Soil Erosion

IN WATERSHED PROTECTION

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Preservation of satisfactory watershed conditions on range lands is vital to the well-being of the West and therefore is of concern to the entire Nation. Most towns and villages, many cities such as Los Angeles, Salt Lake City, and Denver, and innumerable ranches and farms rely on a usable and adequate supply of water produced wholly or in part on range-land watersheds. Irrigation enterprises representing investments of nearly 6 billion dollars depend on a stable soil mantle and stream flow from water-yielding ranges. Water power and recreation for multitudes of people are sustained in many cases by stream flow from range watersheds. A large population is dependent on the soil of range lands to produce forage upon which the 2-billion-dollar grazing industry and its source of income are based.

The range watershed situation presents three aspects: Eighty-five percent of the flow of important western streams comes from about 232 million acres, of which 79 percent is range lands. Silt is being borne down into these streams from erosion on approximately 352 million acres, practically all of which is grazed. Finally, much of the remainder of western range lands, such as those in the Great Basin and Great Plains, is eroding so seriously that it is imperiling productive capacity of the land, even though none of this eroded material is contributing to larger streams.

All this points clearly to the great importance of constantly maintaining an unbroken and productive soil mantle on all range land and the maximum yield of water from range watersheds; yet little thought has been given to the conservation of these values on other than the national forests and some municipally owned areas. Depletion of vegetation, as shown previously, has been the rule for the most part under other types of ownership or control, and with it have come floods and erosion menacing the social and economic security of the entire region. The destruction of soil and impairment of watershed values is without doubt one of the gravest results from misuse of the range.

Watersheds of the Virgin Range

The nature of the vegetation and soil mantle that clothed the watersheds of the virgin range, the normal course of stream flow, and the characteristics of natural erosion can be estimated from the testimony of present conditions on well-managed national forests and protected municipal watersheds, from such vestiges of primitive areas as have thus far escaped depletion, and to some extent from geologic evidence. Here may be seen how, during past centuries, soils were safeguarded against excessive erosion and leaching by the binding power of plant roots which filled the surface and subsurface layers and by the physical protection which the plant cover and organic mulch provided. As rains fell on the area, the full impact was broken by the aerial parts of the vegetation, thereby preventing compacting of the soil surface. On the virgin range dead plants and herbage formed a ground litter, and eventually mixed year after year with the mineral soil and produced a loose, porous earth mantle which absorbed and retained against evaporation the maximum quantity of water from rain and melting snow. The channels formed by plant roots facilitated percolation. As the surface water ran off its velocity was reduced by plant and litter obstructions which checked and broke up the flow. Forest and shrub litter prevented direct access to the soil by water flowing off slopes, and a similar effect though not so complete in semiarid areas resulted from litter of herbaceous plants, hence run-off water was clear or almost so. The water absorbed by the topsoil percolated through the lower soil depths and rock crevices to issue forth later as springs. These maintain the flow of rivers and streams that have made possible irrigation agriculture, electricity for industry, and municipal water supplies.

In that stable and porous soil mantle the young nation pioneering its way into the West had a priceless resource of which it was then and for many decades thereafter unaware. It was a resource built up by the age-old process of soil building and normal erosion, which progresses with the slowness of geologic time, and has throughout millenniums sculptured and molded the face of the earth. The soil of the mountain slopes and the alluvium of the valley floors have been produced in this way—even the rocks of which most mountains are composed have been formed of sediments which are products of older periods of erosion and deposition. The principal method of transportation of the weathered material from the slopes was by natural gravity creep rather than by stripping and gullying by water—the creep of the soil being rarely rapid enough to disturb plant populations or modify their general aspect. Surface run-off carried a minimum of silt, destructive floods were unknown on many areas and uncommon on most others, and streams were generally clear, receiving what silt load they carried from the bottom of channels rather than from the vegetated slopes and protected stream banks.

Ordinarily erosion progressed so slowly that soil was formed or accumulated slightly more rapidly than it was removed. Only under unusual conditions, as in Bryce Canyon, Utah, on certain Mancos shale areas in Colorado and Utah, on the Chinle bad lands of Arizona, and in the Breaks of the Missouri River, have adverse climatic and geologic conditions prevented the fixing of the land surfaces by soil formation and plant growth. In these relatively few instances, run-off has been rapid and normal erosion pronounced, giving rise to muddy streams whose flow fluctuated greatly.

Elsewhere soil and vegetative cover were sustained by virtue of a delicate balance between the constructive and destructive forces. On the one hand the weathering of rock and plant succession built up the soil mantle, and the vegetation that blanketed it served to hold it in place; on the other hand, the destructive forces of a rigorous and variable climate and of steep slopes operated against this accumulation and stabilization. Vegetation was invariably the deciding factor in the balance. The presence of a natural plant cover enabled the constructive forces to hold sway and to preserve watershed values.

The Flood and Erosion Menace of Recent Years

When the white man's herds of cattle and sheep multiplied beyond the capacity of the range to carry them properly, depletion of vegetation upset this natural balance and the utility of the virgin watersheds became impaired. As overgrazing and fire reduced the density of the

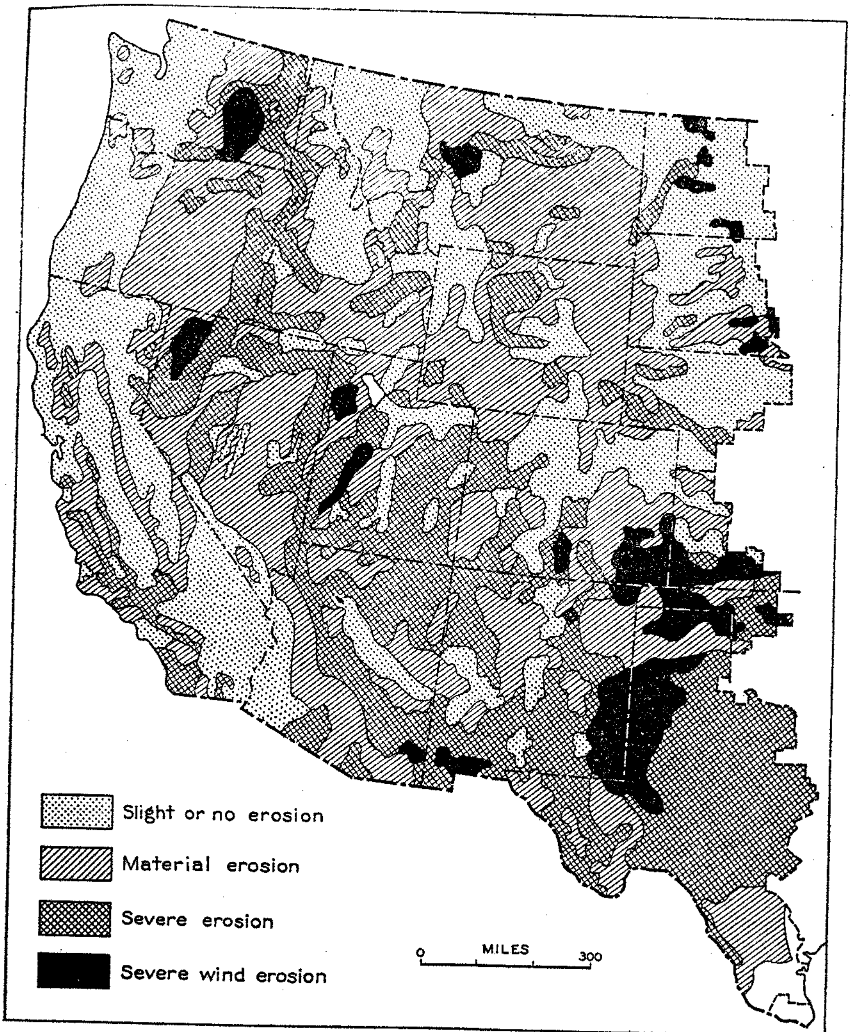

FIGURE 65.—CHARACTER AND EXTENT OF EROSION ON WESTERN RANGE LANDS.

As a result of range depletion, accelerated erosion is fast removing incredible quantities of soil from large areas, resulting in the devastation of range and agricultural lands and serious silting of irrigation improvements. In this process, the fertile topsoil on which the range depends is the first to go.

range cover, and as the litter and humus layers were broken through, the devastating forces of soil erosion were greatly accelerated (fig. 65) and unretarded run-off seriously modified the natural stream flow and caused many floods.

Causes of Accelerated Erosion and Floods

That the present serious problem of floods and erosion on the western watersheds is the result of past misuse of range lands is substantiated by extensive evidence of the part played by various contributing factors. Of these the most prominent are the physical factors of climate, soil, and topography and the biological factors of vegetation and organic matter in and on the soil.

CLIMATE

Climate exerts its influence directly on erosion and floods through the amount, kind, and intensity of precipitation and indirectly through its effect on vegetation and soil. Even this direct effect has many ramifications, however, when it is considered that although the West is essentially arid, and some areas in the lower deserts receive as little as 3 to 4 inches of rainfall annually, other areas in the higher mountains receive as much as 60 inches. The kind and intensity of precipitation vary greatly also. At the lower elevations precipitation falls largely as rain, and in many places in storms of sufficiently great intensity to result in rapid accumulations of water having great erosive force. Because of the naturally scant protective cover of vegetation in the arid and semiarid portions, rains relatively light in character as compared to those in more humid areas may run off so readily and develop into such violent floods that they are classed as torrential. In the mountain areas a large proportion of the annual fall comes as snow, which is released as free water only during the spring and early summer. Rains that fall on steep mountain slopes may be intense, greatly increasing the danger of erosion on any soil not bound in place or otherwise inadequately protected by plants; or they may be moderate, causing severe erosion only where plant depletion is most serious and topography steepest.

Hard rains falling on denuded land, whether in the desert regions or in the mountains, result in rapid accumulations of water that inevitably cause the gullying of slopes and trenching of valleys. If there are depleted range areas in the West today on which erosion is only slight or moderate, it is principally because rainfall there is uniformly low in intensity, slope is negligible, or the soil is unusually porous.

The indirect relation of climate to accelerated erosion and floods is exerted through the effect of drought, high temperature, wind, and high rates of evaporation on vegetation and soil. Undoubtedly drought, particularly protracted drought, has contributed greatly to the decline of the watershed value of certain areas by killing off some of the plants or limiting their growth and reducing their density. The death or diminished growth of the plant means, in turn, a general depletion of the plant cover and less physical protection to the soil. During droughts, the physical properties of the soil are modified by excessive drying, its power of cohesion is lessened, and it becomes more susceptible to the forces of wind and water. The stage is thus set for destructive erosion.

High temperatures and winds, causing excessive evaporation, act on the plants and soil in exactly the same manner as drought. Regardless of how much precipitation occurs, it is of no value as a source of water for plants or for stream flow if it evaporates almost as rapidly as it falls. These various forms of the action of climate on the soil and vegetation mantle are serious enough when soil and topography also favor erosion and flooding, but their effects are most pronounced when the plant cover has been depleted by overgrazing and fire.

SOILS

The inherent nature of the soil plays an important role in determining the rate of erosion and the percent of the total precipitation which runs off the surface of any area. Some soils, deficient in plant nutrients, are capable of supporting only a sparse cover of vegetation which influences their absorptive powers but little and affords them a minimum of physical protection against erosion. The relative erosibility of different soils is greatly influenced by such physical properties as their imperviousness to water and their water-holding capacity. The Mancos shales of certain parts of the West, for example, produce soils that are highly impervious, permitting rapid run-off of a large part of the precipitation and a consequent rapid natural erosion. In contrast, soils from the Wasatch conglomerate naturally absorb water readily, permit less run-off, and consequently are not easily eroded. All soils, however, regardless of their inherent nature and the parent rock from which they are derived, absorb precipitation most readily and are subject to a minimum of erosion when they are well clothed with vegetation.

TOPOGRAPHY

Topography of a watershed is a significant factor in determining the extent of erosion and character of run-off. Steepness of slope naturally influences velocity of run-off; and since the transporting power of water increases as the fourth to sixth power of its velocity, it is evident that soil movement would be greater on steeper slopes, other factors being equal. This in turn increases its cutting power. Increased velocity means also that the flowing water passes over the surface more rapidly, thus allowing less time for absorption and penetration. Gravity creep of certain soils on steep slopes, pendent of the influence of water, is noticeable in som indicating that the natural balance which is so stability hangs very precariously.

The topographic influence expresses of the action of general and local is less likely to suffer wind erosi winds can be generated and blo The action of high temperatures an to the sun's rays, as is evident in and soil mantle on the north and mountains.

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Nearly all the effects of topography, however, as in the case of climate or soil, are greatly modified by the plant growth. Under any but extreme conditions of climate, soil, and topography this vegetation mantle is the critical factor of the watershed. Even on slopes steeper than the angle of repose, soils are built up under it. Furthermore, vegetation is the one factor that man can control. Thus the major interest in analyzing the causes of accelerated run-off and erosion centers on the part played by the plant cover.

VEGETATION

On the nonforested arid and semiarid range lands of the West herbaceous and shrubby plants form the vegetation which furnishes protection to the watersheds. Even on forest lands, and especially those open forest types which are suitable for grazing, the herbaceous and shrubby plant growth materially supplements the value of the timber growth and its litter in affording adequate watershed protection. This is especially true in the open orchard-like stands of the piñon-juniper type, where only a small proportion of the soil is directly protected by tree growth. As in forests (*8*, *86*), it is not the areal growth alone which is of value. The total plant cover, the root system, the litter, and the humic horizon of the upper layers of the soil composed chiefly of decaying organic matter, all make up the range cover of value in the protection of watersheds. In the main, the vegetation present under virgin conditions represents the type developed by natural forces best adapted to the specific climatic, soil, and other conditions of the particular site.

It has been rather generally recognized for a number of years that the protective cover on range lands has a marked effect in controlling soil erosion and abnormal run-off. Where overgrazing and fire have been rampant, serious consequences were observed; and where some degree of protection has been afforded, favorable watershed conditions have prevailed. Restoration of the plant cover on denuded areas has indicated also its beneficial effect. For example, Manti canyon in Utah (*108*), which was overgrazed badly beginning in the late 70's, produced a number of serious floods between 1888 and 1902. In 1903 this area was included within the Manti National Forest and, after 5 years of complete protection followed by regulated grazing, the range cover has been greatly improved, accelerated erosion halted, and all flooding of any consequence stopped.

The general outcome of the many observations on the relation of range cover to conservation of the watershed resource was, however, one of confusion, as shown by the differences in concepts held by some geologists, engineers, ecologists, and foresters. It became apparent that the role of vegetation had to be ascertained quantitatively by detailed investigation. Research on this subject was accordingly undertaken and, though a vast amount of detailed work still remains to be done, certain general concepts have already been developed and proved.

EFFECT OF DENSITY OF VEGETATION

The first of these investigations (*51*) of any consequence on western range land was instituted by the Forest Service on the Wasatch Plateau, near Ephraim, Utah, in 1912, where a study was made of the run-off and erosion from two grazing areas of about 10 acres each, fairly similar except for the cover of vegetation. Area A had an original plant density of 16 percent and Area B a density of 40 percent. Both areas were grazed and for the 6 years, 1915 to 1920, the cover was maintained at the original densities. During the period 1921 to 1923 Area A was allowed to revegetate until its density approximately equaled that of Area B. From 1924 to 1929 both areas were grazed and maintained at equal densities. The results from summer rains are given in table 55.

TABLE 55.—*The influence of vegetation change on run-off percent and sediment removed during summer precipitation period from two test areas on the Wasatch Plateau*

Values per acre for watershed A			Values per acre for watershed B			A/B ratios	
Plant density [1]	Surface run-off [2]	Sediment	Plant density [1]	Surface run-off [2]	Sediment	Run-off percent [2]	Sediment
Percent	*Percent*	*Cubic feet*	*Percent*	*Percent*	*Cubic feet*	*Ratio*	*Ratio*
16	10.33	133.8	40	2.52	24.7	4.10	5.42
16 to 40	8.74	105.0	40	3.03	37.3	2.88	2.82
40	5.49	19.2	40	5.23	7.7	1.05	2.48

[1] Plant density as here used is the percentage of total soil that is covered by the total spread of the plant growth.
[2] Percentages are based on effective precipitation.

With area A in a depleted condition the run-off percent and sediment removed were approximately 4.1 and 5.4 times that from area B. As the plant cover was gradually restored on the former, these differences diminished until the ratios for run-off percent and sediment were only 2.9 and 2.8. Finally, when the densities of the plant cover were made comparable, the run-off percent from the two areas was practically the same, and the excess of silt removed from A was reduced from 109.1 to 11.5 cubic feet.

This reduction of silt removed from area A following revegetation has far greater significance than merely the reduction of soil movement, because of its indirect effect on the future rate of absorption and percolation of the soil. This is shown by studies (*86*) conducted by the California Forest and Range Experiment Station, in which slightly less than 2 percent of sediment was introduced into clear water and allowed to percolate through a soil surface. It was found that the rate of percolation of this muddy water amounted to a reduction of 90 percent within 6 hours over the percolation rate for clear water. The sealing of soil pores by sedimentation not only immediately reduced the speed of percolation but this change remained permanent since the subsequent use of clear water did not restore the original percolation rate. This indicates clearly that break-down of figure 69. A change in percent of slope was materially noticeable in modifying run-off in the downy chess type only, where excessive loss of water occurred on slopes greater than 30 percent. The unexpected decrease in the run-off from the steeper slope in the needlegrass-lupine type is attributed to the coarser texture of the soil on these slopes. Erosion was accelerated, however, by steeper slopes in every type except the bunchgrass. Disturbed soil as compared to undisturbed gave much the same effect as increased percent of slope. In this case decreased run-off following disturbance of the soil in the needlegrass-lupine type is due to the increase of absorption caused by loosening of the surface. High rainfall intensity accelerated both run-off and erosion from all types except the bunchgrass, which continued to afford suitable protection to the soil even when the intensity of the rainfall was doubled.

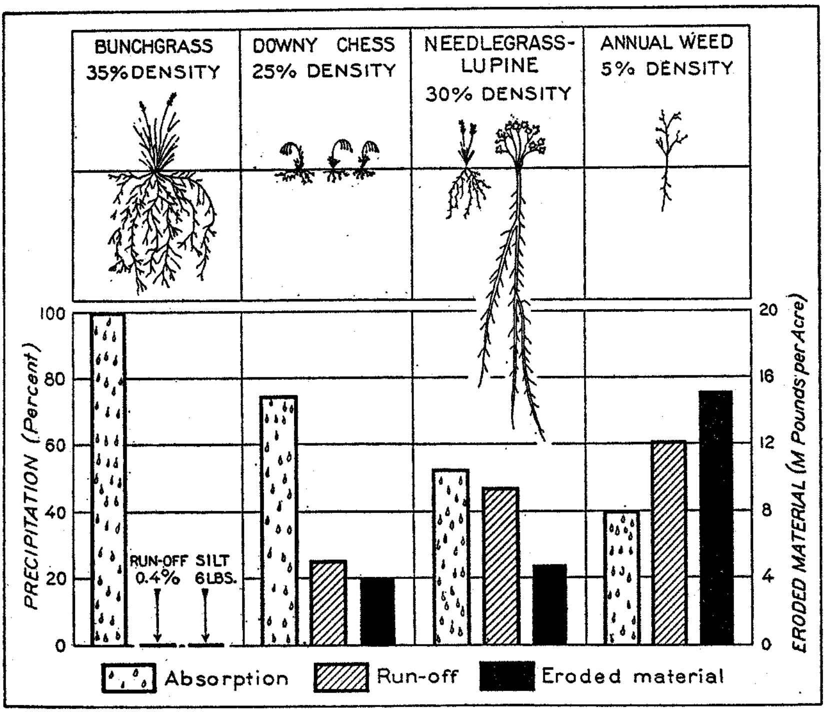

FIGURE 69.—THE MOST DESIRABLE FORAGE PLANTS ARE COMMONLY THE BEST WATERSHED PROTECTORS.

Run-off and erosion from rainfall are negligible where the bunchgrasses predominate—the highly palatable virgin-range cover characteristic of south-central Idaho. Both run-off and erosion are very pronounced where other plants have succeeded bunchgrass because of overgrazing. The greatest percent of run-off and the largest amount of eroded material come from annual weed cover—a plant cover which is an infallible expression of over utilization. A many-branched, fibrous root system is an important factor in retarding soil removal and aiding absorption.

and 16 pairs for plants common on depleted ranges. The results are shown in figure 70. That plots supporting desirable forage plants absorb water more rapidly than contiguous bare plots or even than plots supporting the less desirable plants, is readily understandable. It is interesting to note, however, that bare-soil spots on well-managed range were more absorbent than the bare places on depleted range, owing to the better soil conditions induced by the surrounding vegetation and its wider spreading root systems. Equal quantities of water applied on these plots penetrated approximately 5 inches on vegetated plots on managed range as compared to 3½ inches on vegetated plots on depleted range.

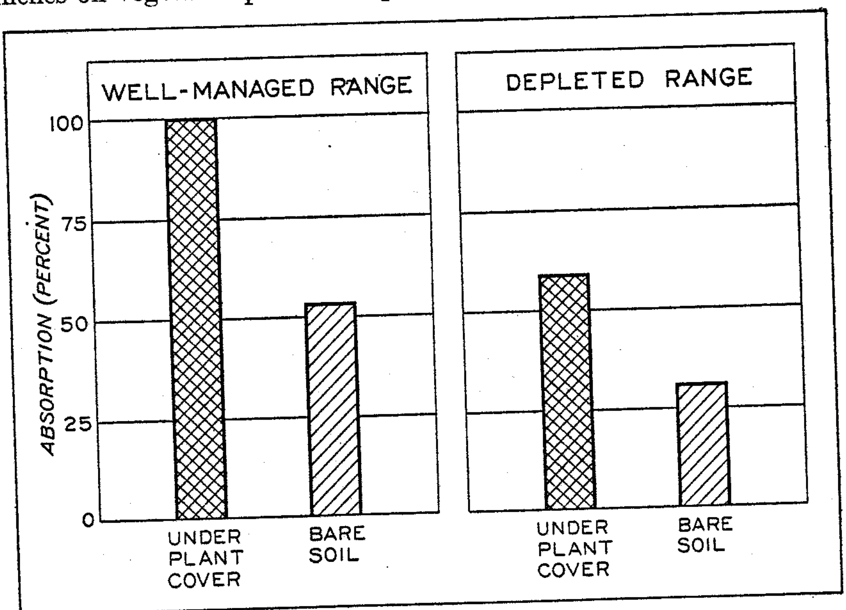

FIGURE 70.—THE EFFECT OF DEPLETION ON ABSORPTION.

Where plants are present, the rate of absorption of water by the soil is materially increased over that on bare soil. It is significant also that bare soil on well-managed range land absorbs water more rapidly than similar spots on overgrazed range. The data shown here are taken from averages obtained on plots on the Boise River watershed. Absorption under plant cover on well-managed range was at the rate of 0.44 inches per hour.

In every case the course of percolation appeared to follow plant roots, demonstrating the superiority of extensive and fibrous roots, characteristic of the perennial plants found on well-managed ranges, over the more poorly developed root systems of plants typical of depleted cover.

The necessity of maintaining an unbroken range cover, as demonstrated on the Boise River watershed, was further substantiated by a general survey of the area made by the Forest Service. This survey brought out the necessity for a plant-cover density of at least 30 percent to avoid erosion, since if grazing depletes the cover below that point, run-off and erosion will be accelerated and the utility of the watershed will be reduced.

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Bennett

range sheep in Oregon and Washington would disappear from a territory which is not suited for the production of crops other than livestock (fig. 92).

At normal price levels the sheep industry represents in the two States at least $60,000,000 in capital investment and its annual gross income is in excess of $20,000,000. Therefore, any condition or change that adversely affects it immediately becomes a matter of State-wide concern. The interrelation between the summer ranges and the capital investment in real and other properties in the range country is very definite, and their proper management is a high public service.

E. N. KAVANAGH, *Forest Service.*

H H Bennett

Erosion vegetation

SOIL-EROSION Studies Show Vegetation Has Dominant Role

For the first time in the history of the United States, protection of watersheds and cultivated fields from costly erosion is receiving some measure of the serious attention it has merited. The President has repeatedly pointed to the necessity for doing something to control the evil. He is backing up his suggestions through the work of the Civilian Conservation Corps, part of which is being devoted to gully control and the planting of trees on strategic watershed areas.

Anyone who critically examines the situation confronting the rolling agricultural lands of the Nation, comprising fully 75 percent of all land in cultivation and an equal percentage of that on the western ranges, readily recognizes the seriousness of the problem of unrestrained soil erosion. The destruction of the fertility of 190,000 acres of formerly cultivated land in a single county and its abandonment would seem sufficient cause for at least slight alarm. That recent surveys and erosion measurements have shown that approximately 35,000,000 acres of formerly cultivated land, most of it originally good land, have been ruined by gullying is still greater cause for alarm, especially when it is pointed out that an additional area nearly four times as large has been made almost hopelessly poor by having the topsoil stripped off. Such devastation and continuing land impoverishment constitute a menacing national problem requiring immediate corrective action.

Vegetation and Erosion

For some reason man has not resorted so much to the oldest and most effective measure for controlling erosion, that is, thick-growing vegetation, such as trees and grass. The primary effort has been to get trees off the land and to destroy the matted prairie grasses so that cultivated crops might be grown. Clearing away all obstacles ahead of seeding has been the first thought of agricultural man, as well as the second and dominating thought, too generally.

Another deterrent to the use of thick-growing vegetation has been sheer ignorance. There was no clear understanding of the fundamental facts involved in erosion processes until recently. No basic studies

marginal and submarginal lands where severe impoverishment or destruction by erosion too often is an inevitable part of their programs of land utilization.

was lost as run-off. On the same kind of land, having the same declivity, covered with bluegrass, neither a drop of water nor a particle of soil was lost because of this same rain.

The total soil loss from an 8-percent slope of Shelby loam (one of the most important corn soils of north-central Missouri and southern Iowa) devoted to corn continuously has been for 2 years 133.8 tons per acre, as against a loss of only 0.39 ton per acre from the same kind of soil on which alfalfa was grown, having the same slope and receiving the same rainfall. The corresponding water losses were 25.8 percent from the cornland and 1.7 percent from the alfalfa land (fig. 93).

The Protective Power of Grass

The average rate of soil loss caused by erosion from the principal type of land on moderate slopes in the wheat belt of western Kansas has been 4,260 times greater where a cultivated crop (kafir) was grown than where the same kind of land was covered with native plains sod. Also, about 400 times as much water has been absorbed where the ground was well grassed. Expressed in another way, where a tilled crop is grown, 58 years would be required to wash off the 7 inches of topsoil covering this kind of land down to comparatively unproductive subsoil, as against 246,000 years to wash off the same depth of soil where grass is grown.

A Permanent Cure for Erosion

Even grain stubble is a potent agency for slowing down erosion (both water and wind erosion). Heavy summer rains (as that of July 30, 1931) and melting snow cause a tremendous amount of washing on summer-fallowed steep slopes in the Palouse wheat belt of Washington, Idaho, and Oregon, but very little when the ground is covered with stubble. This effect is well illustrated in figures 94 and 95.

Vegetation in the form of forest or in thick grasslike growth is an inexpensive, permanent cure for erosion. In one form or another it can be used on all kinds of land, on any degree of slope and under all varieties of climate where there is heat and rain enough to make plants grow. Of course, all land cannot be used for forest and the thick-growing crops. We must devote large acreages to the erosion-producing, clean-cultivated crops, such as corn, cotton, tobacco, and potatoes; but it has been definitely shown that the two types of crops can be grown in conjunction with one another in such a manner as enormously to reduce soil and water losses. It now remains to educate the farmers of the Nation with respect to the advantages of the soil-protective types of agriculture. This can be done as soon as the Nation decides to adopt better farming methods, methods which call for the use of land more nearly in accordance with its adaptability and fitness and for the efficient protection of all cultivated slopes.

H. H. Bennett, *Bureau of Chemistry and Soils.*

One farm of over

is now completely and effectively covered with this cheap, simple system of soil conservation.

Soil Erosion

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In 1934, Bennett (6585) founder of the Soil Conservation Service in the United States stressed the role of vegetation in controlling erosion as follows:

"Unless effective erosion-control measures are widely adopted without much further delay, the country is going to have on its hands a domain of worn-out land...For some reason man has not resorted so much to the oldest and most effective measure for controlling erosion, that is, thick-growing vegetation, such as trees and grass.

"The average rate of soil loss caused by erosion from the principal type of land on moderate slopes in the wheat belt of western Kansas has been 4,260 times greater where a cultivated crop (kafir) was grown than where the same kind of land was covered with native plains sod. Also, about 400 times as much water has been absorbed where the ground was well grassed. Expressed in another way, where a tilled crop is grown, 58 years would be required to wash off the 7 inches of topsoil covering this kind of land down to comparatively unproductive subsoil, as against 246,000 years to wash off the same depth of soil where grass is grown.

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Soil must be preserved at all costs because it cannot be replaced except over geologic time and without it all is lost. Maintenance of land productivity and a high quality natural environment depend on proper management of vegetation.

Soil Erosion

Maladjustments and depletion have caused serious decreases in population with correspondingly bad effects on the social and economic life of the communities. Fifteen representative dry-farm counties in six States, for example, lost from 4 to over 40 percent of their population in the single decade ending in 1930.

More than enough examples have been given to show that a wide diversity of economic and social losses results from range depletion and crop- and range-land maladjustments. The greatest possible security should conversely result from ranges restored and maintained in high productivity, from privately owned units of economic size with a proper balance in area and productivity of range- and crop-land, and from a proper distribution of land between private and public ownership.

FROM EROSION AND FLOODS

In a region of meager precipitation such as most of the West, the availability of water for irrigation, municipal purposes, power, etc.,

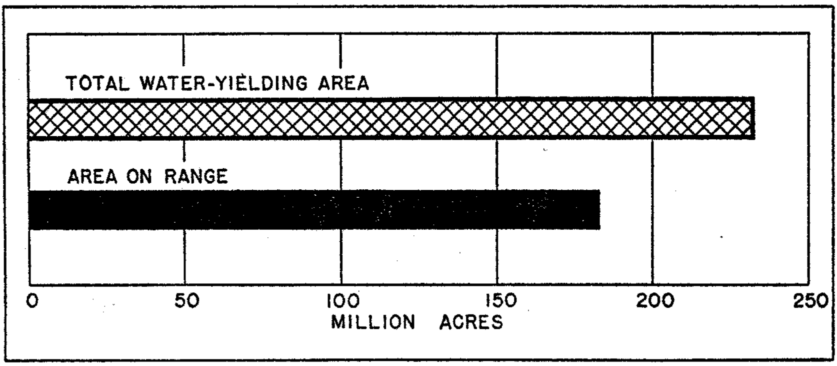

FIGURE 11.—WATER-YIELDING AREAS

Four-fifths of the 232 million acres which produce 85 percent of the water in the major western streams comes from range lands, and low precipitation makes water the limiting factor in nearly all western development.

is in most cases the factor which limits development. All plans for agricultural and municipal security as well as for most other industries must take this definitely into account.

Approximately 85 percent of the water of the principal watersheds of the West is derived from an area of about 232 million acres. Of the utmost significance is the fact that four-fifths of this important water-producing area is made up of range lands (fig. 11).

An additional reason for consideration is the fact that no less than 589 million acres of range lands, according to the best available information, is eroding so seriously that the destruction which it causes compels attention. Still further, 352 million acres of this area is contributing an appreciable amount of silt to major streams (fig. 12).

Watershed values have been most seriously impaired on the public domain and on private lands. Approximately 149 million acres, or 98 percent of the available public domain and minor reservations, is eroding more or less seriously, and 67 million acres is contributing silt to major streams (figs. 13 and 14). Over 80 percent of private land is eroding and 195 million acres is contributing silt. While not so extensive, erosion on State and Indian lands is also critical.

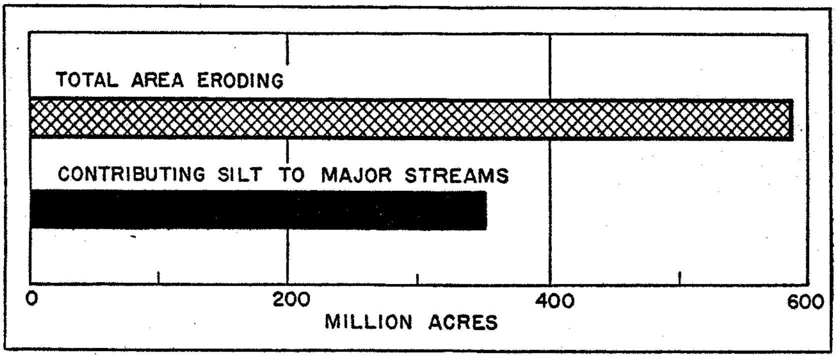

FIGURE 12.—EROSION AND SILTING OF STREAMS.

Eighty percent of the entire range area is eroding more or less seriously, and hence reducing the productive capacity of the soil. Nearly half is contributing silt in disturbing quantities to major western streams, and hence impairing their value for irrigation, power, and municipal water supplies.

Even on the national forests, which have a watershed objective in administration, 32 million acres is eroding and will require additional attention.

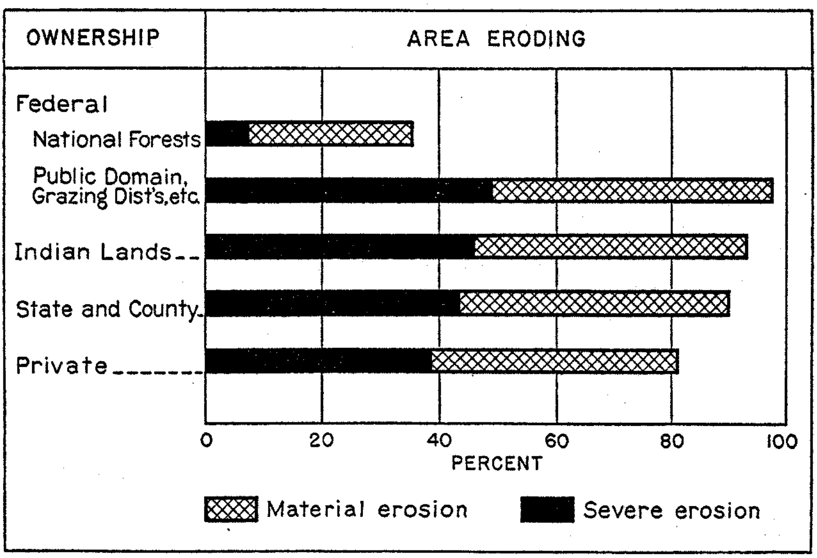

FIGURE 13.—EROSION BY RANGE OWNERSHIPS.

Erosion is most serious on the public domain and grazing districts, and Indian, State and county, and private lands are little better. Even 30 years' management has fallen far short of curing erosion on the national forests.

Scientific investigations have proved beyond a doubt that the plant cover minimizes and often prevents erosion and floods, and conversely, that depletion is a primary cause of both.

Soil Erosion

Studies in Utah to ascertain the effects of range vegetation on run-off and erosion have shown that by increasing plant density from 16 to 40 percent, surface run-off from summer rains is reduced by two-thirds and erosion by more than half its former volume.

In Idaho investigations of the effectiveness of different range types on surface run-off and erosion show that a plant cover of the most desirable forage species yielded practically no surface run-off or sediment, while the poorest cover yielded more than 60 percent of the precipitation in surface run-off and an equivalent of more than three-fourths of a ton of sediment per acre.

From a barren area in Missouri over a 6-year period 123 times as much soil was eroded as from a sod-covered area. Denudation by fire near Los Angeles increased flood run-off fortyfold and erosion approximately a thousandfold.

Geologic evidence in Utah has shown that recent destruction of plant cover has accelerated erosion and increased the number of

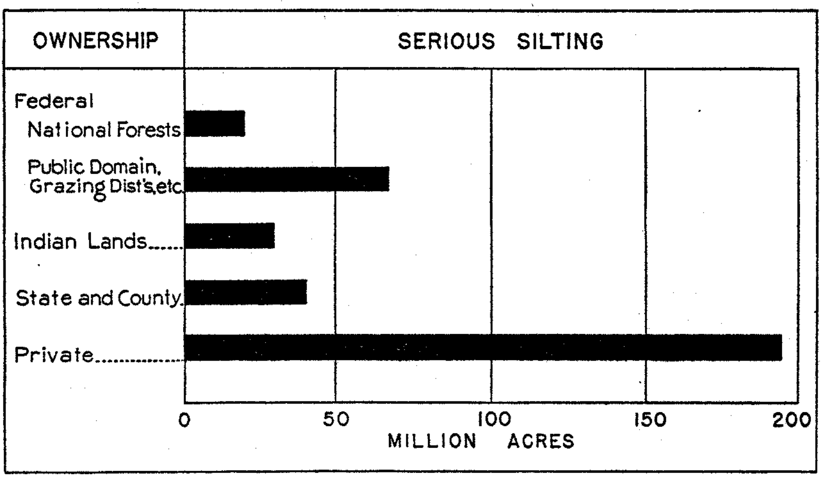

FIGURE 14.—SILTING OF MAJOR STREAMS BY RANGE OWNERSHIPS.

While the area in private ownership contributing silt to major streams exceeds that in all other ownerships combined, several other ownerships or forms of control urgently need attention.

floods beyond anything that had taken place in the preceding 20,000 years. These random examples are merely representative of similar results obtained throughout the West.

Floods are now increasing in frequency and severity from depleted western ranges, until scarcely a summer day passes when newspapers do not carry an account of loss of property or life. In Utah 27 important watersheds flooded in 1932 alone, and investigation showed their source to have been largely on range lands eaten down to the bare soil, while in New Mexico and Arizona historical evidence shows that floods are more frequent and destructive than anything which occurred in the past.

In 1922 the Palo Verde flood caused $1,000,000 damage. A Rio Grande flood in 1932 practically destroyed flood-protection improvements worth $5,000,000 and did more than $1,000,000 damage to other property. Floods in Davis County, Utah, have caused

$1,000,000 damage since 1923. The La Crescenta flood of 1934 took a toll of 30 lives and did $5,000,000 damage.

The loss of almost irreplaceable soil on the western range is as widespread as range depletion itself. In the mountains of all the western States accelerated sheet and gully erosion are stripping and cutting slopes and channeling meadows. Southwestern valleys are being trenched with great arroyos often 100 feet in depth and 300 or more feet wide, and both mesa lands and mountain meadows are being ruined. The silt loads of the rivers of the Great Plains and the "black blizzards" of the last few years, with their threat to farm and industrial values and health, bear testimony to ravaged lands.

Silt deposits filled the small Austin Dam Reservoir in Texas in 13 years. The Elephant Butte Dam is filling at the rate of about 20,000 acre-feet annually. The McMillan Dam in New Mexico is now valuable only for diversion. The same thing is happening in greater or less degree in most of the reservoirs throughout the West.

The grazing value of range watershed lands may not often exceed $3 per acre. The watershed value is much more difficult to determine. Some indication of relative values may be gained, however, from a consideration of dependent investments. More than 5.8 billion dollars is invested in irrigated land and improvements, as compared with about 4.1 billion dollars in range livestock and related ranch properties. Each of the 475 million acres of range land yielding water or contributing silt to streams supports an investment of $12.27 in irrigation works, lands, and facilities, and this figure would be still higher if the investments for power and municipal water supplies were added.

Another measure of the value of the range cover can be obtained by considering the loss in the productive capacity of the soil from erosion as a result of depletion. The fertile top layers go first. Several hundred million acres have already lost 1 to several inches, and the productive capacity may have been reduced by one-fourth or one-half or more. These layers can be replaced only very slowly, as shown by investigations under the more favorable conditions in the East which indicate a rate of about 1 inch per 1,000 years.

Fortunately, man is not helpless in this situation, black as the picture now is. On many of the protected municipal watersheds of the West and on the managed watersheds of the national forests are examples of arrested erosion and controlled floods which are the direct result of range restoration. Not only has the production of forage been increased but the services which watersheds should render in maximum flows of usable water for dependent crop agriculture, in municipal water supplies, in power, in clear fishing streams, and in greater security to life and property have followed as a matter of course.

IN WILDLIFE

Wildlife is one of the natural products of the range. Its present annual economic value is estimated at more than $90,000,000. To evaluate its economic significance, however, expenditures exceeding $40,000,000 by hunters and fishermen should be added, and, in part also, those by recreationists of over $155,000,000, because one of the silt to major streams (figs. 13 and 14). Over 80 percent of private land is eroding and 195 million acres is contributing silt. While not so extensive, erosion on State and Indian lands is also critical.

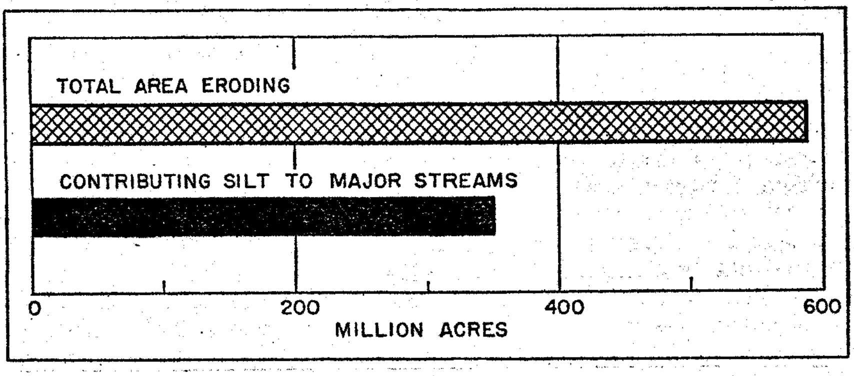

FIGURE 12.—EROSION AND SILTING OF STREAMS.

Eighty percent of the entire range area is eroding more or less seriously, and hence reducing the productive capacity of the soil. Nearly half is contributing silt in disturbing quantities to major western streams, and hence impairing their value for irrigation, power, and municipal water supplies.

Even on the national forests, which have a watershed objective in administration, 32 million acres is eroding and will require additional attention.

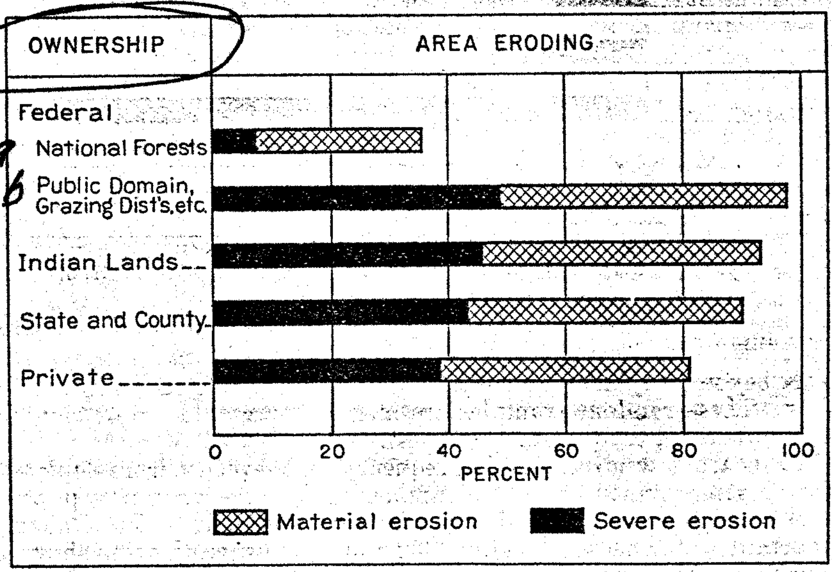

FIGURE 13.—EROSION BY RANGE OWNERSHIPS.

Erosion is most serious on the public domain and grazing districts, and Indian, State and county, and private lands are little better. Even 30 years' management has fallen far short of curing erosion on the national forests.

Scientific investigations have proved beyond a doubt that the plant cover minimizes and often prevents erosion and floods, and conversely, that depletion is a primary cause of both.

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No one familiar with wildlife requirements will question the statement that the range with little or no impairment in its value for other uses could support a vastly larger wildlife population. So far, in fact, have numbers been reduced that any recital of what remains is in itself an indication of both tangible and intangible social and economic losses.

A few outstanding examples will suffice. The former millions of buffalo have declined to the few thousand on reservations; the thirty or forty million antelope to about 65,000; the few mountain sheep, goats, moose, and grizzly bear left are barely holding their own; the scattered remnants of upland game birds and fur bearers are still declining; the reduction of waterfowl has become a matter of national concern. Most of the big-game animals have been crowded off their original range into much less favorable conditions.

The chief factors and causes which are responsible for the present situation, discussed in detail later, need only be listed here:

1. The deterioration of the habitat through range depletion which has destroyed both food supplies and cover for land animals and birds and silted fishing streams.

2. Complications growing out of the passage of large areas of land to private ownership under a policy which offers no incentive to the owner to protect and maintain wildlife.

3. Maladjustments in land use, such as swamp drainage, that have attempted but failed to use for agricultural crop production land which would render its highest social and economic return in wildlife production.

4. Unrestricted or poorly controlled hunting and fishing.

5. A series of ill-advised or poorly handled constructive measures such, for example, as game preserves, transplanting, buck laws, etc., which have created almost as many problems as they have solved.

6. Protection alone defeating its own purpose by leading to overpopulation.

7. Wildlife agencies recruited on the basis of political rather than technical qualifications.

8. The lack of adequate technical knowledge.

9. The belated development of the basic concept that game management is required, having for its purpose production as a crop with provision for the annual harvesting of the production or surplus, this in proper correlation with other legitimate uses of the range.

The fundamental cause, however, is again the typical American philosophy of prodigal destruction rather than the conservation of natural resources.

Public interest in wildlife has increased very rapidly during the last few years, the direct result of the efforts of many sportsmen's and other associations and of State and Federal agencies. Although many of these activities have not reached the fundamental problems, nearly all have constructive aspects. Through them, for example, State agencies have contributed toward the rehabilitation of the wildlife resource. The Biological Survey has established a number of migratory bird and other reservations, controlled predatory animals injurious both to wildlife and domestic livestock, controlled rangedestroying rodents, and conducted research necessary as a basis for wildlife management. The Bureau of Fisheries and numerous State agencies have stocked many western streams and cooperated in their improvement.

The national forests have had a more important effect on the rehabilitation of wildlife in the range country than any other measure so far adopted, and are a concrete, although far from perfect, indication of the possibilities. National forest increases, which for big game animals alone are about 75 percent in the last decade, have been brought about with very little reduction in other forms of use, such as livestock grazing. The reappearance of wildlife has undoubtedly been one of the factors responsible for over 38 million visitors in the national forests in 1934 as compared with 3 million in 1917. These increases have not come without difficulties growing out of rigid State laws which stood in the way of reducing surpluses regardless of whether feed was available to keep the game from starving, or of the legitimate requirements for livestock or other forms of use, nor without other difficulties in working out effective cooperation between State and Federal agencies.

IN RECREATION

During the past half century public opinion regarding the social necessity of outdoor recreation, not alone for the favored few but for all, has undergone as radical a change as that regarding bathtubs and night air. People generally have learned that modern life makes demands for which the most practical remedy is periodic association with nature. The needs and the benefits are both physical and mental.

If increased opportunity for wholesome outdoor activities is not provided, existing play areas will be so crowded that only partial returns for expenditures of time and money can be obtained, and greater leisure time may not as it should contribute to health and happiness. The American people have developed a mobility which dwarfs into insignificance the outdoor spaces that can be dedicated exclusively to recreation.

Range lands, as well as others, possessing the qualities sought by outdoor recreationists have thus acquired economic values which often exceed those for other services. They are capital assets of their communities. They draw large sums of money that otherwise would not be received; money which contributes as fully to economic security as that from any other source.

People do not as a rule pay directly for the privilege of enjoying scenic charm or other recreational values, but they do pay indirectly through purchases of commodities and services for which there otherwise would be no local market. The recreational use of lands means that the market is brought to the resource without cost of transportation.

The serious depletion of most range areas, the reduction in wildlife, the erosion and silting of streams, have all been reflected in impaired recreational values. Where originally the mind was inspired by views of grass-covered and flower-studded slopes, it is now depressed by the sight of a terrain scored and dissected by

Maladjustments and depletion have caused serious decreases in population with correspondingly bad effects on the social and economic life of the communities. Fifteen representative dry-farm counties in six States, for example, lost from 4 to over 40 percent of their population in the single decade ending in 1930.

More than enough examples have been given to show that a wide diversity of economic and social losses results from range depletion and crop- and range-land maladjustments. The greatest possible security should conversely result from ranges restored and maintained in high productivity, from privately owned units of economic size with a proper balance in area and productivity of range- and crop-land, and from a proper distribution of land between private and public ownership.

FROM EROSION AND FLOODS

In a region of meager precipitation such as most of the West, the availability of water for irrigation, municipal purposes, power, etc.,

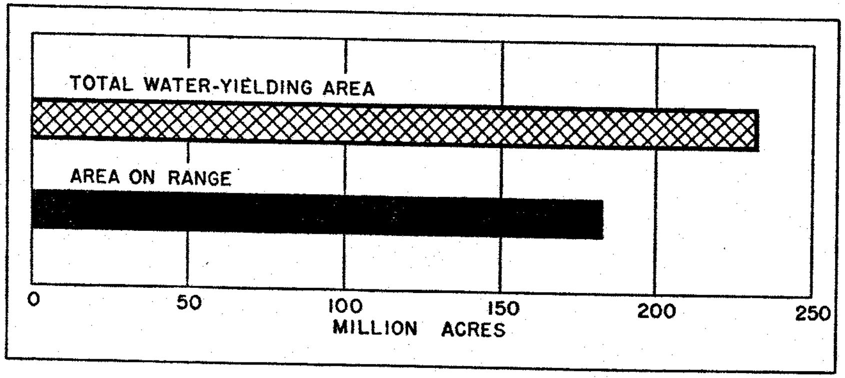


FIGURE 11.—WATER-YIELDING AREAS

Four-fifths of the 232 million acres which produce 85 percent of the water in the major western streams comes from range lands, and low precipitation makes water the limiting factor in nearly all western development.

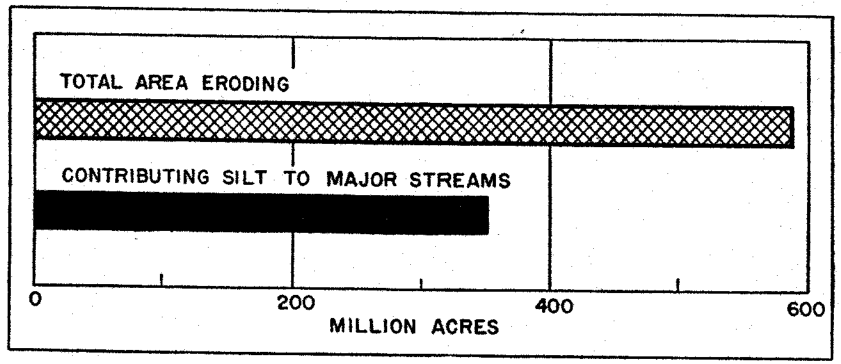
is in most cases the factor which limits development. All plans for agricultural and municipal security as well as for most other industries must take this definitely into account.

Approximately 85 percent of the water of the principal watersheds of the West is derived from an area of about 232 million acres. Of the utmost significance is the fact that four-fifths of this important water-producing area is made up of range lands (fig. 11).

An additional reason for consideration is the fact that no less than 589 million acres of range lands, according to the best available information, is eroding so seriously that the destruction which it causes compels attention. Still further, 352 million acres of this area is contributing an appreciable amount of silt to major streams (fig. 12).

Watershed values have been most seriously impaired on the public domain and on private lands. Approximately 149 million acres, or 98 percent of the available public domain and minor reservations, is eroding more or less seriously, and 67 million acres is contributing

silt to major streams (figs. 13 and 14). Over 80 percent of private land is eroding and 195 million acres is contributing silt. While not so extensive, erosion on State and Indian lands is also critical.



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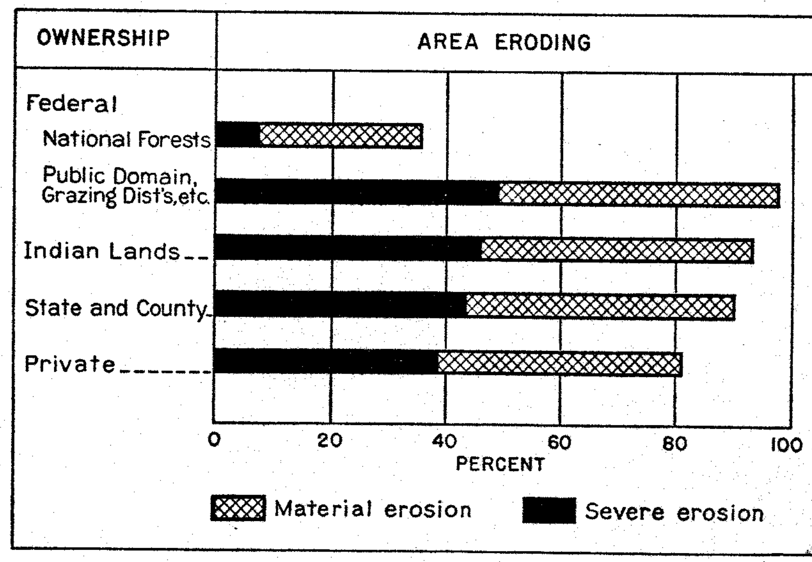

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Studies in Utah to ascertain the effects of range vegetation on run-off and erosion have shown that by increasing plant density from 16 to 40 percent, surface run-off from summer rains is reduced by two-thirds and erosion by more than half its former volume.

In Idaho investigations of the effectiveness of different range types on surface run-off and erosion show that a plant cover of the most desirable forage species yielded practically no surface run-off or sediment, while the poorest cover yielded more than 60 percent of the precipitation in surface run-off and an equivalent of more than three-fourths of a ton of sediment per acre.

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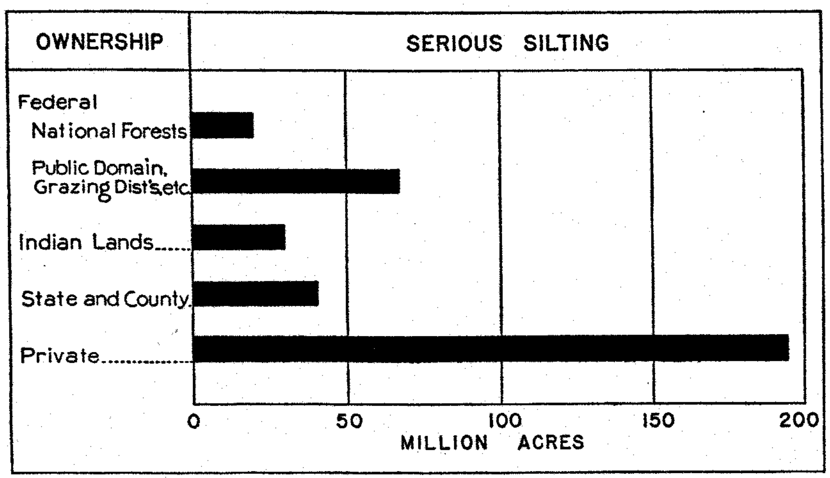

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Soil formation, Ecology

RANGE CONDITION AND RATE OF VEGETATION

The rate of revegetation of a range is determined by its condition, the degree of soil erosion and the kinds of plants on it. Plants and plant composition reflect the condition of the range and are the easiest means of "reading" the range - of getting some idea of the degree of deterioration and potential for improvement. This follows from the close relationship between vegetation and soil.

Aikman (1935) described this relationship as follows:

"From a study of geological evidence the conclusion may be drawn that the surface of the earth was at one time devoid of plant cover and that it gradually became covered with vegetation by the development of successive stages of plant growth from simple to more complex types.

The early stages of plant succession on rock surfaces are separated in time by periods of hundreds to many thousands of years and the later stages by tens to hundreds of years, depending on the structure of the substratum, the climate and the plants involved.

In the early stages of succession (the lichen and moss stages) the percentage of plant cover may be high because there are no tall plants to shade the substratum. After the advent of higher plants in the xerophytic herb and grass stage the dense, but low cover of lichens and mosses is shaded out. From the moss stage to the end or climax, there is a gradual increase in percentage of plant cover. Height of plants and resulting total weight of plant cover increases from the first to the final stage of the succession. The crustose lichen stage is important in producing the first thin layer of soil (1-2 millimeters in depth).

Depth of soil gradually increases from the earlier to the later stages. The first two stages have no root development but beyond this stage the gradual increase in quantity and depth of roots is one of the chief factors in the increase in soil depth. The presence of these roots also contributes to the holding of the soil which is an important property of plant covers in the prevention of erosion. Height of plants and resulting total weight of the plant cover increases from the first to the final stage because of the shading out of lower by higher plants.

The quality of duff resulting from dead plant parts increases from earlier to later stages because of the gradual increase in the total plant cover. Duff is effective in preventing erosion through the protection to the soil surface from the force of rain, and through the effect on texture and structure of the soil to which it is added. Fertility from this decomposition contributes to a gradual increase in quantity of plant cover from the initial to the climax stage of the succession. This increase in the density of the plant cover contributes to its erosion-prevention capacity by breaking rain drops into spray and by means of the soil holding capacity of roots. The depth of soil increases more rapidly in the later stages because the rate of loss by erosion is greatly reduced and the rate of increase in soil depth is accelerated by the addition of larger quantities of duff and by deeper penetration of roots.

The addition to the soil of plant parts which become decomposed, increases the water-holding capacity of the soil.

Any important increase in water-holding capacity in the higher stages of succession, results from an increase in soil depth rather than from an increase in quantity of water held per unit of soil. With the increase in soil depth an added burden is placed on the vegetation, i.e. to hold the soil against erosion; but this increase in depth is accompanied by an increase in the volume of vegetation which in turn results in greater erosion prevention capacity."

Clements (1949) described this relationship briefly in other forms:

"Plant communities arise, grow, mature, attain old age and die from natural causes or by accident...The final or adult community is termed a climax by reason of the fact that it is the highest type of social organism capable of growing in a particular climate and its process of growth is known as succession, from the series of transient population that pass across the scene....The successive waves of plant populations--crustose lichens, foliose lichens, mosses, herbs, shrubs, and trees--each, in turn holds possession of a habitat and produces its profound influences upon it. Beginning slowly, increasing to a maximum, and then gradually receding, the plant populations of each have made conditions fit for the next community but often less fit for their own continuance."

So revegetation and soil develop toward climax conditions hand in hand in a very complex relationship. The revegetation changes over time as the soil changes. It changes not only as soil develops but also as it deteriorates.

Plant indicators of soil condition

With soil deterioration plants characteristic of an earlier successional stage take possession of a site. Generally these plants have tap or cord-like roots that can penetrate rock crevices or heavy subsoil materials and obtain moisture and nutrients for the plant. Such plants pioneer on young soils or grow on deteriorated ones. They consist of certain shrubs and trees and herbaceous species. Annual plants also grow abundantly on deteriorated sites.

In contrast fibrous rooted plants, such as grasses grow on well developed undeteriorated soils or where the soil parent material is already decomposed.

Generalizing tap rooted plants are slowly replaced by fibrous rooted ones as soil develops to climax condtion. Conversely fibrous rooted plants are replaced by tap rooted ones as soil deteriorates. Plants and particularly plant composition indicate, if only roughly, the condition of a soil and its potential for producing certain kinds of plants.

Some of the more conspicuous plant indicators of soil condition in the project area region are listed below. These have increased out of proportion in plant types or have invaded other types because of soil deterioration.

Perennials

Shrubs

Big sagebrush (figs.___, ___)
Silver sagebrush
Low rabbitbrush (fig.___)
Rubber rabbitbrush
Bitterbrush (fig.___)
Shadscale
Greasewood
Horsebrush

Trees
Juniper (figs.___, ___)
Pine (fig.___)

Grasses
Western needlegrass (fig.___)

Forbs
Mule ears (fig.___)
Buckwheat
Flag lily

Annuals

Grasses
Cheatgrass (fig.___)
Fescue

Forbs
Filaree

Rate of revegetation restoration on a site depends on the degree of soil erosion, or fertility level of the soil and on the kinds of plants presently occupying the site.

Where soil erosion has been light a site may revegetate quickly in a matter of a few years. Where erosion is very heavy revegetation may take hundreds even thousands of years, depending on the amount of soil lost. The rate of restoration proceeds as the rate of soil formation and rate of development of soil fertility.

Even where there has been little loss of soil but woody species have encroached upon a site, increase in herbaceous species may be slow because of the competition afforded by the existing species.

Because of the serious consequences soil erosion must be prevented at all costs.

Comments by Shantz (   ) in 1934, on soil-vegetation relationships, erosion, and indicator plants bear repeating here:

"Soil is as much a product of vegetation as vegetation is a product of the soil. The development of a soil, given proper basic material and a proper climate, is inconceivable without vegetation. Certainly the two great factors in developing a soil are climate and plant cover.

"Just as the occurrence of certain kinds of plants indicates bad agronomic practice on cultivated land so the appearance in pastures and range areas of certain plants or their increase in relative numbers indicates destructive grazing practice. At first the destruction may be only in the species constituting the plant cover and as a general rule the most valuable plants disappear first. Also as a rule less valuable or worthless plants, called weeds, take their place. That is, the first changes are qualitative and represent differences in composition rather than in density of plant cover. These changes often result in a loss in actual carrying capacity and unless stocking is reduced lead to serious over-grazing. This may be only the initial stage of destruction, and usually a short period of protection or of carefully controlled grazing will re-established the plant cover. Continued close grazing, heavy trampling, the formation of trails and channels which hasten runoff, all cut down the amount of water penetration into the soil, resulting in a decreased plant growth due to a lack of available moisture. The process is a rapid one, and soon the range will be irreparably damaged. These damaged ranges can be improved, but to develop a soil when it is once destroyed is not a matter of years or tens of years, but of centuries or thousands of years. Soils have been developed through long geological periods and once lost cannot be regenerated in a few years. It is therefore imperative that no national government allow land to be destroyed in this way, be it public or private land.

"Our western ranges, especially on the public domain, must have immediate and constructive attention...Under all cases plants bind down the soil material and prevent its washing away. Erosion starts as a result of destruction of the plant cover. To re-establish this cover is a problem of agronomic or forest practice and generally must follow the course of secondary successions. Secondary successions as recognized by botanists are simply scar tissue in nature's attempt to heal a wound in earth's natural cover. The stages of re-establishment can easily be worked out, and in all cases recovery is most rapid when there is no further interference by partial or total destruction of the plant cover...The presence of weeds may be a sign of improvement or a retrogression and only a trained ecologist can determine which process is taking place. It is all important if man is to direct the re-establishment of our depleted range land that he know the natural stages of revegetation in order that he may further the natural recovery rather than retard it.

"Only a trained field man can determine the amount of damage done on the over-grazed ranges or to eroding soils. Except in rare cases plants are the only factors which can check erosion and aid in rebuilding the soil, and re-establish the carrying capacities of the range.

"Wherever one looks, nature has pointed the way to recovery...And there are well-recognized steps in the recovery. On the high plains the storm troops are the annual weeds, the supporting troops the shortlived grasses and perennial weeds, and the final rehabilitation is established first by buffalo grass followed by blue grama. One must be able to interpret at once the significance of the weeds which enter. In the northern plains Artemisia frigida will dominate in about four to ten years and the grasses will be fairly well established in twenty years. On the southern plains Gutierrezia sarothrae will be established following weeds and short-lived grasses (Schedonnardus texense) in about eight to twelve years, and the short grasses not fully established inside of forth years. The succession is much the same on over-grazed land and on land plowed and allowed to revert. But over-grazing leads not first to the establishment of the early phases, but rather takes the vegetation back through the stages. Over-grazed lands in the North stand out conspicuously at a distance by cause of the silvery Atremisia frigida, and in the South green or yellow due to Gutierrezia. In the Central Plains Region it is usually a mixture of these two.

"The land use program is one of the greatest at present confronting our nation and the erosion problem only a symptom of failure in the past to have made the proper use of land. From a geological point of view and, in fact, from the standpoint of soil development, erosion is a necessity since very old soils are not the most productive. New material must be deposited or the old material rearranged, and erosion is the process by which this is brought about. Still the loss of the productive soils as a result of destruction of the vegetation which naturally protects them is to be avoided. This is the problem of the present erosion program.

"In many parts of the world it is useless to attempt to slow down the natural processes. Where the total rainfall is insufficient to develop a dense enough plant cover to protect the soil the natural process of shifting surface material during heavy rains cannot be controlled. In each area the climax plant development under the climatic and soil conditions obtaining will probably give the greatest protection. But over at least half of the earth's surface there is not sufficient vegetation to hold the earth in place.

"A thorough understanding of the natural vegetation climax and of the secondary stages leading to its re-establishment, when it is once destroyed, is the best possible basis for a revegetation and erosion control program. Every location presents a new problem; every region requires special treatment and no one plan will apply when climate, soil and vegetation change."

There is now way of appraising the fertility of an eroded soil and forecasting with any degree of reliability the species of plants that will establish on the soil as it improves. Forecasting quantitive changes in a given time period is next to impossible because of the factors of soil fertility and plant competition. That the vegetation will improve if rested from use sufficiently is a certainty.