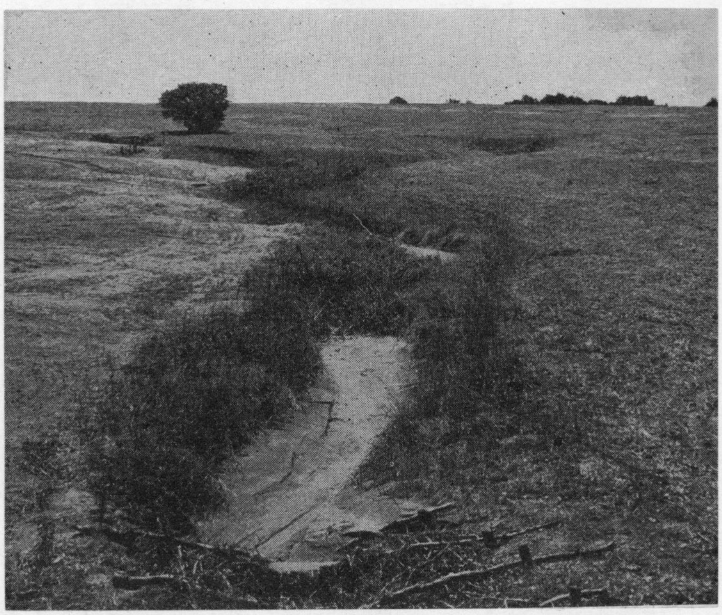
Engineering Means of Checking Gullying

Wire



Logs & Brush

Brush



U.S.D.A. Farmers' Bull. 1234

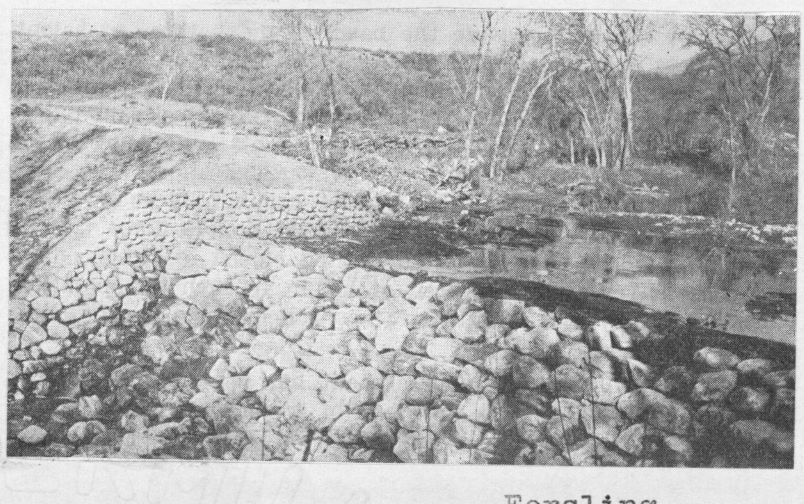
Log Dams

U.S.D.A. Farmers' Bull. 1234

Stone Dam

Forsling

Stone Dam



Forsling

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