THE PROBLEM OF RANGE RETROGRESSION

AND

ITS RETURN TO PRODUCTIVITY

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Introduction

The problem in mind is to determine why it takes so long to bring depleted areas into favorable productivity, whether they be caused by natural erosion or over-grazing, even with the application of the approved range practices.

It has been stated that the continental United States contains 728 million acres of land suitable for livestock use. Of this area, approximately only 95 million acres, or 13%, is in a satisfactory condition; the remaining 633 million acres, or 87%, of the rangeland is in some stage of retrogression due, primarily, to erosion which, in turn, may be instigated by overgrazing. The importance of the problem in question becomes apparent when one considers that in those situations where an attempt is being made to correct this existent maladjustment by the best range practices, the results are slow, almost discouraging. There are reasons why it is so difficult to bring about the arrest of the retrogressive conditions, and the instigation of a favorable plant succession. It is the intention of the writer to throw some light on the subject.

The Explanation of the Causes of Denudation

Denudation is caused fundamentally by erosion, the removal of the soil cover or any property of the soil cover, by water or wind. Under favorable conditions, nature starts at once rebuilding the soil from the decomposition of rocks or by the addition of humus material from decaying vegetable matter. Numerous factors of which climate, soil, topography, and geologic formation are doubtless the most important, influence these processes, but the vegetative cover is the main single controllable factor. This is due to the fact that repeated removal of the vegetative cover causes a condition of soil deterioration, the reduction of the humus content, and the deterioration of the physical conditions of the soil, such as the structure, the porosity, and with these the moisture content which is so important to all plant growth. With the loss of humus and the physical condition of the soil comes a marked decrease in the flora and fauna that play such an important part in the conditioning of the mineral nutrients of the soil to make them available for vegetative productivity.

The erosion loss in the western grazing area has been enormous. Countless slopes, once covered with rich soil and a dense carpet of herbaceous and browse plants capable of profitably supporting millions of cattle and sheep, have been so wasted by sheet and gully erosion following depletion of the vegetation, that they can now support far less than half the number of livestock once grazed upon them. (The original carrying capacity of the western ranges was estimated at 22.5 million animal units against 10.8 million animal units present carrying capacity.)

The natural balance on the western grazing lands, between the forces that tear down and those that build up the soil, is a delicate one, but if the vegetative cover is not disturbed, erosion is usually slight. Natural agencies occasionally produce abnormal erosion. Man's activities, however, by reducing the vegetative cover, can and do upset the balance completely. Where this occurs, these activities are seldom abated, and severe erosion follows. Once started, this may develop to disastrous proportions. Obsako (5) states: "From experimental data obtained from various quadrat measurements, it seems that if the climax type once goes back towards the inferior type, it is generally difficult to progress towards the climax type, i.e., the negative succession is more liable to occur than the positive succession."

In their original condition, the slopes and valleys, except in those arid parts where rainfall was very light, were well carpeted with valuable grasses and a small percentage of herbaceous and shrubby plants. The decaying vegetable matter had built up the surface soil into a friable condition and added to it a large quantity of rich organic matter. The mulch of decaying vegetable matter acted as a sponge, and the friable humus character of the soil allowed a maximum moisture penetration. The result was that the forage plants made the most of the rainfall and the fertile soil produced abundantly.

When erosion removes the top layer of the soil, it robs the plants. If erosion continues, the soil may become incapable of producing the stand it once supported. A comparison of the non-eroded with the eroded soil shows that the former soil is much richer than the latter in lime, phosphoric acid, and total nitrogen; that the water holding capacity is greater; and that the water required by representative plants to produce a pound of dry matter is less. A great many more leaves, greater stem and leaf length, and more dry matter are produced on the non-eroded than on the eroded soil, even with notably smaller supply of water. The conclusion is justly drawn that erosion is detrimental to plant growth chiefly because it brings about two conditions of soil deterioration: (1) Lack of adequate soil moisture for full plant development and seed production; (2) Lack of adequate plant nutrients in the soil for good growth.

Lundegardh (3) in his theory of relativety emphasizes the importance of the limiting factors as follows: "The more nearly a factor is in minimum in relation to the other factors acting upon the organism, the greater is the relative influence of a change of that factor upon the growth of the organism. As a factor increases in intensity, its relative effect upon the organism decreases; and when the factor is in the region of its maximum, the effect of a change upon the organism is nil."

Furthermore, re-establishment of the vegetative cover is made more difficult because of the lowered moisture content resulting from soil exposure, and because of the lowered water holding capacity of eroded soil supporting a thin stand of vegetation. Seeds germinate poorly, and many of those that do germinate suffer early death.

In the case of the climax bunch grass, the optimum herbaceous vegetation over much of the western area, which normally covered about 60 to 80 per cent of the soil surface and that but 2 acres of which was required to furnish a cow a month's feed, the deterioration is somewhat as follows. When the stand is thinned, and the humus is washed out of the soil by erosion, the valuable grasses give way and finally disappear. Then the ruderal weed type composed chiefly of rabbit bush, yellow bush, and annual weeds, takes its place. This type usually covers about 20 to 40 per cent of the soil, and approximately 12 acres of it are required to furnish a cow a month's feed. This exemplifies the more or less typical result of soil deterioration, and unless erosion is abated, the ultimate result may be more correctly stated as bare infertile subsoil or parent rock material.

Thus we have the rather general condition of the causes of denudation applicable to practically any physiographic, climatic, edaphic, or biotic environment.

The General Conditions Existing on Denuded Areas

In the study of the conditions existing on denuded areas, one must not consider the factors from the standpoint of erosion but rather from the standpoint of their ecological significance. It is from the consideration of the conditions, the importance, and the effect of the environmental factors that the full realization of the difficulty encountered by a plant community in becoming established can be analyzed.

Environmental Factors

Fundamentally, the environmental factors are classified into four major groups: physiographic, climatic, edaphic, and biotic. The primary factors, that is, the factors directly influencing vegetative growth are principally climatic and edaphic. The others, secondary in nature, are important as aids, either favorable or unfavorable, to the primary factors and are not considered in the listing below:

Primary Environmental Factors

Climatic

- Heat. (Atmospheric)
- Carbon Dioxide concentration.
- Light.
- Water. (Rain, humidity)
- Oxygen. (Atmospheric)

Edaphic

Oxygen. (Free in the soil)

Water. (Soil moisture)

Mineral nutrients.

Soil temperature.

Climatic Factors

The primary climatic factors have their greatest effect upon the shoot development, which necessarily effects the root development. However, since the climatic factors are relatively the same on a given area, regardless of whether it is denuded or supporting ample vegetation, they cannot be justifiably considered as limiting factors to the re-establishment of a productive vegetative cover.

The primary edaphic factors, however, carry the connotation of omni-importance, instead of that of relative ineffectiveness, for they are the ones that become limiting; they are the ones that change with a change in soil; they are the ones of the greatest variable effectiveness.

Oxygen

Oxygen in the soil is, of course, of greatest importance to respiration. The roots, like the other portions of the plant, are living tissues and carry on their functions as living tissues. Respiration being one of these functions, the roots use oxygen as a raw material, giving off carbon dioxide as a by-product. Therefore without oxygen, respiration ceases and the tissue dies. Oxygen is important in the process of breaking down insoluable minerals into a soluable form and the consequent enrichment of the soil solution. The gas is no less important in the transforming of plant and animal remains into a condition where their nutrient materials become soluable and may be absorbed by plants. Biochemical oxidation proceeds rapidly, when conditions are favorable, and much oxygen is incorporated in the compounds produced. (11)

Oxygen is also necessary for germination of seeds, root growth, root-hair development, and absorption by roots. Without it, nitrification would stop, and earthworms and most other soil organisms would cease their activities. A few microorganisms, i.e., clostidiums, could get their oxygen supply anaerobically by breaking down valuable compounds, containing oxygen, such as nitrates, but in doing so they decrease the soil productivity. Even roots may, for a time, carry on respiration without free oxygen, i.e., anaerobically, but in doing so, they give rise to toxic substances that are definitely harmful to further development.

Water

Water is probably the most important factor in plant development and perhaps is most frequently the limiting factor. It is important in many ways. It is a component of the protoplasm. It is essential in the synthesis of carbohydrates and protein. It maintains turgidity of the cells, the necessary condition for normal functioning. It serves as the solvent, and transporting medium for the mineral nutrients and foods within the plant, for all that enters the cells, or moves from cell to cell, must do so in solution. It directly affects the greatest danger the plant has to meet, that of insufficient absorption and excessive transpiration. In short, all the functions and life processes of a plant are dependent either directly or indirectly upon water, most of which is derived from the soil.

Mineral Nutrients

Mineral nutrients, of which plant fibers are chiefly composed, need little explanation of their importance, for like any other manufacturing process, either organic or inorganic, the raw materials are necessarily a fundamental part of the finished product. The rapidity and extent of the synthesized product is therefore directly proportional to the amount and relative availability of the raw product in need.

Soil Temperature

Soil temperature is very important, since it affects the biological, the chemical and the physical processes in the soil. The activities of the plant are profoundly affected by the soil temperature. It influences the rate of absorption of water and solutes, the germination of seeds, and the rate of growth of the roots and all under ground plant parts as well as the activities of the flora and fauna of the soil. It is the initial energy from which all life has arisen.

Thus is explained the importance of the primary environmental factors that are necessarily prevalent on the denuded habitats in which plants are to become established or are to regain the maximum of productivity. These factors assert their influence on the growth of plants in three distinct ways, namely: (4)

1. Quality, i.e., their potential effectiveness per unit.
2. Quantity, i.e., their respective amounts.
3. Duration of time, i.e., how long they are effective.

The enumeration of the physical, chemical and biological conditions existent on a denuded area, and the explanation of how these conditions effect the environmental factors will allow for a thorough understanding of what will be necessary for the reestablishment of the area to the maximum productivity.

Of the physical conditions, the color, structure, and moisture content are the major factors.

Color is most important when considering soil temperatures. In general, lighter colors absorb less heat from the sun's rays and are less variable in their fluctuation of temperature, i.e., when cold, they remain cold for a longer period of time than darker soil and vice versa. Color is significant, therefore, because denuded areas are invariably lighter in color due to the lack of the darker qualities of humus present in rich soils.

Structure likewise is important when considering temperature because of the freer circulation of air in a porous as compared to that of a compact structure. But, structure is also important to the oxygen and moisture content. The porosity of a good "crumb structure" allows freer circulation of air and greater absorption, circulation, and holding capacity of water. This in turn affects the availability of the mineral nutrients in the soil. The structure of a denuded soil, as a rule, lacks this needed porous "crumb structure". The particles usually are closely compacted together by trampling, pounding rains, or lack of floculation as a result of lessened chemical ionization.

The importance of the moisture content was discussed previously under the heading of environmental factors. The cause of low moisture content is the deficiency of good structure resulting in lowered absorption, percolation, and retention. Because of capillary action and the high surface temperatures of the light soils, evaporation is increased.

The chemical factors, if summed up in the word "humus", are not so numerous, though no less important than the other factors, and can be dispensed with by saying that their primary effect is upon the physical factors which, in turn, deal with the environmental conditions as explained above. This influence on the physical factors is brought about by the relative scarcity of humus in denuded soils.

The biological factors are similar to the chemical factors in that they are dependent upon the physical conditions of the soil. They are also dependent upon the chemical conditions.

With any decrease in the quality of either the physical or chemical conditions comes a decrease in the biological life, and when both the physical and chemical conditions deteriorate, as is the case in denuded lands, there is a very marked decrease in the biological life. Since these three sets of conditions so affect each other, if there is a lessening of any one of them, the remaining two are affected accordingly. These facts tend to substantiate Obsako's (5) opinion that, "The negative succession is more likely to occur than the positive succession once retrogression begins."

To understand more fully the importance of the biological life, an example or two will be fitting at this time.

First consider the numerous types, classes, and combinations of biological life shown by the following outline from Lyon and Buckman (12).

Biological Life of the Soil

Micro-fauna.

I Protozoa

II Nematodes

III Worms, insects, etc.

Micro-flora.

I Algae and Deatoms

II Fungi, including Actinomycetes

III Bacteria

A. Autotropic, deriving their energy from the oxidation of simple inorganic compounds and their carbon from carbon-dioxide. They are:

1. Nitrifying bacteria

2. Sulphofying bacteria

3. Iron bacteria

B. Heterotrophic, deriving their carbon from complex organic compounds. They include:

1. Nitrogen fixing bacteria

   a. Symbiotic, e.g., Bacteria radicicola.

   b. Free living

      (i) Aerobic, e.g., Azotobacter.

      (ii) Anaerobic, e.g., Clostridium.

2. Bacteria concerned with the process of ammonification.

3. Cellulose bacteria and other bacteria decomposing fiberous materials.

This outline tends to bring out the types and classes of the micro-organisms in the soil, but is not explanatory enough as to the numbers present in the various types of soil. However, using an example given by Professor R. E. Stephensen will aid in establishing some conception of the vast numbers of organisms in the soil. His example is as follows: "A gram of the poorest soils, which is about one-half a thimblefull, contains more organisms than there are people in the state of Oregon; a gram of good soil contains more organisms than there are people in the United States; while a gram of compost contains more organisms than there are people in the world." This plainly expresses the magnitude of organic life, and in view of one investigator's findings, namely, about 146,000,000,000 organisms in one gram of compost, the example is decidedly conservative.

It has already been stated that the reduction in organic life is dependent on the physical and chemical conditions of the soil. Likewise the amount of decrease can readily, if but roughly, calculated from the above comparison of approximately 150,000,000 organisms in a gram of good soil to 1,000,000 organisms in a gram of poor soil.

Summing up all the conditions favorable and unfavorable to plant growth on a denuded area, it seems that one would have a very good description of a situation where plants could not survive. In actuality this is the rule rather than the exception.

General Conditions Necessary for the Return to Satisfactory Productivity

The problem of rebuilding and maintaining the optimum vegetative crop on our range land, and at the same time of stopping the wastage of soil by erosion, is one not so readily solved. The key, however, lies in due control of the water which falls on each parcel of land, along with the maintenance of the humus content of the soil. The water and humus are assets of great possible value and should be looked upon as such, and conserved. The loss is great when the water and humus are permitted to waste away and doubly so if the water is permitted to carry away the valuable, potential growing qualities of the soil.

Of first importance is the establishment and conservation of the optimum vegetative cover. Plants not only lessen the force of rainfall but intercept a part of it. Vegetation improves the soil structure, allowing greater holding capacity of the soil by increasing the humus content; it breaks the effect of drying winds; it binds the soil and lessens sheet erosion; it obstructs run-off and reduces the velocity of flow and the carrying power of the water; and by catching soil particles it tends to form miniature terraces on slopes and retains the richer portion of the soil on the area.

The establishment of such a vegetative cover requires, as a rule, a much longer period of time than is generally conceded, for as Mc Dougal (4) states, "The duration of the pioneer stages, of plant succession, is relatively short, and the duration of the intermediate stages increases until the climax stage is reached. This is relatively permanent."

To shorten the duration of the various stages of plant succession it is necessary, if possible, to increase the structure of the soil. This may be done, by increasing the humus content, which tends to break the soil into a "crumb structure"; by increasing the root systems, thereby physically breaking up the densely compacted soil, and furnishing humus by the sloughing off of root hairs and the dying of the roots themselves, which in turn leave small tubular openings down into the soil; by increasing the biological content of the soil which is very materially affected by the humus content; and by the shrinkage and swelling caused by variation in moisture content, by heat, and freezing and thawing, which is also benefited by the humus content of the soil. (11). Likewise, as is already seen, it is necessary to increase the humus content of the soil to aid in the development of the proper soil structure, and the maximum biological life in the soil. This may be done only by conserving the growth of plants on the area, by its being not too heavily stocked; by the area's being grazed at the right time, and for the proper length of time; and principally by leaving an adequate reserve of the year's vegetation to prevent loss from erosion.

Of the major factors influencing the possibility of establishing a vegetative cover, the humus content appears to be the one of greatest importance.

It creates a more favorable physical medium for plant growth, by improving the water content and aeration, as well as compactness which so profoundly effects root development (11). It makes both light and heavy soil more retentive of available moisture. It retards the removal of important plant nutrients, especially from mineral soils. It supplies the plants with a continuous source of nutrients during its decomposition by microbial agencies. Finally, it is the source of food supply for the countless millions of important biological forms of life in the soil.

In actuality there seems to be a three-side cycle between the physical, chemical (humus), and biological conditions that are either favorable or unfavorable to the soil. That is, if any one of these conditions become unfavorable, its effect upon the other two will cause them to be more or less unfavorable too. If, on the other hand, it changes to favorable, the reverse is true.

Of the three, the humus content has the most pronounced effect (1). It is the one that, if it can be controlled, will do the most toward bringing about the desired results. It is the one that ultimately must be protected from loss to prevent retrogression which now is so prevalent on the western range areas.

Conclusions

1. The main obstacle to action and one that has greatly delayed remedial measures has been the lack of information as to the seriousness of the situation, as well as the lack of information regarding the concrete things which should be done under specific conditions.

2. Owners of range land should consider the use of their land not so much for immediate gain, but more for a sustained yield of the forage crop.

3. The most feasible economic range practices should be thoroughly studied, and put into practice to give nature a helping hand in maintaining a natural balance.

4. Soil erosion must be stopped to maintain and improve the productive capacity of the range land.

5. Careful consideration should be given to the adjustment of the number of livestock to the grazing capacity of the forage on the range land.

6. The grazing capacity should be estimated on a sustained yield basis. This should be determined from the standpoint of the ecological factors involved in plant growth rather than on the basis of the plant itself.

7. The grazing should be so regulated that the humus content of the soil is kept at the optimum for the

given locality.

8. It must ultimately be realized that the sustained yield of forage crops on the range can be maintained only so long as the mineral nutrients, i.e., calcium, phosphorous, iron, sulphur, etc., liberated by the natural weathering of the parent rock material, are made available through the action of the acids, and biological life in the soil as rapidly as the loss of the same minerals are incurred by the livestock consuming the forage, later to be taken from the range never to be returned.

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